JTG

Industry Standards of

the People's Republic of China

中华人民共和国行业标准

JTG D20—2017（EN）

Specifications for Highway Geometric Design

公路路线设计规范

Issue date: September 28, 2017 Effective date: January 1, 2018

Issued by Ministry of Transport of the People's Republic of China

Industry Standards of the People's Republic of China

中华人民共和国行业标准

Specifications for Highway Geometric Design

公路路线设计规范

JTG D20—2017（EN）

Editing organization in charge: CCCC First Highway Consultants Co., Ltd.

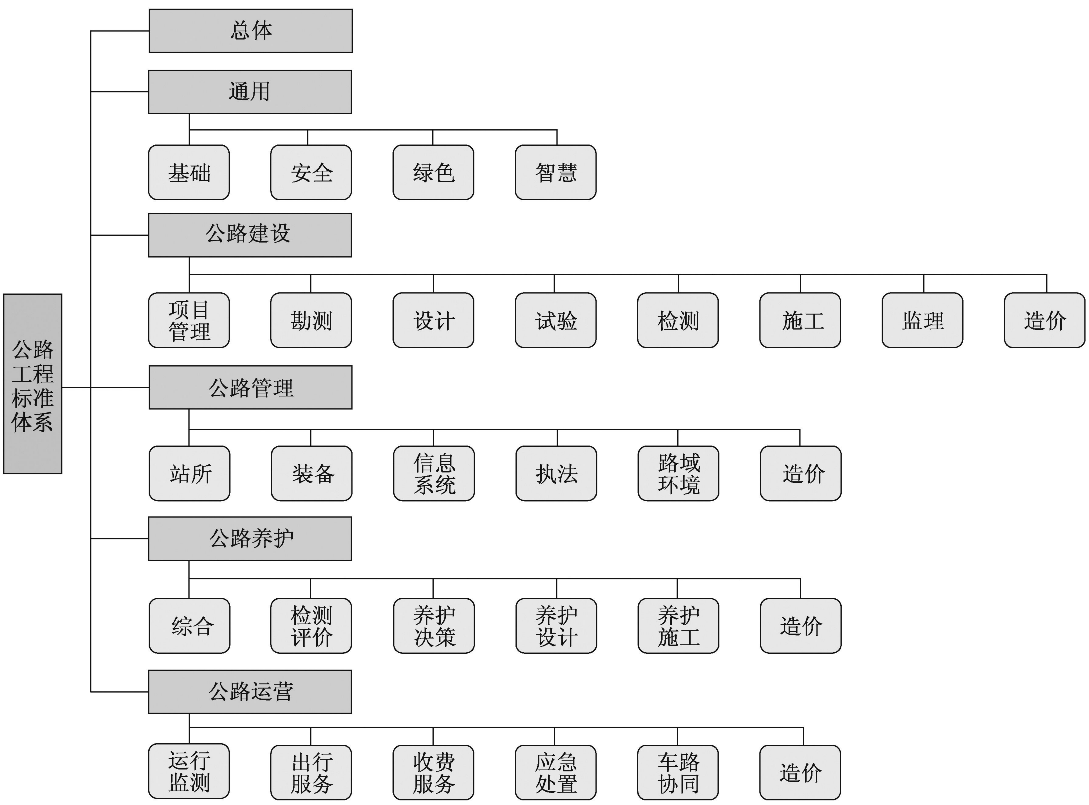
Issuing authority: Ministry of Transport of the People's Republic of China

Effective date: January 1, 2018

英文版编译出版说明

标准是人类文明进步的成果，是世界通用的技术语言，促进世界的互联互通。近年来，中国政府大力开展标准化工作，通过标准驱动创新、协调、绿色、开放、共享的共同发展。在丝绸之路经济带与21世纪海上丝绸之路，即“一带一路”倡议的指引下，为适应日益增长的全球交通运输发展的需求，增进世界连接，促进知识传播与经验分享，中华人民共和国交通运输部组织编译并发布了一系列中国公路行业标准外文版。

中华人民共和国交通运输部发布的公路工程行业标准代号为JTG,体系范围涵盖公路工程从规划建设到养护和运营管理全过程所需要的设施、技术、管理与服务标准，也包括相关的安全、环保和经济方面的评价等标准。



中国政府历来高度重视交通基础设施建设，不断完善公路基础设施建设科技与相关的行业技术标准。20 世纪 80 年代，中国在原《公路工程技术标准》（JTJ01-81）基础上，开始制定公路路线、路基、路面、桥梁、涵洞等专业技术规范；1984 年，中国颁布实施了《公路路线设计规范》（JTJ 011-84），尔后，经历了 1994 年的第一次修订（JTJ 011-94）、2006 年的第二次修订（JTG D20-2006）以及 2017 年的第三次修订（JTG D20-2017），经过近四十年的技术发展，建立了内容较为完整的公路路线设计规范和各项技术指标体系。本次编译的《公路路线设计规范》（JTG D20-2017）中文版于 2017 年 9 月修订发布，并于 2018 年 1 月 1 日实施。

到 2019 年底，中国公路通车总里程超过 500 万公里，高速公路通车总里程接近 15 万公里。《公路路线设计规范》（以下简称《规范》）作为基础性的重要技术文件，在项目前期规划和项目线位选择、平纵指标选用、桥隧立交等构造物设施布局，以及决定项目规模、标准等方面，发挥了非常重要的作用。本《规范》重点对公路几何设计的设计方法、控制要素、指标参数、设计要点、各专业协调等进行规范和指导。《规范》充分吸收中国相关工程的科研成果和大量的工程实践经验，广泛采用国际先进理念与技术，总体指标安全适用。本《规范》更加关注各类复杂建设条件下的应用，也适用于发展中国家从无到有、从通到畅、从线到网、从侧重经济性到兼顾生态环保等不同发展阶段的建设需求。本英文版的编译发布便是希望将中国的工程经验和技术成果与各国同行进行交流分享，为其他国家类似地形地质条件的公路建设提供参考借鉴。

需要特别指出的是，本规范内容包括合理确定公路功能、技术等级、建设规模、主要技术指标，以及公路选线、横断面设计和线形设计、各种交叉口设计等。传统上这些内容在中文中统称为“路线设计”，而英语国家的公路建设行业通常将这些内容称为路线规划（Route planning）和几何设计（Geometric design）。为准确表达本规范的技术内涵，对规范名称中的“路线设计”选用了几何设计（Geometric design）一词，故本英文版规范名称译为“Specifications for Geometric Design of Highways”。

本英文版的编译工作由中华人民共和国交通运输部委托中国路桥工程有限责任公司主持完成，并由中华人民共和国交通运输部公路局组织审定。

本英文版标准的内容与现行中文版一致，如出现异议时，以中文版为准。

感谢中文版主要编写者郭腾峰先生在本英文版编译与审定期间给予的指导与支持。

如在执行过程中发现问题或有任何修改建议，请函告英文版主编单位（地址：北京市东城区安定门外大街丙88号中路大厦，邮政编码：100011，电子邮箱：kjb@crbc.com），以便修订时研用。

英文版主编单位：中国路桥工程有限责任公司

英文版主编：姚海冬，卢山

英文版参编人员：彭巍，李志强，张庆红，何保炳，王昊卿，张朝贵，任钰芳，郭猛，司晓炜

英文版主审：张永文

英文版参与审查人员：艾列克斯维瑟教授（南非），张慧彧，柴华

The People’s Republic of China
Ministry of Transport
Public Notice
No. 38

Public Notice on Issuing the *Specifications for Highway Geometric Design*

Hereby the *Specifications for Highway Geometric Design* (JTG D20—2017) is issued as one of the Highway Engineering Industry Standards, to become effective on January 1, 2018. The former edition of the *Design Specification for Highway Alignment* (JTG D20—2006) shall be superseded from the same date.

The general administration and final interpretation of the *Specifications for Highway Geometric Design* (JTG D20—2017) belong to Ministry of Transport, while particular interpretation for application and routine administration of the *Specifications* shall be provided by CCCC First Highway Consultants Co., Ltd.

Comments, suggestions and inquiries are appreciated and should be addressed to CCCC First Highway Consultants Co., Ltd. (Address: No. 63, Keji Erlu, Xi’an City, Shaanxi Province, 710075). The feedbacks will be considered in future revisions.

It is hereby announced.

Ministry of Transport of the People's Republic of China

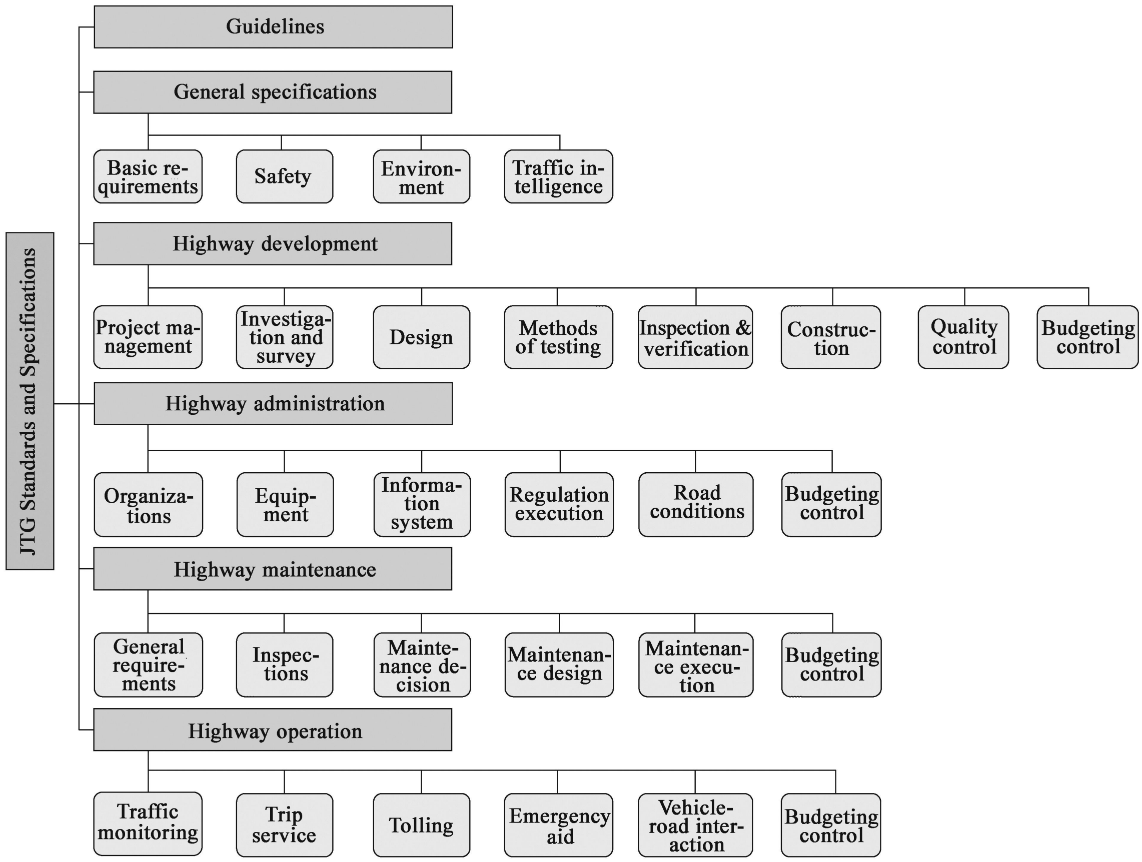
September 28, 2017

General Office of Ministry of Transport Printed on October 9, 2017

Foreword

Standards reflect the achievement of civilization, provide common language for technical communications, and improve global connectivity. In recent years, the Chinese government has been proactively implementing a strategy on standardization to stimulate innovation, coordination, greening, opening up and sharing for reciprocal development in China and worldwide. In the light of mutual development along the Silk Road economic belt and the 21st-century maritime Silk Road (so called 'one belt one road' initiative), the Ministry of Transport of the People's Republic of China organized translation and published an international version of the Chinese transportation industry standards and specifications to cater for the increasing demands for international cooperation in world transportation, achieve interconnected development and promote knowledge dispersion and sharing experience.

JTG is the designation referring to the standards and specifications of the highway transportation industry, issued by the Ministry of Transport of the People's Republic of China. It covers the standards and specification in terms of technology, administration and service for the process from highway planning through to highway maintenance. The criteria for safety, environment and economic assessment are also included.



Transportation plays a pioneering role in the national economic development. The technologies and industry standards for highway infrastructure have been innovatively developed and continuously updated and improved. In the early 1980's, the ***Technical Standards for Highway Engineering (JTJ01-81)*** was formulated, followed by a series of technical specifications covering highway planning, geometry design, earthworks, pavements and structural work. The first edition of the ***Specifications for Geometric Design of Highways (JTJ 011-84)*** was published and implemented in 1984, with a first revised edition (JTJ 011-94) in 1994, a second revision (JTG D20-2006) in 2006, and now the third revision (JTG D20-2017). This revision was issued in September 2018 and put into effective use on January 1, 2018. After 40 years development and improvement, the technical system of highway geometric design and relevant technical criteria is well established.

By the end of 2019, more than 5 million kilometers of highways, including 150 thousand kilometers of motorways, have been built and put into operation. The Specifications for Geometric Design of Highways, as one of the fundamental technical documents, has been playing a leading role in highway highway planning, the selection of horizontal and vertical alignment and the layout of bridges, tunnels and interchanges. It also provides guidelines for the determination of project scale and the selection of technical standards. These specifications provide procedures and guidelines in terms of design methods, control elements, parameters and criteria, the key points of design and the coordination of various specialists involved in the design. These specifications are based on extensive technical research and successful experience in China, and incorporated international advanced concepts and technology, thus the parameters adopted are safe and practicable. Spectial attentions have been paid to various complex construction conditions in which a project may encountered during implementation, and thus these specifications may also applicable to the demands for new highway development, upgrading from accessibility to mobility, extension from highway routes to highway network, and promotion from economic focus to integrated ecologic and environmental protection. The English version of these specifications is therefore issued for the purpose of sharing Chinese experience with the professionals in the world and provides references for highway development in other countries.

Note that these specifications provide guidelines for determination of highway functions, technical classifications, and technical criteria, as well as highway route planning, and design of roadway, alignment and intersections. These may be categorized as 'highway route planning 'and 'geometric design' in other countries. In order to accurately express the application the title '*Specifications for Geometric Design of Highways*' is used.

The English translation of these specifications was conducted by China Road and Bridge Corporation under the authorization of the Ministry of Transport and approved by the Highway Administration of the Ministry of Transport.

The content of the English version are exactly the same as those in the Chinese version. In event of any ambiguity or discrepancies, the Chinese version should be referred to and accepted.

Gratitude is given here to the Honorable Senior Eng. Guo Tengfeng, the Editor in charge of the Chinese version for the valuable assistance and suggestions during the translation and approval of the English version.

Comments, suggestions and inquiries are welcome and should be addressed to the editing organization in charge of the English version: China Road and Bridge Corporation (Address: 88C AndingmenwaiDajie, Postal Code: 10011, E-mail: kjb@crbc.com). The feedback shall be considered in future revisions.

Organization in charge：	China Road and Bridge Corporation
Lead editors:	Yao Haidong, Lu Shan
Associate editors:	Peng Wei, Li Zhiqiang,Zhang Qinghong, He Baobing, Wang Haoqing, Zhang Chaogui, Ren Yufang, Guo Meng, Si Xiaowei
Review editor:	Zhang Yongwen
Co-Reviewers:	Prof Alex T Visser (South Africa), Zhang Huiyu, Chai Hua

Preface to Chinese Version

According to the ministerial circulation paper 'The Notice on Programs for Formulating and Updating Highway Industry Standards' (ref. JGLF[2011] 115) of Ministry of Transport, CCCC Highway Consultants Co., Ltd. was authorized to update the former edition of the specifications. The Research Institute of Highway of MoT, CCCC Second Consultants Co. Ltd., Shanxi Provincial Institute of Transport Planning and Engineering, and Jilin Provincial Institute of Transport Planning and Design have also participated in the work. During the updating of the Specifications, assistances and contributions have also been received from the provincial (municipal and regional) departments of transport and other stakeholder organizations.

The updating work is based on and governed by JTG B01-2014: *Technical Standards for Highway Engineering*. The revisions made in this edition are mainly as follows.

1 According to JTG B01-2014: Technical Standards for Highway Engineering, the revisions have been made to highway functional and technical classifications, design vehicles, level of service, and vehicular equivalent factors, to highlight the functions dominant in highway design.

2 Comprehensive revisions have been made to the chapter on overall design, to highlight the leading role of an overall design in whole process and all respects.

3 Relevant technical criteria and rules have been provided for continuous long and steep downgrades to ensure traffic safety.

4 A systematic review has been made to the chapters, sections and provisions about highway alignment, profile and cross-sections, based on which revisions have been made to the widening of circular curves, placement of transition segments, geometrics of roadway cross-sections and design criteria on the roadway cross-sections of 10-lane or more motorways.

5 More details have been given to the design verification by operating speeds, traffic safety evaluation, upgrading of existing highways and emergency aid and rescue.

6 A new chapter of highway roadside facilities has been added in this edition with the provisions and design requirements for geometrics of toll stations, service areas, rest areas, bus bays and U-turn facilities.

7 Technical criteria and design requirements have been updated for highway-highway junctions and highway-other facility crossings.

The new edition of these specifications comprises 13 chapters, namely general provisions, highway classifications and selection, highway capacity, overall design, route location, highway cross-sections, highway alignment, highway profile, geometric design, at-grade junctions, grade-separated junctions, highway- railway, highway-farm road, highway-pipeline crossing, and highway roadside facilities.

Inquiries, suggestions and comments are welcome and should be addressed to the administration team of these specifications, CCCC First Consultants Co. Ltd,, contact person: Guo Tengfeng (mail address: 63, Keji Road 2, Xi-an, Shaanxi Province, Post code:100011, China; Tel. 8610-82016537; Fax:8610-82016573; E-mail: goutf@ccroad.com.cn). Feedbacks shall be taken into account in future updating.

Editing organization in charge of Chinese version: CCCC First Consultants Co. Ltd.

Associate editing organizations for Chinese version:

Research Institute of Highway, MoT

CCCC Second Highway Consultants Co. Ltd.

Shanxi Provincial Institute of Highway Transport Planning and Engineering

Jilin Provincial Institute of Highway Transport Planning and Design

Chief Editor: Wang Shuangjie

Co-editors: Guo Teng-feng, Luo Manliang, Zhou Ronggui, Huo Ming, Nie Chengkai, Wang Zuo, Wu Mingxian, Liao Chaohua, Liu Jianpei, Feng Zixian, Hu Shan

Contents

1 GENERAL PROVISIONS

1.0.1 These specifications are formulated to provide guidelines for highway design in terms of highway function, technical classification, the scope of construction and the main technical indicators.

1.0.2 These specifications are applicable to the design of a new highway, or the upgrading or re-construction of an existing highway.

1.0.3 In a highway design, the highway function shall be determined by broad analyses of the region, nature of traffic, and structure of the road network. Technical classification and major engineering criteria shall be selected based upon the highway function, traffic volume and terrain conditions.

1.0.4 An overall design shall be conducted for a classified highway. The overall design shall cover the full project process from feasibility study to detailed design, and involve all relevant aspects of highway engineering.

1.0.5 In a highway design, the location of a highway route and the highway corridor shall be determined in accordance with the highway function, service task and its role in the highway network, by taking the other transportation modes such as railroads, water ways, aviation and pipelines into account, and based on the inter-relationship with the urban and farming development plan, so as to effectively serve the demands of integrated transportation.

1.0.6 A route option shall be developed within the selected corridor and the major control points on it, which can be further developed into an overall design by applying the technical criteria. Various route options shall be assessed and compared to each other to determine the design route. Technical-economic assessments shall be conducted in a similar way as for design speeds, as technical criteria and design options have significant impacts on traffic safety, construction cost, natural environment and social economic benefits.

1.0.7 The location and relevant geometric parameters of a proposed highway route shall be selected in accordance with terrain and land features, based on thorough investigations of geology, hydrology, meteorology, natural hazards, geotechnical, ecological environment, natural landscaping, and characteristics of the regional climate.

1.0.8 Highway geometric design must always adhere to thefundamental national policies on environmental protection and land conservation in the determination of structure and layout of man-made works including subgrade, pavement, bridges, tunnels, road junctions, traffic engineering facilities, roadside facilities, and planning of borrow pits and land acquisition. The impact of highway construction on the local ecology shall be minimized and effective measures such as revegetation shall be taken to harmonize human works and the natural landscape so as to improve the roadside environmental qualities.

1.0.9 Geometric design of a highway shall be conducted based on design speeds and taking into account operating speeds in order to assure alignment continuity. Moreover, relationships among alignment, profile and cross-section of a highway shall be coordinated to maintain smooth alignments with a balanced profile and compatible cross-section.

1.0.10 Traffic safety assessments shall be conducted for motorways, Class 1 highways and class-2 arterial highways during the design stage, and may be conducted for other classified highways wherever necessary.

1.0.11 For a highway to be built in phases, the overall design shall adhere to the principle of *planning holistically and implementing in phases*, ensuring that the works implemented in early phases shall be fully utilized in later phases, maintaining the required links and ideal conditions for further implementation.

1.0.12 For upgrading or reconstruction of existing highways, evaluations of alternatives, either to upgrade the existing highway or to build a new section of the highway shall be conducted. If the upgrading option is adopted, the principle of combining utilization and reconstruction shall be followed in order to effectively and efficiently make the best use of the existing works.

2 HIGHWAY CLASSIFICATION AND CLASS SELECTION

2.1 Highway Function and Classification

2.1.1 Highways are categorized by function into arterial highways, collector-distributor highways and local highways. Arterial highways are further categorized into primary arterial highways and secondary arterial highways, while collector-distributor highways are further categorized into main collector-distributor highways and minor collector-distributor highways.

2.1.2 Highways are classified, by traffic characteristics and capacity of interference control, into five classes, namely, motorway, Class-1 highway, Class-2 highway, Class-3 highway, and Class-4 highway.

1 Motorway is a multi-lane highway with full control of access, specific for motor vehicles to travel along channelized lanes on divided roadways. The annual average daily traffic (AADT) to be served by a motorway should be greater than 15,000 pcu.

(Passenger car unit, pcu, is defined as the standard unit of measuring traffic volumes by converting vehicles in the traffic stream to the equivalent standard vehicle in terms of the space occupied).

2 Class-1 highway is a multi-lane highway with on-demanding full or partial control of access for motorized vehicles to travel on divided roadways. The annual average daily traffic (AADT) for a Class-1 highway should be greater than 15,000 pcu/day.

3 Class-2 highway is a two-way two-lane highway mainly for motorized vehicles to travel on it roadway. The annual average daily traffic (AADT) for a Class-2 highway should be 5,000-15,000 pcu/day.

4 Class-3 highways are two-lane highways for both motorized and non-motorized traffic. The annual average daily traffic for aClass-3 highway shall be between 2,000-6,000 pcu/day.

5 Class-4 highways are either two-lane or single-lane highways for both motorized traffic and non-motorized vehicles. The annual average daily traffic for a two-lane Class-4 highway should be below 2,000 pcu/day while that for a single-lane Class-4 highway should be below 400 pcu/day.

2.1.3 The design vehicle for geometric design of a highway route and the junctions on it shall be selected in accordance with the highway functions, vehicle composition, and other factors. The outline of a design vehicle is given in Table 2.1.3 and shall comply with the following provisions:

1 arterial highways and main collector-distributor highways shall accommodate all types of design vehicles;

2 minor collector-distributor highways shall accommodate cars, trucks, and buses.

3 local highways shall accommodate cars and buses;

4 for special-purpose highways, the design vehicles may be selected after specific evaluation.

Table 2.1.3 Outline Dimensions of Design Vehicles

Vehicle type	overall length (m)	Overall width (m)	Overall height(m)	Front overhang(m)	Wheel base (m)	Rear overhang(m)
Passenger car	6	1.8	2	0.8	3.8	1.4
Bus	13.7	2.55	4	2.6	6.5+1.5	3.1
Articulated bus	18	2.5	4	1.7	5.8+6.7	3.8
Single-unit truck	12	2.5	4	1.5	6.5	4
Articulated trailer	18.1	2.55	4	1.5	3.3+11	2.3

Note: The wheel base of an articulated trailer (3.3+11)m, means 3.3m from front axle to the point of articulation and 11m from the point of articulation to the last axle.

2.1.4 Design speed of a classified highway shall comply with the criteria given

Table2.1.4 Design Speed

Classification	Motorway			Class-1 highway			Class-2		Class-3		Class-4
Design speed （km/h）	120	100	80	100	80	60	80	60	40	30	30/20

in Table 2.1.4.

2.2 Selection of Highway Technical Classification and Design Speed

2.2.1 Traffic volume prediction for highway design shall comply with the following provisions:

1The design period of volume prediction shall be 20 years for motorways or Class-1 highway, 15-yearsfor Class-2 or Class-3 highway. For Class-4 highway， the design period can be determined for the actual situation.

2 The base year of the design volume forecast shall be the first year of the highway opening to traffic.

3 In the prediction of design traffic volume, the influence of long term social-economy development planning and multi-transportation systems shall be taken into account.

2.2.2 Highway technical classification shall be selected based on the highway function verification, by taking the other transportation systems in the region into account, and in accordance with the long-term development plans and design traffic volume.

1 Motorways shall be selected as primary arterial highways serving as the main access that are the highest hierarchical level in the National Highway Network.

2 Class-2 or higher classified highways shall be selected as secondary arterial highways which supplements the primary arterial highways;

1) Class-1 highways or motorways should be selected where the design traffic volume exceeds 15,0000 pcu/day,

2) Class-1 highway should be selected where traffic volume reaches 10,000 pcu/day and lateral interference along the route is severe;

3) Class-2 highway may be selected where design traffic volume is below 10,000pcu/day, and in the case of a high percentage of truck traffic, a passing lane should be provided to mitigate interference of vehicles travelling in the same direction.

3 Class-1 or Class-2 highways should be selected as main collector-distributor highways serving as the connections to either arterial highways or local highways;

1) Class-1 highway may be selected where traffic volume reaches 15,000 pcu/day;

2) Class-2 highways may be selected where design traffic volume is in the range of 5000 to 15000 pcu/day; Class-1 highway should be choice in the case where design volume reaches 10,000 pcu/day and roadside interference along the route is high,;

3) Class-2 highways should be selected where AADT is less than 5,000pcu/day.

4 Class-2 or Class-3 highways should be selected as minor collector-distributor highways serving the regional traffic among villages in a county.

1) Class-2 highways should be selected where AADT reaches 5,000pcu/day.

2) Class-3 highways should be selected where AADT is less than 5,000pcu/day.

5 Class-3 or Class-4 highways should be selected as local highways. However, a Class-2 highway should be selected in the case where AADT reaches 5,000 pcu/day.

6 Where the existing highways fail to serve the expected functions, necessary upgrading shall be planned in conjunction with the highway network development program.

2.2.3 Design speeds shall be selected in accordance with highway functions, technical classifications, and other elements including terrain, engineering economy, expected operating speeds and land use along the highway route. The following rules shall be applied.

1 The design speed for a motorway should not be less than 100km/h. However, a design speed of 80km/h may be selected in topographic and geological constrained conditions.

2 The design speed for a Class-1 arterial highway should be 100km/h. However, a design speed of 80km/h may be selected in terrain and geologically constrained area. For a Class-1 collector-distributor highway, the design speed should be 80km/h, or 60km/h in topographic and geological constrained conditions.

3 For motorways or Class-1 arterial highways, Design speed of 60 km/h may be adopted for segments in vulnerable areas where new construction may induce geological hazards. Such a segment should not be longer than 15km except those between two successive interchanges.

4 The design speed for a Class-2 arterial highway should be 80 km/h. A design speed of 60km/h could be selected in topographic and geological constrained conditions. The design speed for a Class-2 collector-distributor highway should be 60km/h, or 40km/h in topographic and geological constrained conditions.

5 The design speed for a Class-3 highway should be 40km/h. A design speed of 30km/h could be selected in terrain and geologically constrained areas or other difficult conditions.

6 The design speed for a Class-4 highway should be 30 km/h. A design speed of 20 km/h could be selected in terrain and geologically constrained areas and other difficult conditions.

2.2.4 Different technical classes may be assigned to different segments of one highway route. Different design speeds may be selected for different segments of one classification. Suitable connecting locations or points shall be selected between the sections with different technical classes or between the segments with different design speeds for smooth transition and harmonized connection to each other.

2.2.5 For checking by operating speed, the differential of the operating speeds used in two adjacent segments shall be less than 20km/h, and the differential of design speed and operating speed used in the same segment should be less than 20km/h.

2.2.6 Speed limits shall be determined by verification in accordance with design speeds, operating speeds, access interference, and environmental factors.

2.3 Control of Access

2.3.1 A motorway is a highway with full control of access, on which accesses are only provided for specifically selected highways, urban expressways or roadside facilities. Grade separated junctions must be provided for the crossing of other highways, urban roads, railroads, pipelines and so forth; isolation must be provided to prevent pedestrians, vehicles or animals from trespassing on the motorway.

2.3.2 The control of access for a Class-1 highway shall conform to the requirements as follows.

1 Partial control of access shall be applied to the Class-1 highways served as secondary arterials.

2Access management, which is to control the location, number and modes of accesses, shall be applied to the Class-1 highways that serve as collector-distributor;

2．3．3 Where control of access is adopted, the separation facilities shall comply with the criteria as follows:

1 Boundary fences, hedges and other types of separation facilities may be placed in the following localities:

1) at the borders of highway reserve on both sides of a highway section where control of access is applied;

2) at borders of an interchange, service area, parking lot, bus bay or any other facilities.

3) at the separation strip between a slow-moving lane and other normal traffic lanes where slow-moving lanes are placed in a class-1 highway,

4）on the intersected highway in a range of 150m each side extended from the at-grade junction on a classi-1 highway section where control of access is applied,

5) in the places specially required on a highway section where control of access is applied

2 isolation facilities may not be placed where the highway sections are hardly accessible.

3 The design of ends and openings of a fence shall conform to the following requirements:

1) the point from which a fence is unnecessary to install may be taken as the end of the fence but shall be designed so that it is inaccessible;

2) Gates shall be provided at appropriate places for maintenance or management purposes.

2.3.4 The placement of emergency exits shall comply with the following requirements:

1 The highway with control of access should be provided with emergency exits at or near the locations where emergency aid, fire-fighting or medical assistance are available or accessible.

2 Emergency exits shall be located at places with good visibility and convenient accessibility to external roads.

3 The external road connecting to an emergency exit should be a Class-3or higher class highway.

3 HIGHWAY CAPACITY

3.1 General

3.1.1 Traffic capacity and service level shall be analyzed and evaluated during a highway design in order to maintain consistent and balanced level of service and in compliance with the following criteria:

1 Capacity analysis and level-of-service assessment must be conducted for the road sections, the interchanges including ramps, diverge, merge or weaving segments, and the toll stations and plazas of a motorway or a class-1 highway.

2Capacity analysis and level-of-service assessment shall be conducted for the road sections on a class-2 highway or a class-3 highway and the at-grade junctions on a class-1 highway or a class-2 arterial highway.

3 A capacity analysis and level-of service assessment should be conducted for the at-grade junctions on a class-2 collector-distributor highway or a class-3 highway.

3.1.2 The analysis and assessments of capacity and level of service shall be conducted separately and individually in each traffic direction of a motorway or class-1 highway, but conducted holistically for both traffic directions of a class-2 or class-3 highway. An individual analysis and assessment shall be conducted for any continuously climbing grade of a class-3 or higher highway.

3.1.3 Representative vehicle types shall comply with Table 3.1.3.

hicle Types

Representative Vehicle Types	Descriptions
Passenger cars	Passenger vehicles with 19 seats or less Trucks with payload ≤ 2t
Medium Vehicles	Passenger vehicles with more than 19 seats Trucks of 2t<payload≤7t
Large Vehicles	7t < Payload ≤20t
Combination vehicles	Payload over 20t

3.1.4 Passenger car is used as the standard vehicle type for traffic volume conversion. The volume conversion of non-motorized vehicles shall comply with the provisions as follows.

1 Each farm tractor travelling on a highway is equivalent to 4 pcu.

2Vehicles on crossing local roads, roadside parking vehicles, non-motorized vehicles such as animal-powered vehicles, man-powered carts, the influence of roadside urbanization are considered as roadside interference factors. The level of roadside interference factors shall comply with the criteria in Table 3.1.4.

Equivalency factors for capacity analysis shall be selected in accordance with the types of road sections and junctions as well as topographic conditions and traffic expectations.

Levels of Roadside interference		Description of Typical Situation
1	Light	Highway conditions in compliance with standards; normal traffic status; very little roadside interference
2	Moderate to light	Farmlands on both sides of the highway; a few bicycles and pedestrians travelling along or crossing the highway
3	Moderate	The highway through a village or town; occasional roadside car parking; a few vehicles to or from intersected local roads
4	Severe	Quite a number of non-motorized vehicles travelling on the highway
5	Very severe	Markets, vendors on roadside; poor traffic management or bad traffic behavior

3.2 Level of Service

3.2.1 Level of service shall be selected in accordance with highway function, technical classification and terrain conditions and shall not be lower than the criteria listed in Table 3.2.1.

Technical Classification	Motorway	Class-1 highway	Class-2 highway	Class-3 highway	Class-4 highway
Level of Service	LOS-3	LOS-3	LOS-4	LOS-4	**Highways** --

3.2.2 Level of service of classified highways and service flow rate shall comply with Tables 3.2.2-1, 3.2.2-2 and 3.2.2-3.

Table 3.2.2-1 Level of service provided by segments of motorways

Level of service	Volume to capacity ratio (v/C)	Design speed (km/h)		
		120	100	80
		Max. volume to be accommodated [pcu/(h·ln)]	Max. volume to be accommodated [pcu/(h·ln)]	Max. volume to be accommodated[pcu/(h·ln)]
LOS-1	v/C≤0.35	750	730	700
LOS-2	0.35＜v/C≤0.55	1200	1150	1100
LOS-3	0.55＜v/C≤0.75	1650	1600	1500
LOS-4	0.75＜v/C≤0.90	1980	1850	1800
LOS-5	0.90＜v/C≤1.00	2200	2100	2000
LOS-6	v/C＞1.00	0~2200	0~2100	0~2000

Note: v/C is the ratio of maximum service flow to nominal capacity. Nominal capacity is defined as the maximum hourly traffic volume corresponding to level-of-service 5.

Table 3.2.2-2 Class-1 highways

Level of service	Volume to capacity ratio (v/C)	Design speed (km/h)		
		100	80	60
		Max. volume to be accommodated [pcu/(h·ln)]	Max. volume to be accommodated [pcu/(h·ln)]	Max. volume to be accommodated [pcu/(h·ln)]
LOS-1	v/C≤0.3	600	550	480
LOS-2	0.3＜v/C≤0.5	1000	900	800
LOS-3	0.5＜v/C≤0.7	1400	1250	1100
LOS-4	0.7＜v/C≤0.9	1800	1600	1450
LOS-5	0.9＜v/C≤1.0	2000	1800	1600
LOS-6	v/C＞1.0	0~2000	0~1800	0~1600

Table 3.2.2-3 Class-2 and Class-3 highways

Level of service	extent of delay（%）	Design speed（km/h）										
		80				60				≤40		
		speed (km/h)	v/C			speed (km/h)	v/C			v/C		
			No-overtaking zone %				No-overtaking zone %			No-overtaking zone %		
			＜30	30~70	≥70		＜30	30~70	≥70	＜30	30~70	≥70
LOS-1	≤35	≥76	0.15	0.13	0.12	≥58	0.15	0.13	0.11	0.14	0.12	0.10
LOS-2	≤50	≥72	0.27	0.24	0.22	≥56	0.26	0.22	0.20	0.25	0.19	0.15
LOS-3	≤65	≥67	0.40	0.34	0.31	≥54	0.38	0.32	0.28	0.37	0.25	0.20
LOS-4	≤80	≥58	0.64	0.60	0.57	≥48	0.58	0.48	0.43	0.54	0.42	0.35
LOS-5	≤90	≥48	1.00	1.00	1.00	≥40	1.00	1.00	1.00	1.00	1.00	1.00
LOS-6	>90	＜48	—	—	—	＜40	—	—	—	—	—	—

Note: Extent of delay is the percentage of vehicles with a headway of less than 5 seconds in the total traffic volume.

3.3 Design hourly volume for highway

3.3.1 The design hourly volume for highway design should be the 30th highest hourly volume during the year. Alternativelyit may take the most economic and reasonable value between the 20th and the 40th highest hourly volumes in accordance with the characteristics of the hourly traffic volume changes in the region.

3.3.2 Design hourly volume for a motorway and class-1 highway shall be calculated by using equation (3.3.2).

$$DDHV = AADT \times D \times K \quad (3.3.2)$$

Where: DDHV—directional design hourly volume (veh/h),

AADT — annual average daily traffic (veh/day);

D -- factor of directional non-uniformity, should take the percentage between 50% and 60%, or may be determined by traffic counts;

K —factor of design hourly traffic, which is the percentage of selected percentile hourly traffic to AADT

3.3.3 Design hourly volume for a class-2 or class-3 highway shall be calculated by using equation (3.3.3).

$$DHV = AADT \times K \qquad (3.3.3)$$

Where: DDHV—directional designhourly volume (veh/h),

AADT — annual average daily traffic (veh/day);

K —factor of design hourly traffic, which is the proportion of AADT occurring in the analysis hour

3.3.4 The factor of design hourly volume（DHV）for a new highway may be determined by referring to the data derived from observation on the highways with similar highway functions, traffic volumes, regional climate and terrain conditions. In the case where there is no observation data available, the factor may be taken from Table 3.3.4. For upgrading or reconstruction of existing highways, the factor of design hourly traffic should be determined in conjunction with the actual data on the existing highway.

region		North China	North-east China	East China	Central-south	South-west	North-west
		Beijing，Tianjin, Hebei, Shanxi. Inner Mongolia	Liaoning, Jilin, Heilongjiang	Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong	Henan, Hunan, Hubei, Guangdong Guangxi, Hainan	Sichuan, Yunnan, Guizhou, Tibet, Chongqing	Shaanxi, Gansu Qinghai, Ningxia, Xinjiang
近郊 suburban	Motorway (%)	8.0	9.5	8.5	8.5	9.0	9.5
	Class-1 highways(%)	9.5	11.0	10.0	10.0	10.5	11.0
	Class-2 and Class-3 highways(%)	11.5	13.5	12.0	12.5	13.0	13.5
城间 inter-city	Motorway (%)	12.0	13.5	12.5	12.5	13.0	13.5
	Class-1 highways(%)	13.5	15.0	14.0	14.0	14.5	15.0
	Class-2 and Class-3 highways(%)	15.5	17.5	16.0	16.5	17.0	17.5

3.4 Design capacity of Motorway or Class-1 Highway Segments

3.4.1 For the design level of service, the maximum volume on one lane of a motorway or class-1 highway shall conform to the criteria in Tables 3.4.1-1 and 3.4.1-2.

Table 3.4.1-1 Max. Volume for the Design Level of Service on One Lane of a Motorway

Design Speed (km/h)	120	100	80
Max. Capacity [pcu/(h·In)] under LOS-2	1200	1150	1100
Max. Capacity [pcu/(h·In)] under LOS-3	1650	1600	1500

Table 3.4.1-1 Max. Volume for the Design Level of Service on One Lane of a Class-1 Highway

Design Speed (km/h)	100	80	60
Max. Capacity [pcu/(h·In)] under LOS-3	1400	1250	1100
Max. Capacity [pcu/(h·In)] under LOS-4	1800	1600	1450

3.4.2 Design capacity of the segments of a motorway or class-1 highway shall be derived by using equation (3.4.2-1).

$$C_d = MSF_i \times f_{HV} \times f_p \times f_f \quad (3.4.2\text{-}1)$$

Where:

C_d—design capacity [veh/(h·In)];

MSF_i—maximum service flow under design LOS[pcu/(h·In)]:

f_{HV}—adjustment factor for heavy-vehicles in traffic stream, which is calculated by using equation (3.4.2-2);

$$f_{HV} = \frac{1}{1+\sum P_i(E_i - 1)} \quad (3.4.2\text{-}2)$$

P_i— percentage of vehicle type-i in total volume;

E_i—passenger car equivalent factor for vehicle type-i, taken from Table 3.4.2-2;

f_p—Driver population factor, determined by site investigations, usually ranging between 0.95 and 1.00;

f_f—adjustment factor for roadside interference, taking 1.0 for motorways; for other classified highways, the level of roadside interference shall refer to Table 3.1.4 and the adjustment factor is given in Table 3.4.2-1.

Level of Roadside interference	1	2	3	4	5
Adjustment factor	0.98	0.95	0.90	0.85	0.80

Table 3.4.2-2 Passenger Car Equivalency Factors for Motorway and Class-1 highway segments

Representative vehicle type	Traffic volume [pcu/(h·ln)]	Design speed(km/h)		
		120	100	≤80
Medium Vehicle	≤800	1.5	1.5	2.0
	800~1200	2.0	2.5	3.0
	1200~1600	2.5	3.0	4.0
	>1600	1.5	2.0	2.5
Large vehicle	≤800	2.0	2.5	3.0
	800~1200	3.5	4.0	5.0
	1200~1600	4.5	5.0	6.0
	>1600	2.5	3.0	4.0
Articulated vehicle	≤800	3.0	4.0	5.0
	800~1200	4.5	5.0	7.0
	1200~1600	6.0	7.0	9.0
	>1600	3.5	4.5	6.0

3.5 Capacity of Interchange

3.5.1 The capacities of interchange ramps, merge, diverge, and weaving areas shall be calculated and determined separately and individually.

The capacity of a ramp at an interchange shall be determined based on the capacity of the at-grade junction where the ramp connects the intersected highway if there is no toll station on the ramp; otherwise capacity shall be determined based on the capacity of the toll station on the ramp.

3.5.3 The capacity of a merge area or a diverge area at an interchange shall be determined in accordance with the design speed, the traffic volume on two outer lanes of the main route, ramp traffic, the length of speed-change lanes, and so forth.

3.5.4 The capacity of a weaving area at an interchange shall be determined in accordance with the design speed, the number of lanes, the forms of weaving, the ratio of weaving volumes, the length of the weaving area, and so forth.

3.6 Capacity of a Class-2 or Class-3 Highway

3.6.1 The maximum traffic volume accommodated for the design level of service on a Class-2 or Class-3 highway shall be selected from Table 3.6.1.

Table 3.6.1 Maximum Traffic Accommodated on a Class-2 or Class-3 highway under Design LOS

Highway Classification	Design Speed (km/h)	Typical Capacity (pcu/h)	Percentage of No-overtaking zone (%)	Volume to Capacity Ratio v/C	Max. volume for design LOS (pcu/h)
Class-2 highway	80	2800	<30	0.64	1800
	60	1400	30~70	0.48	650
	40	1300	> 70	0.35	450
Class-3 highway	40	1300	< 30	0.54	700
	30	1200	> 70	0.35	400

Note: for the percentage of no-overtaking zone that is outside the ranges listed this table, the maximum traffic volume under design level of service shall be determined by calculation using the value of v/C found in Table 3.2.2-3

speed	volume	delay	volume
Fig. 3.2 Speed-volume relationship of class-2 highway		Fig. 3.3 Delay-volume relationship of class-3 highway	

3.6.2 Design capacity of a class-2 or class-3 highway shall be calculated using equation (3.6.2)

$$C_d = MSF_i \times f_{HV} \times f_d \times f_w \times f_f \quad (3.6.2)$$

Where C_d— design capacity [veh/h]

MSF_i— Maximum service flow under designed level of service [pcu/h]

f_{HV} — adjustment factor for heavy vehicles in a traffic stream, calculated by equation (3.4.2-2) where E_i, passenger car equivalent factor for vehicle type-i, taken from Table 3.6.2-1.

Table 3.6.2-1 Passenger Car Equivalency Factors for two-lane highway segments

Representative vehicle type	Volume(veh/h)	Design speed (km/h)		
		80	60	40
Medium vehicle	≤400	2.0	2.0	2.5
	400~900	2.0	2.5	3.0
	900~1400	2.0	2.5	3.0
	≥1400	2.0	2.0	2.5
Large vehicle	≤400	2.5	2.5	3.0
	400~900	2.5	3.0	4.0
	900~1400	3.5	5	7.0
	≥1400	2.5	3.5	3.5
Articulated vehicle	≤400	2.5	2.5	3.0
	400~900	3.0	3.5	5.0
	900~1400	4.0	5.0	6.0
	≥1400	3.5	4.5	5.5

f_d— Adjustment factor for directional distribution of traffic, taken from Table 3.6.2-2;

Directional distribution	50/50	55/45	60/40	65/35	70/30
Adjustment factor	1.00	0.97	0.94	0.91	0.88

f_w— adjustment factor for lane width and shoulder width, taken from Table

Lane width (m)	3.0	3.25	3.5	3.75			
Shoulder width (m)	0	0.5	1.0	1.5	2.5	3.5	≥4.5
Adjustment factor	0.52	0.56	0.84	1.00	1.16	1.32	1.48

3.6.2-3.

f_f —adjustment factor for roadside interference, taken from Table 3.6.2-4, the level of roadside interference shall refer to Table 3.1.4.

Level of roadside interference	1	2	3	4	5
Adjustment factor	0.95	0.85	0.75	0.65	0.55

4 OVERALL DESIGN

4.1 General

4.1.1 An overall design shall identify and determine the functions, technical criteria, and the scope of works and implementation methods of a highway project.

4.1.2 An overall design shall coordinate internal and external relations among various specialist and functional works in terms of highway geometry, subgrade, drainage, bridges, tunnels, intersections, traffic engineering works and roadside facilities, identify and define design interfaces and connections clearly and precisely, and integrate these into a cohesive engineering system so as to serve the overall objectives for safety, environmental protection and sustainable development.

4.1.3 The tasks of an overall design shall be differentiated in terms of the highway characteristics, specific environment and technical classification and shall focus on the specific subjects of the design phase it serves.

4.2 Highway Function and Technical Criteria

4.2.1 The role and contribution of a highway in the highway network shall be analyzed and identified so that the function of the highway shall be determined in accordance with the national and regional highway networks, regional environment, traffic factors, and purpose of the project.

4.2.2 The technical classification shall be verified and determined in accordance with the highway function, traffic volume, and construction conditions.

4.2.3 Design vehicles shall be determined in accordance with the highway function, traffic composition, and proportion of vehicle types.

4.2.4 The number of lanes on a motorway or class-1 highway shall be determined in accordance with the highway function and design traffic volume, and shall be increased in pairs.

4.2.5 Design speed shall be selected in segments of a classified highway in accordance with terrain, geological and other natural conditions.

1 The length of a segment for a specific design speed should not be too short. The design speeds shall not be changed too frequently along one highway.

2 The point or interface of any two segments with different technical classifications or design speeds shall be placed before and after a large structural works, interchange, at-grade junction, a village or town, or anywhere that roadside conditions are significantly different.

4.2.6 The main controlling criteria for alignment, profile, sight distances, superelevation and widening shall be determined in accordance with the segment design speeds, and the terrain, geology and traffic demands along the highway.

4.2.7 The width and arrangement of road cross-sectionsshall be determined in accordance with highway classification, design traffic volumes, environmental conditions along the highway, and functions of cross-sectional elements.

4.2.8 The technical criteria and indicators for the highway after the upgrading shall be used for an upgrading project. For the reutilized segments, where increasing the design speed may induce geotechnical distresses, increased construction costs or cause negative impacts on the environment， historic heritage or both, the original design speeds and criteria may remain subject to specific assessment. In such cases, the segment should not be longer than 15 kilometers for a motorway; 10km for a class-1 or class-2 highway. However, the classification shall not be lower than the original one.

4.3 Scope of project and Implementation Plan

4.3.1The scope of a highway development project, which is defined by the end points of the highway, the main control points and length of the highway route, and the number of intersections, administration facilities and service facilities along the highway, shall be identified and determined based on the highway network program and highway functions, in accordance with the configuration and layout of various transportation modes (such as railroads, waterways, aviation, and pipelines) in the transportation corridor, and by taking the status quo and prospect of urban and industrial development, and resource reserve and exploitation into account.

4.3.2 An implementation plan shall be developed in accordance with the scope of project, critical conditions of construction, the demands of traffic development and financing arrangement. The project to be implemented in phases shall comply with the requirements as follows.

1 An overall design and phased implementation plan must be developed based on detailed analysis and verification to ensure that the works built in

preceding phases shall be fully utilized, reserve space exist and to provide convenience for further development in subsequent phases.

2 Besides the demands of transportation development and project financing arrangements, the verification of a phased implementation plan shall account for the impacts on the environment, local travel, traffic management, and traffic safety during the whole period of construction.

3 Based on highway network planning and traffic development, a motorway may be implemented segment by segmentorproject by project.Motorwaysegments with integral cross-sections must not be implemented in phases roadway by roadway. The segments with separated cross-sections of a motorway or class-1 highway may be implemented in phases roadway by roadway. In such cases, one of the roadways, which is built in a preceding phase and is open to two-way traffic in the interim, shall be administrated in compliance with the operating conditions for class-2 highways with a speed limit up to 80km/h.

4.3.3 The cross-sections of a highway shall conform to the following provisions.

1 Either integrated or separated cross-sections may be adopted for a motorway or Class-1 highway in accordance with terrain and geologic conditions. Option assessment and verification shall be conducted wherever necessary on the geometric proposals regarding types of cross-sections, heights of embankment fill, and bridge and tunnel solutions.

2 In Gobi, desert and steppe areas, wide median, low embankment, gentle embankment slopes, and wide and shallow side drains shall be selected for motorways and class-1 highways.

3 Integrated roadway cross-sections shall be selected for class-2, class-3 and class-4 highways.

4 For class-1 and class-2 highways, the need for placing climbing lanes shall be assessed in accordance with the highway function and the volume and composition of mixed traffic. If it is confirmed, the type of placement, cross-section and width of the climbing lanes shall be determined.

5 A transition section shall be placed wherever necessary between any two highway segments with different cross-sections and roadway widths. Such transition sections should be located at or close to cities and intersections.

6 The arrangement of roadway cross-sections shall consider the needs for the placement of traffic control devices and safety facilities.

4.3.4 The positioning and layout of the highway, adjacent railways and pipelines shall be properly arranged based on thorough investigations on their alignments and locations, and in compliance with the following requirements.

The number of highway-railway crossings and highway-pipeline crossings shall be minimized. Wherever inevitable, the location and mode of such a crossing shall be determined based on specific assessment, and a large intersection angle shall be adopted. Furthermore, the intersected railways, pipelines and their associated works must neither intrude into the highway clearance profile nor block highway sight distances.

2 A necessary spacing shall be maintained between the highway, and the railway or pipeline located parallel to the highway. Any part of a railway, pipeline or its associated works must not enter into the building control areas along both sides of the highway.

4.3.5 The type of intersection of the highway and other highways shall be determined in accordance with highway function, classification and traffic management measures, and shall comply with the requirements as follows.

1. In order to ensure traffic efficiency and safety of arterial highways, the existing roads in the highway network shall be merged or diverged and new frontage roads shall be constructed to reduce the number of highway-highway junctions and thus increase their spacing.

2 A grade-separated junctions must be placed wherever a motorway intersects another classified highway. Whether an interchange or a grade separation is placed shall be decided by assessment in accordance with the demands of traffic movement.

3Where a class-1 highway intersects another class-1 or lower class highway, the mode of such an intersection shall be determined in accordance with the main function of the class-1 highway. An interchange should be placed where a class-1 arterial highway intersects another highway with large traffic flow. The number of at-grade junctions shall be minimized and the spacing between any two at-grade junctions shall be maximized if the class-1 highway serves a collector-distributor function.

4 An at-grade junction may be placed where a class-2, class-3 or class-4 highway intersects any class-2 or lower class highways.

5 For class-1 or lower class highway, isolation facilities shall be placed wherever necessary at the segments close to or through cities and towns.

4.3.6 Traffic engineering and roadside facilities design shall be conducted at the same time as the design of main works of a highway. The locations, forms, spacing and configuration of administration and operation facilities including toll stations or plazas, service areas, and parking lots shall be decided in accordance with highway function, classification, mode of traffic management, traffic safety, and operational management. If necessary, these works, based on predicted traffic volumes, may be executed as part of the phased implementation under a once-for-all master plan subject to specific assessment.

4.3.7 A geometric design shall be determined based on analytical assessment addressing various influencing factors in up-down sequence from networks, corridors to the highway route, which shall conform to the requirements as follows.

1 Investigations shall be carried out to identify the geologic and hydrologic environment, the distribution, scope and risk of potential natural disasters and geologic distresses, and their impact on highway works. The potential geologic disasters that may significantly affect the selection of a highway route shall be identified and analyzed carefully, based on which alternatives, either by-passing or crossing through with corresponding treatment measures, shall be evaluated and compared before selection.

2The proposed location and arrangement of super-large bridges or extra-long tunnel, and its impacts on the highway corridor and the location of highway route shall be analyzed. Alternatives shall be proposed, assessed and selected. For other bridges and tunnels, locations and arrangements should follow the general layout of the highway route and the requirements for highway geometric design.

3 For the segments of high embankment, alternative evaluations on whether a high embankment is necessary shall be conducted. For the segments of deep cutting, alternative of deep cutting versus tunneling shall be evaluated and selected.

4.3.8 The design for the upgrading or reconstruction of an existing highway shall follow the policy of reconstruction under prevailing traffic. Based on safety assessment on the existing highway and the examination on the existing subgrade, bridges, and tunnels, the criteria and methodology shall be developed for utilization of the existing segments and structures. The existing works shall be utilized as far as possible in compliance with the requirements as follows.

1 A traffic maintenance and diversion plan shall be proposed in accordance with conditions in the highway network for the project that requires traffic maintenance during the construction period. The impacts of the project construction activities on the existing traffic shall be minimized and traffic

safety shall be ensured at all times. The level of service during the construction period of the upgrading segments of a motorway may be reduced by one level lower but the speed limit should not be lower than 60km/h.

2 In areas with low traffic volumes, such as desert, Gobi or steppe, where the existing class-2 highway is being upgraded as one of the two separated roadways of a proposed motorway, the design flood frequency may remain unchanged and by-pass roads shall be placed depending on the traffic needs in the region.

3 The materials removed from the existing highway shall be reutilized as far as possible to save construction resources.

4.4 Environmental Stewardship and Resource Conservation

4.4.1 The environment policy for highway development requires *protection first, mainly prevention during comprehensive treatment*. In practice it requires assessment-planning-action procedure, namely, environmental impact assessment (EIA), soil and water conservation plan and environmental protection must be designed, implemented and put into operation simultaneously with the main works. Following the policy and procedure, an overall design shall embody the issues and actions in relation to environmental protection, coordinate the relationship between highway development and environmental protection and minimize the adverse impacts on the environment.

4.4.2 Alternatives for highway corridor and highway layout shall be carefully evaluated. The impacts on environment, such as land use, to use of mineral resources, deep cutting, and reduction of river channel shall be taken as the main factors for assessment. Preference shall be given to the alternatives with minimized resource consumption and less impact on the environment.

4.4.3 Borrow pits and quarries shall be properly planned. Roadside borrowing should not be too close to the road embankment. Borrow by cutting the hill slopes at roadsides shall be avoided. The materials from road excavation or tunnel drilling shall be used for filling and backfilling as far as possible. In the cases where the excavated materials could not be fully used, disposal sites shall be specifically designed and properly placed to ensure the stability of the disposed material stockpiles and prevent from soil erosion and environment contamination.

4.4.4 The topsoil stripped from borrow pits or disposal sites shall be collected for reutilization. Vegetation on the land temporarily utilized for borrow pits, disposal sites and construction accesses shall be protected and restored.

4.4.5 Attention shall be paid to the treatment of production and domestic sewage in roadside service areas and parking lots to ensure the sewer water be properly collected, stored and treated for recycling. Green energy, such as wind, solar, and geothermal heat shall be adopted as the power supply for traffic control devices and roadside facilities.

4.5 Design Checking and Safety Assessment

4.5.1 A highway design shall be checked by operating speeds to analyze and confirm the geometric design in terms of highway route location, geometric parameters, and alignment combination as well as to examine the harmonization and consistency of operating speeds.

4.5.2 A road safety audit (RSA) shall be conducted at the design stage for motorways, class-1 and class-2 highways and may be conducted whenever feasible for other classified highways. Based on the conclusion of RSA, the alignment design and the selected geometric parameters shall be adjusted accordingly for optimization, the traffic safety devices and management measures shall be examined for improvement, which shall comply with the following requirements.

1 In the uphill direction of a segment with continuous and long steep grades, the analysis and assessment shall focus on the passing capacity and level of service in accordance with traffic volume, the composition of vehicle types and the changes of operating speeds, based on which traffic management and traffic control measures shall be proposed and the necessity of climbing lanes may be assessed.

2 In the downhill direction of a segment with continuous and long steep grades, the analysis and assessment shall focus on traffic safety in accordance with traffic volume, the composition of vehicle types and the performance of the major truck types. Effective traffic control devices and roadside safety facilities shall be arranged, based on which traffic management and speed control measures shall be proposed and the necessity of emergency escape ramps may be assessed.

3 For road segments at waterside, on a cliff or high embankment, the remaining roadside risks shall be analyzed and assessed for proposed safety facilities and improvements shall be made to the roadside barriers in accordance with the highway function, design speeds and traffic volumes. Traffic management details may be proposed or the level of roadside protection may be increased wherever necessary.

5Highway Route Location

5.0.1 Highway route location shall refer to the whole process of selection and determination of primary orientation, route corridor, route proposal, and route location.

5.0.2 Selecting the orientation and its control points of a highway route shall conform to the requirements as follows.

1Control points of primary orientation of a highway route shall include origin and destination of a proposed highway, the cities and towns that must be interlinked, important zones, industrial or mining sites and transport transfer centers, and the localities of particular super-large bridges and particular extra-long tunnels.

2 Control points of orientation of a highway route shall include the localities of super-large and large bridges, extra-long and long tunnels, interchanges, and railway crossings, and shall follow the primary orientation of a highway route.

3 Localities of medium and small bridges, culverts, medium and short tunnels, and other ordinary structural works shall follow the orientation of a highway route.

5.0.3 The focuses of highway route location at different design stages shall be differentiated from each other. A route location shall be developed in a way of continuous improvement, as the tasks carried out in an earlier stage shall be detailed and optimized in the next stage.

5.0.4 Highway route location shall follow the principles as follows.

1 A highway route corridor shall be determined by taking into account the allocation and coordination among various transportation systems and between different levels of a road network within the corridor. Based on its functions, the highway route corridor shall be planned in a systematic way to provide rational and sustainable frameworks for both short-term needs and long-term strategies

2 Highway route location shall be executed in a stepwise manner from the network to a corridor, and then from the corridor to a route based on thorough investigations on terrain, geologic, hydrologic, and meteorological conditions, and environmental sensitive areas. Alternative assessments shall be conducted wherever more than one feasible route proposals are identified for a route segment with the same origin and destination.

3 The positioning of a highway route shall account for the development programs of irrigation, resource exploitation, and urbanization.

4 A highway route location shall ensure the fully utilization of the land for the highway reserve based on the policy on strict protection for farming lands. Eco-environment shall be protected. The proposed highway shall be in harmony with the local landscape.

5 A highway route shall be kept away from immovable cultural relics, water sources and natural reserves.

6 A highway route shall be kept in a safe distance from hazards such as flammables and explosive materials.

7 The upgrading or reconstruction of an existing highway shall account for resource conservation. Utilization of existing materials and works shall be in priority for reconstruction.

5.0.5 Highway route location shall conform to the following requirements.

1 The geology and hydrogeology in the network areas and the transportation corridors along the highway route shall be investigated and surveyed in depth and detail. Their impact on highway works shall be identified and evaluated. For the segments in unfavorable geological conditions, highway route alternatives for bypassing, avoiding or crossing shall be assessed in accordance with the geologic impact on the highway route.

2 The sensitive places and mineral resources along a highway route shall be investigated and their impact on the proposed highway route shall be studied in order to identify and select the best location of a highway route.

3 For a motorway or class-1 highway, the connections from major traffic sources to the highway route shall be realized by taking advantage of the existing regional network or by construction of new link roads.

4 For a class-2 or class-3 highway, the highway route shall avoid passing through cities or towns wherever possible but nevertheless providing compliance with its basic function and orientation.

5The relationships in terms of positions and elevations shall be coordinated for the structural works and roadside facilities such as bridges, tunnels, interchanges and service areas.

6 Parallel or crossing relations between the highway and other transportation modes such as railways, electric lines, and pipelines shall be taken into

account to properly utilize resources in the corridor and minimize land occupation.

7 In plain terrain, higher technical indicators should be used. A long tangent and small deflection angle of a curve shall be avoided wherever possible.

8 In mountainous terrain, the location of a mountain pass shall be selected in accordance with topographic conditions. High fills or deep cuttings shall be avoided wherever possible.

9 Along river or stream bank, the position and elevations of a highway route shall be determined in accordance with design flood level, terrain and geological conditions. Comparison of a bridge alternative with hillside road alternative should be conducted if necessary.

5.0.6 Either a desk study or field method may be used for highway route location and shall comply with the provisions as follows.

1 Field verification must be conducted if method desk study is used for route location of a motorway or class-1 highway.

2 Field method may be used for the location of a class-2,class-3 or class-4 highway. Where it is feasible or constrained by terrain, desk study location or relocation followed by field verification may be adopted.

5.0.7 Highway route location shall proceed in two stages. The first stage is to gather the existing information that may be relevant to highway route location, including programs, plans, statistics, and various topographic maps, geological and meteorological logs. Much of the information may be available from local authorities. The second stage is to conduct detailed site investigations and surveys. Remote sensing, aero mapping, satellite positioning, and digital technology shall applied to ensure adequacy, accuracy and quality. No feasible alternatives shall be ignored.

6 HIGHWAY CROSS-SECTIONS

6.1 General

6.1.1 Types and elements of typical roadway cross-section of a highway shall conform to the provisions as follows：

1 There are two types of typical roadway cross-sections for motorways and class-1 highways, i.e. integral type and separated type. A typical cross-section of an integral roadway shall consist of traffic lanes, the median (including a central dividing strip and left margins) and shoulders (including right hard shoulder and earth shoulder). A typical cross-section of separated roadways shall consist of traffic lanes, shoulders (right hard shoulders, left hard shoulders, and earth shoulders).

2 A typical cross-section of a class-2 highway shall consist of traffic lanes and shoulders (including hard shoulders and earth shoulders).

3 A typical cross-section of a class-3 or class-4 highway shall consist of traffic lanes and shoulders.

6.1.2 Roadway cross-section of a highway shall be determined in accordance with the highway function, technical classifications, traffic volumes, terrain and so forth. Typical roadway cross-sections of classified highways are shown in Figures from 6.1.2-1 to 6.1.2-4 and shall conform to the provisions as follows.

1 Either integral type or separated type of a cross-section shall be adopted for a motorway or class-1 highway depending on specific needs.

2 Combined type of roadway cross-section may be adopted for a motorway with 10 or more lanes.

3 Integral type of roadway cross-section shall be adopted for class-2, class-3 and class-4 highways.

6.1.3 The width of elements of a roadway cross-section shall be determined in accordance with the highway technical classification, traffic volumes and element functions, which shall conform to the provisions as follows.

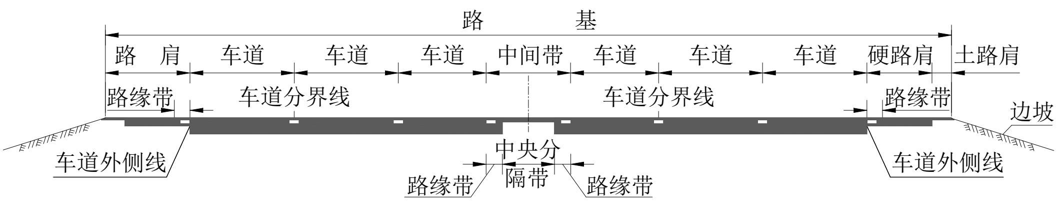
1 Roadway width is the sum of lane widths and shoulder widths, and shall also include the widths of median, speed changing lanes, climbing lane,

turnouts, passing bays, passing lane, outer separations, non-motor vehicle lane (or slow vehicle lane) and sidewalks, if there are any.

2 Outer separations, non-motor vehicle lanes, and sidewalks may be placed as needed on the highways with a high proportion of non-motorized and pedestrian traffic or on the highways linking to urban areas.

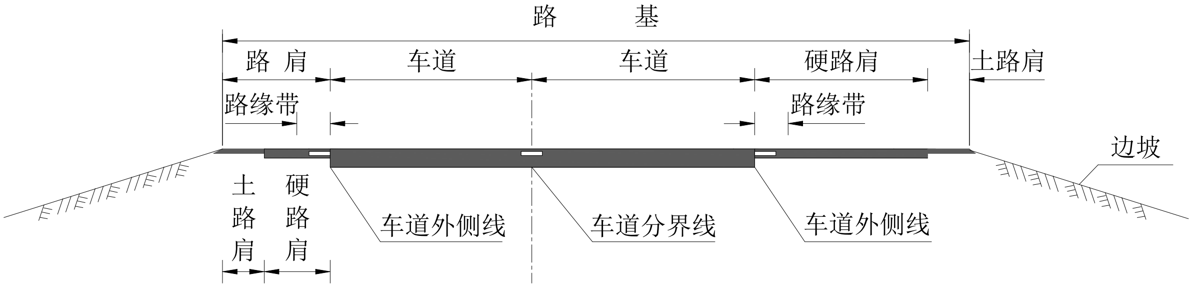
3 In the segments of a class-1 highway where the proportion of slow-moving vehicles is high, the slow moving lane may be placed by using right hard shoulders (which shall be widened in the case of insufficient width) , but separation facilities shall be installed in between such a shoulder lane and adjacent lane.

4 In the segments of a class-2 highway where the proportion of slow moving vehicles is high, slow lanes may be arranged as needed by widening hard shoulders, while additional safety devices shall be placed as needed and traffic control measures shall be reinforced.



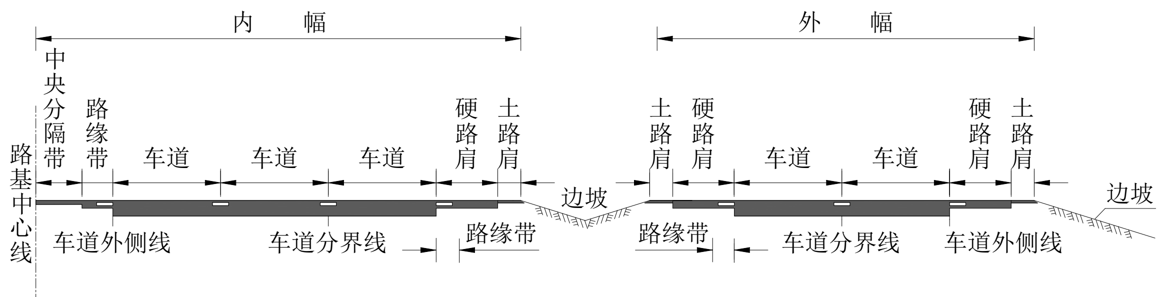
路基 roadway									
路基 shoulder	车道 lane	车道 lane	车道 lane	中间带 median	车道 lane	车道 lane	车道 lane	硬路肩 Hard shoulder	土路肩 Earth shoulder
Marginal strip	车道分界线 Lane lines				车道分界线 Lane lines			路缘带 Marginal strip	边坡 Side slope
车道外侧线 Outer edge line				中央分隔带 Central dividing strip			车道外侧线 Outer edge line		
			路缘带 Marginal strip		路缘带 Marginal strip				

Figure 6.1.2-1 Integral type cross-section of a motorway or class-1 highway



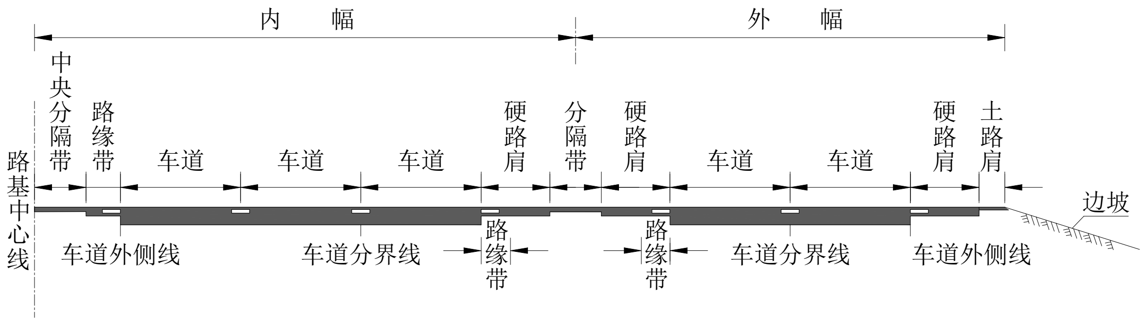
路基 Roadway				
路肩 Shoulder	车道 Lane	车道 lane	硬路肩 Hard shoulder	土路肩 Earth shoulder
路缘带 Marginal strip			路缘带 Marginal strip	
土路肩 Earth shoulder	硬路肩 Hard shoulder	车道外侧线 Outer edge line	车道分界线 lane line	边坡 Side slope

Figure 6.1.2-2 Separated type cross-section (right roadway only) of a motorway or class-1 highway



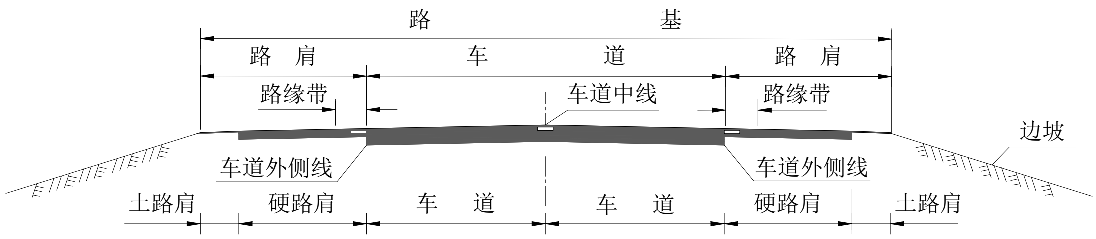
	内幅 Inner roadway						外幅 Outer roadway					
路基中心线 Highway central line	中央分隔带 Central dividing strip	路缘带 Marginal strip	车道 Lane	硬路肩 Hard shoulder	土路肩 Earth shoulder	边坡 Side slopes	土路肩 Earth shoulder	硬路肩 Hard shoulder	车道 Lane	Hard shoulder	Earth shoulder	边坡 Side slope
	车道外侧线 Outer edge line		车道分界线 Lane line	路缘带 Marginal strip			路缘带 Marginal strip		车道分界线 Lane lin e		车道外侧线 Outer edge line	

Figure 6.1.2-3-1 separated type, combined cross-section (right roadway only) of a motorway



	内幅 Inner roadway					外幅 Outer roadway				
路基中心线 Highway central line	中央分隔带 Central dividing strip	路缘带 Marginal strip	车道 Lane	硬路肩 Hard shoulder	分隔带 Dividing strip	硬路肩 Hard shoulder	车奥 Lane	硬路肩 Hard shoulder	土路肩 Earth shoulder	边坡 Side slope
	车道外侧线 Outer edge line		车道分界线 Lane lines	路缘带 Marginal strip		路缘带 Marginal strip	车道分界线 Lane lines		车道外侧线 Outer edge line	

Figure 6.1.2-3-2 Integral Type combined cross section (right roadway only) of a motorway



	路基 Roadway				
	路肩 Shoulder	车道 Traveled-way		路肩 shoulder	
	路缘带 Marginal strip		车道中线 Center line	路缘带 Marginal strip	
	车道外侧线 Edge line			车道外侧线 Edge line	边坡 Side slope
路肩 Earth shoulder	硬路肩 Hard shoulder	车道 lane	车道 lane	硬路肩 Hard shoulder	土路肩 Earth shoulder

Figure 6.1.2-4 Typical cross-section of class-2, class-3 and class-4 highways

6.2Traffic Lane

6.2.1 Lane widths shall conform to the criteria shown in Table 6.2.1 and the provisions as follows.

Table 6.2.1 Lane Widths

Design speed (km/h)	120	100	80	60	40	30	20
Lane width (m)	3.75	3.75	3.75	3.50	3.50	3.25	3.00

1 The lane width of 3.5m may be adopted for first and second inner lanes, which are designed only to accommodate passenger cars on a multilane highway with eight or more lanes.

2 Where the traffic is dominated by medium or small passenger vehicles and the design speed is over 80km/h, 3.5m can be adopted as the lane width subject to the approval after specific assessment.

3 The lane width shall be 3.5m for a dual single lane, class-4 highway.

4 The width of the slow lane on a class-2 highway shall be 3.5 m.

5 Where a non-motor vehicle lane or a sidewalk or both are needed, the width may be determined according to the needs.

6.2.2 The number of lanes of each classified highway shall conform to the criteria in Table 6.2.2 and the provisions as follows.

Table 6.2.2 Number of Lanes of Classified Highway

Highway Classifications	Motorway or Class-1	Class-2	Class-3	Class-4
Number of Lanes	≥4	2	2	2（1）

1 The number of lanes of a motorway or class-1 highway shall be determined in accordance with design traffic volume and design capacity, which shall not be less than four lanes and shall be increased in pairs and symmetrically on each side.

2 A class-2 and class-3 highway shall have two lanes.

3 A class-4 highway usually shall have two lanes. Dual single lane may be adopted only in the highway segments where traffic volumes are small and physical conditions are extremely difficult.

6.2.3 The placement of a climbing lane shall conform to the provisions as follows.

1 Where a climbing lane is placed in the continuous ascending upgrade of a motorway, class-1 highway or class-2 highway, its width shall not be narrower than 3.5m and not wider than 4.0m. For six or more multilane motorways and class-1 highways, climbing lanes may not be placed.

2 The climbing lane on a motorway or class-1 highway shall be placed at the outer edge of traveled way. The width of the hard shoulder abutting to the right edge of a climbing lane shall not narrower than 0.75m even if constrained by environment.

3 The climbing lane on a class-2 highway shall be placed abutting to the outer edge of the travelled-way and the hard shoulder may be used as part of it. A hard shoulder, which has to be reserved for accommodating non-motor vehicles, shall be shifted to and placed at the outer edge of the climbing lane.

6.2.4 The placement of acceleration lanes or deceleration lanes shall conform to the provisions as follows.

1 On a motorway or class-1 highway, speed-change lanes (either acceleration or deceleration lanes) shall be placed at interfaces between the main route and interchanges, service areas, rest areas, transit bus bays, administrative and maintenance facilities, scenic overlooks and so forth. The width of a speed-change lane shall be 3.5 m.

2 On class-2 highways, transition segments shall be placed at the accesses to or from service areas, rest areas, bus bays, administration and maintenance facilities, gas stations, scenic overlooks and so forth.

6.2.5 On a dual single-lane class-4 highway, passing bays shall be placed at proper locations at a spacing not longer than 300m from each other and enable a driver to see the oncoming vehicles between two adjacent passing bays ahead. The roadway where a passing bay is placed shall not be less than 6.5m in width and 20m in its effective length.

6.2.6 Road safety audit shall include the verification of placing emergency escape ramps at continuously long and steep downgrades. The width of an emergency escape ramp shall not be less than 4.50m. The emergency escape ramp shall be placed at a proper position where it is easily seen at a distance from the descending segment of the main route. If possible, a rescue access should be placed beside the emergency escape ramp.

6.3 Median

6.3.1 A median, which consists of a central dividing strip and two left marginal strips, must be placed on the integral type roadway of a motorway or class-1 highway and shall conform to the provisions as follows.

1 The width of the central dividing strip on a motorway or class-1 arterial highway shall be determined by the functions to be served by the central dividing strip

2 The width of a central dividing strip on a class-1 arterial highway shall be determined in accordance with the spacing for the installation of median barriers.

3 Width of a left marginal strip shall not be less than the values specified in Table 6.3.1.

Note: 1 'Normal' refers to the values to be taken under normal circumstances;

Table 6.3.1 Width of Left Marginal Strip

Design speed (km/h)		120	100	80	60
Width of left marginal strip (m)	Normal	0.75	0.75	0.50	0.50
	Minimum	0.50	0.50	0.50	0.50

2 'Minimum' refers to the values may be taken for the segments where the design speed is 120km/h or 100km/h but restrained by terrain and ground objects or the inner lanes are assigned to accommodate small vehicles only, subject to the approval of specific assessment.

6.3.2 The spacing of separated roadways shall be adequate for installing drainage and safety facilities and blend with the surrounding terrain and landscape.

6.3.3 Median openings shall be placed before and after an interchange, tunnel, super-long bridge, service area, and at a split (or merging) point from integral type roadway to separated type roadway, which shall conform to the provisions as follows.

1 Median openings shall be placed as actually needed. The minimum spacing between any two median openings shall not be less than 2km.

2 The width of a median opening should not be greater than 40 m. The width of a median opening on an eight or more multilane motorway may be appropriately wider, but shall not be greater than 50m.

3 A median opening shall be placed on the segment with good sight distance. Where a median opening is on a curved segment, the superelevation on the circular curve shall not be greater than 3%.

4 Both ends of a median opening may be in a semi-circular shape where the width of the central dividing strip is narrower than 3.0m; or should be in bullet shape if the width of the central dividing strip is equal to or wider than 3.0m.

6.3.4 Separated roadways shall be provided with cross-over links for maintenance, repairs, and emergency rescue.

6.4 Shoulders

6.4.1 The width of right shoulders of a classified highway should conform to the criteria in Table 6.4.1 and the provisions as follows.

Table 6.4.1 Width of Right Shoulder

Highway classification (function)		Motorway			Class-1 arterial highways	
Design speed (km/h)		120	100	80	100	80
Width of right hard shoulder (m)	Normal	3.00（2.50）	3.00（2.50）	3.00（2.50）	3.00（2.50）	3.00（2.50）
	Minimum	1.50	1.50	1.50	1.50	1.50
Width of earth shoulder (m)	Normal	0.75	0.75	0.75	0.75	0.75
	minimum	0.75	0.75	0.75	0.75	0.75
Highway classification (function)		Class-1 collector-distributor highway and Class-2 highway		Class-3 and class-4 highway		
Design speed (km/h)		80	60	40	30	20
Width of right hard shoulder (m)	Normal	1.50	0.75	—	—	—
	Minimum	0.75	0.25			
Width of earth shoulder (m)	Normal	0.75	0.75	0.75	0.50	0.25(two lane) 0.50(single lane)
	minimum	0.50	0.50			

Note: 1 ‘Normal ‘values shall be used under normal circumstances; ‘minimum’ values may be adopted subject to approval after specific assessment for the segments with climbing lanes, speed-change lanes or passing lanes, restrained by terrain or on multilane bridges.

2 The values in brackets may be used for the motorways and class-1 arterial highways mainly accommodating passenger cars.

3 The width of a right hard shoulder shall not be narrower lower than 1.5m on the motorway segments where a design speed of 60km/h is adopted.

1 On a motorway or class-1 highway, a right marginal strip shall be placed within the width of a right hard shoulder. The width shall be 0.50m;

2 On a class-2 highway, the hard shoulders can be used by non-motor traffic. On the segments where the non-motor traffic is large, fully paved shoulders may be adopted.

3 The signboards, guarding facilities installed on shoulders of a class-2, class-3 or class-4 highway must not intrude into the highway clearance profile. The shoulders shall be widened wherever necessary.

6.4.2 Left shoulder on a motorway or class-1 highway shall conform to the provisions as follows.

1 Left shoulders shall be placed in a motorway or class-1 highway with separated type roadways. The width of a left shoulder shall be as shown in Table 6.4.2. A left hard shoulder contains a 0.50m wide left marginal strip.

Table 6.4.2 Width of Left Shoulder on a Motorway or Class-1 Highway

Design speed (km/h)	120	100	80	60
Width of left hard shoulder (m)	1.25	1.00	0.75	0.75
Width of left earth shoulder (m)	0.75	0.75	0.75	0.50

2 Left shoulders should be placed in the motorway segments with an integral type cross-section with dual eight or more multilane roadway. The width of such a left shoulder shall not be less than 2.5m.

3 A left hard shoulder shall be placed in the motorway segments with 4 or more lanes on each separated roadway. The width of a left hard shoulder should not be less than 2.5m.

6.4.3 The placement of turnouts shall conform to the provisions as follows.

1 Intermittent turnouts shall be placed where the width of right hard shoulder of a motorway or class-1 arterial highway is narrower than 2.50m. The width of a turnout shall not be narrower than 3.50m and its effective length shall not be shorter than 40m. The spacing between any two turnouts shall not be greater than 500m. A transition section equal to or longer than 70 m shall be placed before and after the turnout.

2 Turnouts may be placed on super-large bridges or in extra-long tunnels of a motorway or class-1 highway. The spacing between any two turnouts should not be longer than 750m.

3 Turnouts may be placed on a class-2 highway. The spacing between any two turnouts shall be decided based on actual conditions.

6.5 Road Crown and Cross-slope

6.5.1 Road crown should be adopted for an integral roadway cross-section of a motorway and Class-1 highway, of which the highest point is in the middle and a cross-slope downward towards both edges. The cross-slope of a road crown should be 2% in moderate rainfall areas and may be appropriately increased in the areas with higher rainfall.

6.5.2 For the motorways and class-1highways with separated roadways, a single cross-slope, downward toward the outer edge of each roadway, should be used, and a crown with two downward cross-slopes may also be used. In the areas venerable to snow cover and ice freezing, a road crown with two downward cross-slopes should be used.

6.5.3 For dual divided highways with 6 or more lanes, a crown with two downward cross-slopes may be used if the cross-slope in a superelevation transition section is too flat. A specific drainage analysis shall be conducted for the segment where cross-slope is comparatively flat.

6.5.4 A road crown with two cross-slopes downward from middle toward both edges of roadway could be applied for Class-2, -3 and -4 highways, of which the cross-slope shall be determined in accordance with local environment, but shall not be less than 1.5%.

6.5.5 The cross-slope design for hard shoulders and earth shoulders shall conform to the provisions as follows.

1 The down-slope towards the outer edge shall be adopted for hard shoulders on a tangent alignment with the same grade as that of the cross-slope of the adjacent traffic lane. A cross-slope of 3% to 4% should be used in the segments with edge curbs.

2 For the hard shoulders at either the inner side or outer side in a segment on curve, the value and direction of cross-slope shall be the same as those for the adjacent traffic lane where the superelevation is 5% or less while the cross-slope shall not be greater than 5% but in the same direction where the superelevation is greater than 5%.

3 The cross-slope of a hard shoulder shall transition along with the cross-slope of the adjacent traffic lane at a transition rate between 1/330 and 1/150.

4 The cross-slope of an earth shoulder on a tangent segment or the inner side of a segment on curve, where the cross-slope of travelled way or hard shoulder is 3% or greater, shall be the same as that of the travelled way or

the hard shoulder; or shall be 1% or 2 % greater than that of the adjacent traffic lane or hard shoulder. Furthermore, the cross-slope of an earth shoulder on the outer side of a segment on a curve shall be at a reverse grade of 3% or 4%.

5 The cross-slopes of hard shoulders on segments of medium or larger bridges or in tunnel segments shall be the same as that of the roadway.

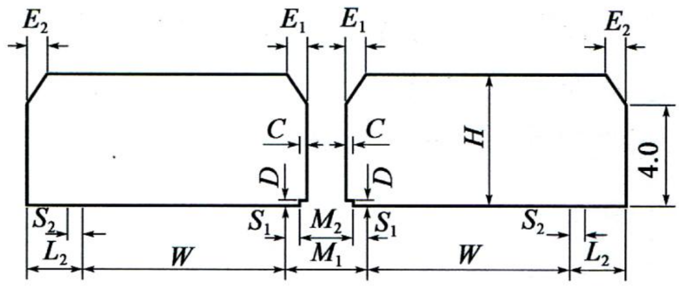
6.6 Highway Clearance Profile

6.6.1 No obstacle subjects shall intrude into the highway clearance profiles. Traffic signs, road barriers, lighting posts, cable brackets, plantations, roadside trees and any part of the bottom of an overpass bridge, bridge piers and abutments must not intrude into the highway clearance profile.

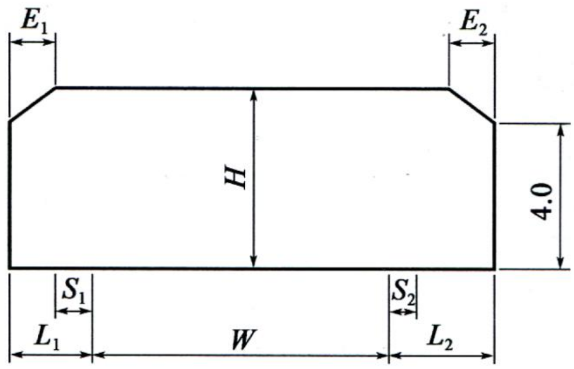
6.6.2 The clearance profile of a classified highway shall conform to Figure 6.6.2 and the provisions below.

1 The travelled way shall include the width for accommodation of any auxiliary traffic lanes such as speed-change lanes, turnouts, climbing lanes, passing lanes, and non-motor lanes, as well as channelization facilities.

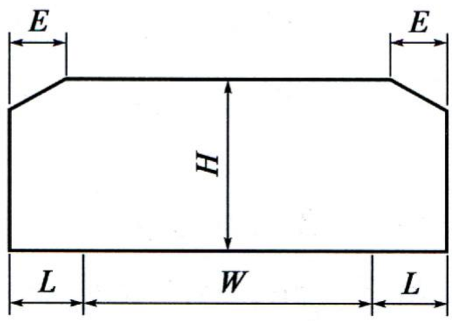
2 The clearance profile on a motorway (integral type) of eight or more lanes shall include the width of the left hard shoulder provided that such a facility is constructed.



Motorway and class-1 highway (integral type)



b) Motorway, class-1 highway (separated type)



c) Class-2, class-3 and class-4 highway

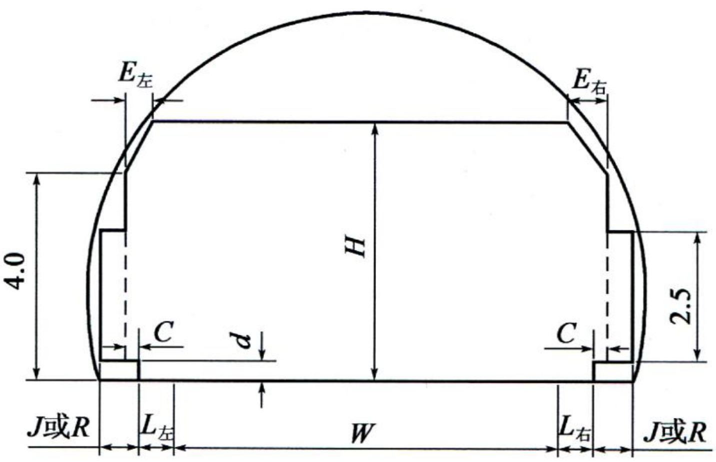
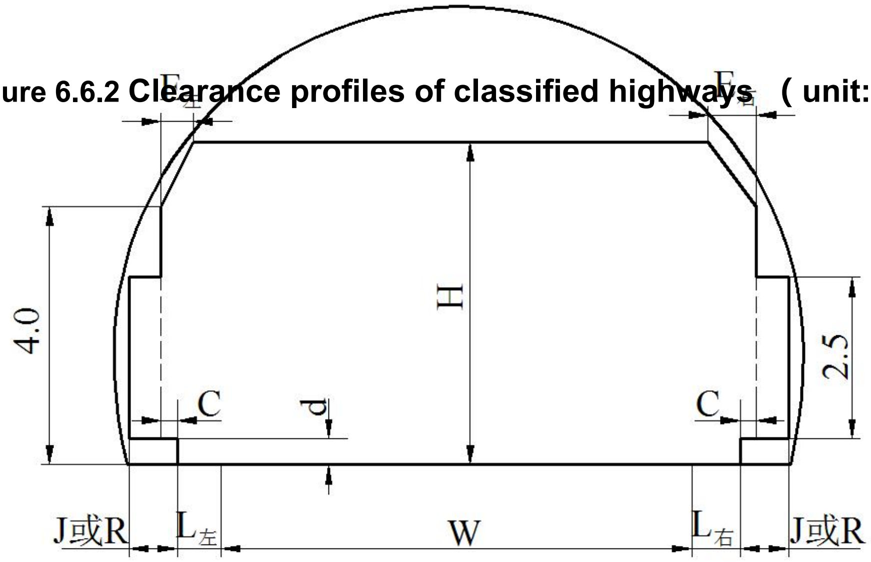


Figure 6.6.2 Clearance profiles of classified highways (unit: m)



d) Highway tunnel

In the figures above:

W – width of travelled-way；

L_1 -- width of left hard shoulder；

L_2 -- width of right hard shoulder；

S_1 -- width of left marginal strip；

S_2 – width of right marginal strip；

L – side width, which is the width of hard should on one side of a class-2 highway; or the width of hard shoulder on one side minus 0.25m for a class-3 or class-4 highway; the side width may include widening for the needs of barrier installation;

L_{left} ——left side width in a tunnel;

L_{right} ——right side width in a tunnel;

C — take 0.5m where design speed is over 100km/h, or 0.25m where design speed is 100km/h or lower;

D — the height of curbs, shall not be higher than 0.25m. Under normal circumstances, no curbs need to be installed on motorways;

M_1 — width of median;

M_2 — width of central dividing strip;

J—width of maintenance path;

R—— width of sidewalk;

d — height of maintenance path or sidewalk;

E —width of top corner of the clearance profile, E=L where $L \leq 1$m; E=1m where L>1m。

E_1 —— width of top corner of the clearance profile, $E_1=L_1$ where $L_1<1$m, or $E_1=S_1+C$ *where* $S_1+C<1$m,; $E_1=1$m where $L_1 \geq 1$m 或 $S_1+C \geq 1$m;

E_2 —— width of top corner of the clearance profile, $E_2=1$m;

E_L — width of top corner on left of the clearance profile, E=L where $L \leq 1$m; E=1m where L>1m。

E_R — width of top corner on right of the clearance profile, E=L where $L \leq 1$m; E=1m where L>1m。

H — vertical clearance

Table 6.6.2 Minimum side widths in a Tunnel

Design speed（km/h）	Motorway, class-1 highway				class-2, class-3 and class-4 highway				
	120	100	80	60	80	60	40	30	20
Left side width L_{left}（m）	0.75	0.75	0.5	0.5	0.75	0.5	0.25	0.25	0.50
Right side width L_{right}（m）	1.25	1.00	0.75	0.75	0.75	0.5	0.25	0.25	0.50

3Minimum side widths in a tunnel are given in Table 6.6.2

4 Where maintenance paths, sidewalks, or both are placed on a bridge or in a tunnel, the clearance profile shall include the widths of these facilities.

5 The vertical clearance shall be 5.00m for motorways, class-1 highways, and class-2 highways; or 4.50m for class-3 and class-4 highways.

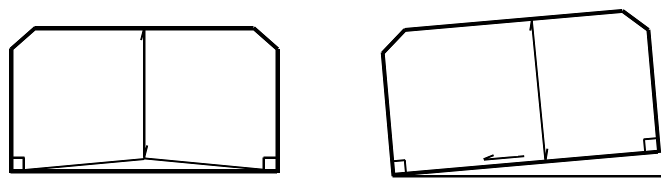
6 The vertical clearance shall be 2.50m for sidewalks, bicycle lanes and maintenance paths where these facilities are placed separately from the travelled way.

7 The highway clearance profile on the approach roads to bridges or tunnels shall be treated in the same way as that for transition sections.

6.6.3 The highway clearance profile shall be demarcated in accordance with Figure 6.6.3 and conform to the provisions below.

1 For the segments with no superelevation, the top line shall be horizontal and both side lines shall be at a right angle to the top line;

2 For the segments with a superelevation, the top line shall be parallel to the cross-slope and both side lines shall be at a right angle to the cross-slope.



a) a normal crowned section b)a superelevated section

Figure 6.6.3 Demarcation of Clearance Profile

6.6.4 The vertical clearance of a highway shall conform to the provisions below.

1 According to the locality and position, the vertical clearance shall be kept constant over the length of a highway.

2 An additional 20cm shall be reserved for vertical clearance of a class-3 or class-4 highway where the pavement is asphalt penetration, asphalt macadam, asphaltic surface dressing, or gravel macadam.

3 Where bridge piers, abutments or signboard posts are placed in the central dividing strip or on road shoulders, the front edge of such facilities or structures must not intrude into the highway clearance profile, and any part of such facilities and structures must not touch the highway facilities. A lateral spacing shall be ensured for collision buffering and absorbing.

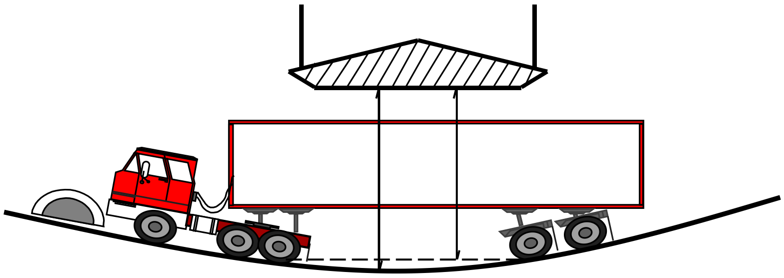


Figure 6.6.4 Effective vertical clearance on a sag curve

3 Where an overpass structure is above a sag vertical curve, the effective vertical clearance shall be adequate for the articulated semi-trailer or extra-long vehicle passing through, as shown in Figure 6.6.4.

4 Where the overpass structure with a large span or a large skew angle over a highway, the effective vertical clearance measured from any point along the bottom edge of the overpass structure to the road pavement shall conform to the relevant provisions and regulations.

6.7 Land Acquisition for Highway Reserve

6.7.1 Land acquisition for highway reserve shall conform to the policies in terms of resource conservation, land utilization, protection of farmland， and sustainable socio-economic development. A highway reserve shall be determined in accordance with properly controlled scope of the project, carefully selected technical criteria and elaborately developed construction program.

6.7.2 The scope of a land acquisition for highway reserve shall be determined in compliance with the provisions as follows:

1 The boundary of the highway reserve shall not be less than 1m from the outer edge of the side drains beside an embankment (or the toe of fill-slope with no side drains), or from the outer edge of the interception drain on top of a cut slope (or the top of a cut slope with no interception drain) along a highway. Such spacing should be extended to 3 meters or wider for motorways and class-1 highways, and 2 meter or wider for class-2 highways.

2 In the areas subject to adverse climatic or geological conditions such as sandstorms, heavy snow falls, landslides, or debris flows, the highway

reserve shall be determined for the actual needs for installing preventive or protective facilities, or the needs for ground improvement of expansive or saline subsoil.

3 The highway reserve shall be determined for the actual needs for bridges, tunnels, interchanges, grade separations, intersections, safety devices, service facilities, administrative facilities, landscaping, and other off-road works and installations.

4 The land reserve shall consider the actual needs of planting multiline tree belts in the cases where suitable or are required by the environment.

5 Highway reserve for an upgrading or reconstruction project may be executed by referring to the provisions for new highway projects.

7 HIGHWAY HORIZONTAL ALIGNMENT

7.1 General

7.1.1 Highway horizontal alignment consists of three elements, namely tangent, circular curve, and transition curve. Spirals shall be used as transition curves.

7.1.2 A horizontal alignment must be in harmony with terrain, landscape and environment. Attention shall be paid to alignment continuity, equilibrium, and its coordination with vertical alignment and cross-sections.

7.2 Tangent

7.2.1Atangent segment should not be very long. If a long tangent segment has to be adopted in an area which is constrained by terrain or other conditions, effective engineering measures shall be arranged in accordance with the specific situation.

7.2.2 The length of the tangent connecting two circular curves shall not be very short, and shall conform to the provisions as follows.

1 Where design speed is 60 km/h or higher, the tangent between two circular curves in the same direction shall have a minimum length (m) not less than 6 times the design speed (km/h), while the tangent between two reversed circular curves shall have a minimum length (m) not less than two times the design speed (km/h).

2 The provision above may also be applied where design speed is 40 km/h or lower.

7.3 Circular Curve

7.3.1 A circular curve shall be placed where two tangent alignments intersect regardless of the deflection angle. The radius of a circular curve shall fit the design speed.

7.3.2 The minimum radius of a circular curve shall be determined in accordance with design speed, as shown in Table 7.3.2.

7.3.3 The maximum radius of a circular curve should not exceed 10,000m.

Table 7.3.2 Minimum Radii of Circular Curves

Design speed (km/h)		120	100	80	60	40	30	20
Normal value for Min. Radii (m)		1000	700	400	200	100	65	30
Limiting value for Min. Radii (m)	I_{max} =4%	810	500	300	150	65	40	20
	I_{max} =6%	710	440	270	135	60	35	15
	I_{max} =8%	650	400	250	125	60	30	15
	I_{max} =10%	570	360	220	115	-	-	-

Note: ‘Normal values’ shall be taken under normal circumstances; ‘limiting values’ may be taken under constrained conditions; ‘I_{max}’ is the maximum value of superelevation; ‘-’ refers to the circumstance where the maximum superelevation is not considered.

7.4 Spiral

7.4.1 A spiral shall be placed where a tangent connects a circular curve with the radius smaller than that required for non-superelevated curves in Table 7.4.1 for motorways, class-1, class-2 and class-3 highways. For class-4 highway, a spiral may not be placed, beta transition section for super elevation and widening shall be provided.

Table 7.4.1 Minimum Radii for Non-superelevated Circular Curves

Design speed (km/h)		120	100	80	60	40	30	20
Min. Radius for non-superelevation	Cross slope ≤2%	5 500	4 000	2 500	1 500	600	350	150
	Cross slope >2%	7 500	5 250	3 350	1 900	800	450	200

7.4.2 A spiral shall be provided at the connection between two same-directional circular curves with different radii. However, such a spiral may not be placed in any of the following cases.

1 where the smaller radius is greater than the values specified in Table 7.4.1;

2 where the smaller radius is larger than the values specified in Table 7.4.2 for any of the following:

1) The difference between the inner shifts of larger and smaller circles would be less than 0.10m if a minimum length of spiral is used for the small circle;

2) Design speed is greater than or equal to 80km/h, and the ratio of large radius (R_1) to small radius (R_2) is less than 1.5;

3) Design speed is lower than 80km/h, and the ratio of large radius (R_1) to small radius (R_2) is less than 2.0.

Table 7.4.2 Critical Radius of the Smaller circle in a Compound Circular Curve

Design speed (km/h)	120	100	80	60	40	30
Critical radii (m)	2 100	1 500	900	500	250	130

7.4.3 The length of a spiral shall conform to the provisions as follows.

1 The length of a spiral shall be increased as the radius of circular curve becomes larger.

2 Where superelevation is placed on a circular curve as specified, the length of the spiral shall not be less than the length of the superelevation transition section.

3 The minimum length of a spiral shall be in compliance with Table 7.4.3.

Table 7.4.2 Minimum Length of Spiral

Design speed (km/h)	120	100	80	60	40	30	20
Min. Length of Spiral	100	85	70	50	35	25	20

Note: for Class 4 highways, the length refers to that of transition section for widening and superelevation.

7.5 Superelevation on Circular Curve

7.5.1 Superelevation shall be placed on a curve where the circular curve has a radius less than the minimum radius for non-superelevated curves as specified in Table 7.4.1, and shall conform to the provisions as follows.

1 Maximum superelevation in circular curve sections of a classified highway shall comply with the criteria in Table 7.5.1.

2 Minimum superelevation of circular curve sections of a classified highway shall be the same as that of cross slope of normal crown in tangent sections of the highway.

Table 7.5.1 Maximum superelevation Value on Circular Curve of Classified Highways

Highway classification	Motorway and Class-1 Highway	Class-2, Class-3 and Class-4 Highway
Ordinary areas	8 or 10	8
Freezing areas	6	
Urban areas	4	

Note: In ordinary areas, the maximum superelevation on a circular curve shall be 8% for motorways and class-1 highways where dominant traffic is medium and small passenger vehicles, the maximum superelevationcan be taken as 10%.

7.5.2 For segments of a class-2, class-3, or class-4 highways near cities or towns, where travel speed is limited due to a large volume of mixed traffic, the maximum superelevation shall be selected from the values given in Table 7.5.2.

Table 7.5.2 Maximum superelevation under Limited Vehicle Speed

Design speed (km/h)	80	60	40、30、20
Superelevations (%)	6	4	2

7.5.3 The superelevation corresponding to the radii of circular curves shall be calculated and determined according to design speeds, radii of circular curves, highway environment, and natural conditions.

7.5.4 A superelevation transition section must be placed where cross-slopes change. The superelevation transition rate shall be determined in accordance with the position of the axis of rotation and Table 7.5.4.

Table 7.5.4 Superelevation Transition Rate

Design speed (km/h)	Revolving position	
	center line	edge
120	1/250	1/200
100	1/225	1/175
80	1/200	1/150
60	l/175	1/125
40	1/150	1/100
30	l/125	1/75
20	1/100	1/50

7.5.5 Methods of superelevation transition shall conform to the provisions as follows.

1 For highways without a median, where superelevation is equal to the cross slope of road crown, outer lanes shall be revolved about the centerline of roadway up to the superelevated cross slope; where superelevation is

greater than the cross slope of the road crown, the traveled way shall be revolved about the inner edge, centerline or outer edge. The following requirements shall be used depending on specific situations:

1）The traveled way revolved about its inner edge should be adopted for new construction projects;

2) Revolving about the centerline may be adopted for upgrading or reconstruction projects;

3) Revolving about the outer edge may be adopted where the outer edge of the traveled way is constrained or there are special requirements for road surface appearance.

2 For highways with a median, there are three methods for superelevation transition, namely revolving about the centerline of the median, revolving about the edge of the median, and revolving respectively about the centerlines of traveled ways. A decision shall be made based on the actual situation.

1) Revolving about the edge of the median may be adopted for all highways with a median.

2) Revolving about the centerline of the median may be adopted for a highway with a narrow median.

3) Revolving about the centerline of each traveled way may be adopted for a highway that has more than four lanes.

3 For a highway with separated roadways, superelevation transition should be designed individually as for a highway without median.

7.5.6 Transition of superelevation shall be distributed over the full length of a spiral. In the case of a longer spiral, superelevation transition shall be spread within a certain part of the spiral. The transition rate must not be less than 1/330, and a fully superelevated segment should start at circular-transition point and end at transition-circular point.

7.5.7 Linear application should be used for superelevation transition.

7.5.8 More crown lines should be added on a six or more multilane highway.

7.5.9 In the case of steep grades on a motorway or class-1 highway with an integral roadway, different superelevations may be adopted on each of the divided traveled ways.

7.5.10 Superelevated hard shoulders shall conform to the provisions as follows.

1 Where the superelevation of a hard shoulder is the same as that of the abutting traffic lane, the lengths of both superelevation transition sections as well as the transition rates shall be the same for both.

2 Where superelevation of a hard shoulder is smaller than that of the adjoining traveled way, the cross slope of the hard shoulder shall be changed to be the same as that of the crown of the traveled way; both rotate together until the full superelevation is reached.

7.6 Widening on Circular Curve

7.6.1 The pavement shall be widened where the radius of a circular curve of a class-2, class-3, or class-4 highway is less than or equal to 250m. The required pavement widening for a two-lane highway is given in Table 7.6.1.The values for widening on circular curves shall be determined in accordance with highway function, technical classification, and traffic composition, which shall conform to the provisions as follows.

1 Type 3 widening values shall be used for class-2 arterial highways;

2 For class-2 and class-3 collector-distributor highways, type-3 widening values shall be used where articulated trailers are to be accommodated; or type-2 widening values may be used where articulated trailers are not to be accommodated.

3Type 1 widening values may be adopted for class-3 and class-4 local highways.

4 Widening values for a special highway that allows some extraordinary vehicles shall be verified and determined in accordance with the specific extraordinary vehicles.

Table 7.6.1 Widening Values for Two-Lane Highway Pavement

Type	Design vehicle	Radius of Circular Curve (m)								
		200～250	150～200	100～150	70～100	50～70	30～50	25～30	20～25	15～20
1	小客车	0.4	0.5	0.6	0.7	0.9	1.3	1.5	1.8	2.2
2	载重汽车	0.6	0.7	0.9	1.2	1.5	2.0	—	—	—
3	铰接列车	0.8	1.0	1.5	2.0	2.7	—	—	—	—

Note: The pavement widening width of a single-lane highway shall be half of the values listed in the table.

7.6.2 The widening on a circular curve shall be placed at the inside of the circular curve. Consequently, the road subgrade shall also be widened.

7.6.3 On segments with small-radius curves of a two-lane highway, which are directionally divided by compulsory measures, the widening values at the inner edge of the traveled way shall be greater than that at the outer edge, and shall be calculated and determined during design.

7.6.4 The placement of widening transition sections shall conform to the provisions as follows.

1 Where a spiral or superelevation transition section is placed, the length of a widening transition section shall be the same as that of the spiral or superelevation transition section.

2 Where no spiral or superelevation transition section is placed, the length of a widening transition section shall be long enough to accommodate the widening at a transition rate of 1:15 and not shorter than 10m, whichever is longer.

7.6.5 For class-2, class-3, and class-4 highways, the widening transition shall be spread proportionally over the length of a widening transition section.

7.7 Superelevation and widening transition sections on class-4 highways

7.7.1 Superelevation and widening transitions instead of spirals may be used for class-4 highways. A transition section for widening/superelevation shall be placed where a tangent connects to a circular curve that needs to be widened and its radius is smaller than the minimum radius for non-superelevated curves specified in Table 7.4.1.

7.7.2 The length of a transition section on a class4 highway shall be calculated in terms of superelevation and widening respectively and the longer one shall be taken, as long as it conforms to the requirements for maximum transition rate of 1.15 and minimum length of 10m.

7.7.3 On a class-4 highway, a widening and superelevation transition section shall be placed on the tangent segment that is directly connected to the start or end point of a circular curve. Where constrained by terrain or other conditions, a portion of the widening and superelevation transition section may be inserted into the curve. However, the inserted length shall not be more than half of the length of the widening and superelevation transition section. In the case of compound curves, the superelevation/widening transition sections shall be placed symmetrically on the tangent segments before and after a tangent-curve point.

7.7.4 At the places where structural works are located on a class-4 highway, the obvious turning, if there is any at the starting or end point along the inner edges of the circular curve due to the placement of superelevation/widening transition sections, may be removed by making the edge line of widened pavement tangent to the circular-arc edge of widened pavement in the circular curve section.

7.8 Length of Horizontal Curve

Table 7.8.1 Minimum Lengths of Horizontal Curves

Design speed (km/h)		120	100	80	60	40	30	20
Min. Length（m）	Normal	600	500	400	300	200	150	100
	Minimum	200	170	140	100	70	50	40

7.8.1 Minimum length of a horizontal curve shall conform to the criteria in Table 7.8.1.

Note: 'Normal' is the values taken under normal circumstances; 'minimum' is the value that may be used under constrained conditions.

7.8.2 Where the deflection angle of an alignment is less than or equal to 7 degrees, a longer horizontal curve, as specified in Table 7.8.2, shall be placed.

Table 7.8.2 Length of Horizontal Curve with a Deflection Angle equal to or smaller than 7º

Design speed (km/h)	120	100	80	60	40	30	20
Normal	1400/Δ	1200/Δ	1000/Δ	700/Δ	500/Δ	350/Δ	280/Δ
Minimum	200	170	140	100	70	50	40

Note: *Δ* in the table above is the deflection angle (°) of a highway alignment. Take $\Delta = 2°$ where $\Delta < 2°$for calculation，.

7.9 Sight Distance

7.9.1 Stopping sight distance shall be adopted as the sight distance for motorways and class-1 highways. The stopping sight distance on each lane of the ordinary segment of a motorway or class-1 highway shall not be shorter than the criteria specified in Table 7.9.1.

Table 7.9.1 Stopping Sight Distance for Motorway and Class-1 highway

Design speed (km/h)	120	100	80	60
Stopping sight (m)	210	160	110	75

7.9.2 Passing sight distance shall be adopted as the sight distance for class-2, class-3, and class-4 highways. Stopping sight distance may be used for the sections with divided traffic flows due to the terrain or other conditions. The passing distances and stopping distances shall not be shorter than the criteria in Table 7.9.2.

Table 7.9.2 Sight Distance for Class-2, Class-3 and Class-4 Highways

Design speed (km/h)	80	60	40	30	20
Meeting sight distance (m)	220	150	80	60	40
Stopping sight distance (m)	110	75	40	30	20

7.9.3 Intermittent segments which permit overtaking shall be placed on class-2, class-3 and dual class 4-highways. An overtaking segment, on which overtaking sight distance is provided, should allow a 3-minute travelling distance on a class-2 arterial highway. Minimum values of overtaking sight distances shall conform to the criteria in Table 7.9.3.

Table 7.9.3 Minimum Value of Overtaking Sight Distance

Design speed (km/h)		80	60	40	30	20
Min. Value of Overtaking sight distance	Normal	550	350	200	150	100
	Minimum	350	250	150	100	70

Note: 'normal' refers to the values taken under normal circumstances; 'minimum' refers to the values that may be used under constrained conditions.

7.9.4 On motorways, class-1 highways, the down-grade segments of class-2 and class-3 highways with a high proportion of large-size vehicles the stopping sight distance of trucks on down-grade shall be verified. The stopping sight distances of trucks on a downgrade shall not be shorter than the criteria shown in Table 7.9.3.

Table 7.9.4 Stopping Sight Distance of a truck on down-grade

Design speed (km/h)		120	100	80	60	40	30	20
Grade (%)	0	245	180	125	85	50	35	20
	3	265	190	130	89	50	35	20
	4	273	195	132	91	50	35	20
	5	—	200	136	93	50	35	20
	6	—	—	139	95	50	35	20
	7	—	—	—	97	50	35	20
	8	—	—	—	—	—	35	20
	9	—	—	—	—	—	—	20

7.9.5 Decision sight distances shall be provided on segments with exits to interchanges, service areas, rest areas, and transit bus stops, and shall conform to the provisions below.

1 Decision sight distances corresponding to design speeds should conform to the criteria in Table 7.9.5

Table 7.9.5 Decision Sight Distance

Design speed (km/h)	120	100	80	60
Decision distance (m)	350（460）	290（380）	230（300）	170（240）

Note: The figures in brackets are the values of sight distances that shall be taken for a complicated driving environment and where much substantial access information is provided at the roadside.

For the segments constrained by terrain and geological conditions, a decision sight distance may be taken as 1.25 times the stopping sight distance associated with the speed limit and traffic control.

7.9.6 In a geometric design, distance verification shall be conducted in the road segments or areas where sight distances might be inadequate due to lower geometric parameters, poor alignment combination, and on segments with barriers and glare screens in the median, segments with deep cut slopes, high structures, accesses or at-grade junctions at roadside, and the segments of tunnels. Non-conformities to the requirements for sight distance shall be corrected by effective technical countermeasures or engineering treatments.

7.10 Switchback Curve

7.10.1 A highway route in mountainous terrain shall be naturally located along the land and shall avoid placing switchback curves wherever possible. Switchback curves may only be used in class-3 or class-4 highway segments where a natural location cannot provide adequate distance to overcome the elevation difference or are restricted by terrain and geological conditions.

7.10.2 A longer spacing than that for normal curves shall be provided between two adjacent switchback curves. The distance from the end of a switchback curve to the start of the adjacent switchback curve shall not be less than 200m, 150m, and 100m corresponding to design speeds of 40km/h, 30km/h, and 20km/h respectively.

7.10.3 Technical parameters of a switchback curve shall conform to the criteria in Table 7.10.3

Table 7.10.3 Technical Criteria of Switchback Curves

Design speed of main route	40		30	20
Design speed of switchback curve	35	30	25	20
Min. Radius of circular curve	40	30	20	15
Min. length of spiral	35	30	25	20
Superelevation (%)	6	6	6	6
Widening of two-way highway	2.5	2.5	2.5	3.0

pavement (m)				
Max. grade (%)	3.5	3.5	4.0	4.5

7.10.4 The alignments before and after a switchback curve shall be continuous and uniform with good visibility. A transition curve shall be provided at each end of the switchback curve. Speed limit signs and traffic safety facilities shall be provided wherever needed.

8 HIGHWAY PROFILE

8.1 General

8.1.1 Design elevations on a highway profile, i.e. highway design levels, shall conform to the following provisions:

1The design elevations for a new highway to be built: the elevation of the outer edge of the median strip should be used for a motorway or a class-1 highway; the elevations of the outer edge of the roadway, which refers to the elevations before applying superelevation and widening if there is, should be used for a class-2, class-3, or class-4 highway.

2 The highway design elevations for an existing highway to be upgraded or reconstructed: the provisions in sub-clause 1 of this clause are for new highways should be referred to and applied in general; however, the elevations at the centerline of the median or the traveled way may be used in specific situations.

Highway class	Motorway	Class-1	Class-2	Class-3	Class-4
Design flood frequency	1/100	1/100	1/50	1/25	depending

Table 8.1.2 Highway Design Flood Frequency

8.1.2 Highway design flood frequency shall conform to the criteria in Table 8.1.2.

1 For a road segment along a river or susceptible to being flooded, the lowest edge elevation, which is estimated based on the design elevation, shall be higher than the water level based on the flood frequency as specified in Table 8.1.2, plus the backwater height, the wave height and a 0.5m safety allowance.

2 For a road segment along the upstream of a reservoir, the lowest edge elevation, which is estimated based on the design elevation, shall account for the rise of water table resulting from the rise in reservoir level, the rise of backwater curve due to reservoir sedimentation and the height of waves. In cold regions, the impacts of ice jamming on the rise of water levels shall also be considered.

3 The lowest edge elevation is estimated based on design elevation to the approaches of a large or medium bridge in a flooding area, which shall be at least 0.5m higher than the design flood level plus backwater height and wave height. The lowest edge elevation adjacent to a small bridge or a culvert shall be at least 0.5m higher than the level of backwater (excluding wave height).

4 In suburban areas, the highway design flood frequency shall be determined from the criteria for city flood prevention and by taking into account the needs for rescue accesses, drainage and flood discharge.

8.2 Grades

8.2.1 Maximum grades of classified highways shall not be greater than the criteria in Table 8.2.1 and shall conform to the provisions as follows.

Table 8.2.1 Maximum Grades

Design speed (km/h)	120	100	80	60	40	30	20
Maximum grade (%)	3	4	5	6	7	8	9

1 Subject to specific techno-economic assessments, maximum grades may be increased by 1% in segments constrained by terrain or other conditions on motorways with a design speed of 120km/h, 100km/h and80km/h.

2 Subject to specific techno-economic assessments, maximum grades may be increased by 1% in segments to be upgraded with a design speed of40km/h, 30km/h and20km/h;

3 For class-4 highways, maximum grades shall not be greater than 8% on segments in areas with elevation higher than 2000m above sea level or in seasonal snow and freezing areas.

8.2.2 For highways on highlands, where the design speed is 80 km/h or lower and the elevation is higher than 3000m a.s.l., the maximum grade shall be reduced in accordance with the requirements in Table 8.2.2. However, 4% shall be taken as the maximum grade if the value after reduction is less than 4%.

Table 8.2. Deduction Values of Grades on Highland

Elevation a.s.l (m)	3000～4000	4000～5000	Above 5000
Grade deduction	1	2	3

8.2.3 Highway grades should not be less than 0.3%. In cases where a flat cross slope between 0% and 0.3% has to be used on segments of insufficient drainage or long cuttings, specific design of table drains shall be conducted for longitudinal drainage.

8.2.4 The grades on a bridge deck and the approaches to the bridge shall conform to the provisions as follows.

1 Grades on small bridges shall follow the design for the highway route grades.

2 The geometric indicators of a bridge and its approaches shall coordinate with the overall layout of the highway route. The grades of the bridge deck of a medium or large bridge should not be greater than 4%, the grades of approaches should not be

greater than 5%. The alignment of the approaches to the bridge ends shall match the alignment of the bridge.

3 Grades of a bridge deck susceptible to freezing and snow cover should be appropriately reduced.

4 Grades of bridges and bridge approaches accommodating large volumes of mixed traffic in suburban areas shall not be greater than 3%.

8.2.5 Grades in a tunnel and at tunnel portals shall conform to the provisions as follows.

1 The gradients in a tunnel shall be greater than 0.3% and smaller than 3% unless the tunnel is shorter than 100m.

2 For medium and short tunnels of a motorway or class-1 highway, where constrained by environmental conditions and subject to the approval of specific techno-economic assessment, the maximum grade may be increased but should not be greater than 4%.

3 In general, the grades inside a tunnel should be in one longitudinal direction. However, saw-tooth grades should be adopted for tunnels in geology with excess groundwater, or for long and extra-long tunnels.

8.2.6 Flatter grades may be adopted for highway segments that accommodate large non-motorized traffic near cities.

8.3 Length of Grade

8.3.1 Minimum length of a highway grade shall conform to the criteria in Table 8.3.1

Table 8.3.1 Minimum Length of Grade

Design speed (km/h)	120	100	80	60	40	30	20
Minimum length of grade (m)	300	250	200	150	120	100	60

Table 8.3.2 Critical lengths of Various Grades

Design speed (km/h)		120	100	80	60	40	30	20
Gradient (%)	3	900	1000	1100	1200	-	-	-
	4	700	800	900	1000	1100	1100	1200
	5	-	600	700	800	900	900	1000
	6	-	-	500	600	700	700	800
	7	-	-	-	-	500	500	600
	8	-	-	-	-	300	300	400
	9	-	-	-	-	-	200	300
	10	-	-	-	-	-	-	200

8.3.2 Critical length of a highway grade shall conform to the criteria in Table 8.3.2.

8.3.3 A reduced grade section shall be placed between two grades with lengths not greater than those specified in Table 8.3.2, in accordance with the speed loss of trucks on a continuous upgrade section of a classified highway, which shall conform to the provisions as follows.

1 The gradient of a reduced grade section shall not be steeper than 3%where the design speed is 80 km/h or lower, or shall not be steeper than 2.5% where the design speed is higher than 80km/h.

2 The length of a reduced grade section shall be greater than the figures in Table 8.3.1'

8.3.4 For the continuous upgrade and downgrade sections in a ridge crossing route of a class-2, class-3 or class-4 highway, the average gradient shall not be steeper than 5.5% where the elevation difference is between 200 and 500 m, and not be steeper than 5% where the elevation difference is greater than 500 m. The average gradient of any 3-kilometer continuous road section should not be steeper than 5.5%.

8.3.5 The average gradient and the length of continuous grade on a motorway or class-1 highway shall not exceed the criteria in Table 8.3.5. In a case where the criteria are exceeded, a traffic safety assessment shall be conducted, based on which speed control and traffic management plans shall be developed, traffic control and safety devices shall be improved, and mandatory truck stopping areas shall be considered and placed if necessary.

Table 8.3.5 Average Gradient and Length of Steep and Continuous Grades

Average Gradient (%)	<2.5	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Length of Grade	不限	20.0	14.8	9.3	6.8	5.4	4.4	3.8	3.3
Relative Level Difference	不限	500	450	330	270	240	220	210	200

8.4 Climbing lane

8.4.1On the continuous upgrade sections of a four-lane motorway, four-lane class-1 highway or class-2 highway, a climbing lane should be placed on the right of the traveled way on an upgrade direction for any one of the circumstances as follows.

1 where the operating speed of trucks on continuous upgrade direction may drop to a

Design speed (km/h)	120	100	80	60	40
Allowable minimum speed (km/h)	60	55	50	40	25

8.4.1 Allowable Minimum Upgrade Speed

level lower than the allowable minimum speed listed in Table 8.4.1.

2 where the length of a continuous single grade exceeds the criteria in Table 8.3.2 or the design capacity of the upgrade section is lower than design hourly volume (DHV).

3 if the techno-economic assessment in terms of ratio of effectiveness-cost and traffic safety shows that the alternative of placing a climbing lane is superior to the others.

8.4.2 The rate of superelevation shall conform to the criteria in Table 8.4.2. The axis of rotation shall be at the inner edge of the traveled way on an upgrade.

8.4.3 The widening value of a climbing lane shall conform to the value specified for the widening of one lane on a curve.

8.4.4 A turnout shall be placed where the climbing lane on a motorway or class-1 highway is longer than 500meters.

Table 8.4.2 Value of Superelevation on Climbing Lane

Superelevation (%) of traveled way	10	9	8	7	6	5	4	3	2
Superelevation (%) of climbing lane	5		4					3	2

8.4.5 The start point, end point, and length of a climbing lane shall be determined in compliance with the requirements as follows.

1 A climbing lane shall begin at the place where the operating speed of a truck on a steep upgrade drops to the ‘allowable minimum speed’ as listed in Table 8.4.1;

2 A climbing lane shall end at the place where the operating speed of a truck after a steep upgrade has speeded up to the ‘allowable minimum speed’ or at the end of an additional length extended beyond the steep upgrade. The additional length extended beyond a steep upgrade shall conform to the criteria in Table 8.4.5-1.

3 Two successive climbing lanes should be linked into one if they are closely placed.

Table 8.4.5-1 Additional length extended beyond steep upgrade

Gradient of additional length (%)	downgrade	flat	upgrade			
			0.5	1.0	1.5	2.0
Additional length	100	150	200	250	300	350

4 Tapered diverge and merge sections shall be placed at the beginning and end points of a climbing lane over a length as specified in Table 8.4.5-2.

Table 8.4.5-2 Length of Tapered Merge/Diverge Section of Climbing Lane

Highway classification	Merge Section Length (m)	Diverge Section Length (m)
Motorway, Class-1 highway	100	150～200
Class-2 highway	50	90

8.5 Resultant Gradient

8.5.1 The maximum resultant gradient of a highway shall be as specified in Table 8.5.1.

8.5.2 Where a steep grade overlaps a circular curve with small radius, the smaller resultant gradient shall be applied. The resultant gradient must be less than 8% in the following cases.

1 On road sections in the areas covered by snow and ice in winter.

2 On road sections of a hillside route where the natural cross slope is comparatively steep;

Table 8.5.1 Maximum Resultant Gradient of Highway

Classified Highway	Motorway			Class-1 Highway			Class 2 Highway		Class 3 highway		Class 4 highway
Design speed (km/h)	120	100	80	100	80	60	80	60	40	30	20
Resultant gradient (%)	10.0	10.0	10.5	10.0	10.5	10.5	9.0	9.5	10.0	10.0	10.0

3 On road sections with heavy non-motorized traffic.

8.5.3 The minimum resultant gradients should not be less than 0.5%. The resultant gradient on a superelevation transition section should not be 0% and effective drainage measures shall be provided where the resultant gradient is less than 0.5% in order to ensure pavement drainage.

8.6 Vertical Curves

8.6.1 A vertical curve shall be placed at the intersection of grades. Circular curve or parabolic curve may be used as a vertical curve. The minimum radius and length of a vertical curve shall conform to the criteria in Table 8.6.1.

Table 8.6.1 Minimum Radius and Length of Vertical Curve

Design speed (km/h)		120	100	80	60	40	30	20
Minimum radius of crest vertical curve (m)	Normal value	17000	10000	4500	2000	700	400	200
	Limiting value	11000	6500	3000	1400	450	250	100
Minimum radius of sag vertical curve (m)	Normal value	6000	4500	3000	1500	700	400	200
	Limiting value	4000	3000	2000	1000	450	250	100
Length of vertical curve (m)	Normal value	250	210	170	120	90	60	50
	Limiting value	100	85	70	50	35	25	20

Note: "Normal value" means the value is adopted under normal conditions; "Limiting value" and "Minimum value" means the value shall be adopted under restricted conditions.

9 GEOMETRIC DESIGN

9.1 General

9.1.1 Highway geometric design shall consist of a trinity of plane, profile, and cross-section in harmony with the natural environment.

9.1.2 Apart from the requirements for driving kinetics, a geometric design shall take road users' visual, psychological and physical responses into account to provide safe, comfort, and cost-effective highway transportation.

9.1.3 The emphasis in geometric design shall be focused to serve diversified highway functions and designated design speeds. In general, a highway geometric design shall conform to the following policies.

1 The geometric design of motorways, class-1and class-2 arterial highways shall place emphasis on the smoothness of alignments, equilibrium in technical parameters, sufficient sight distances, environmental harmony, traffic safety, and driving comfort. The higher the design speed, the more factors shall be considered and integrated into the design of highway geometry.

2 For class-1 highways and class-2 collector-distributor highways, the roadway cross-sections shall be arranged according to the mixed traffic conditions with emphasis on the combination of alignments on at-grade crossings and junctions to ensure visibility, traffic capacity, and safety.

3 For two-lane highways with design speed lower than or equal to 40km/h, and subject to traffic safety, the geometric elements shall be properly selected and combined. The specified values of geometric element shall be accurately applied, or supplementary technical measures such as traffic control devices shall be deployed accordingly for the benefit of the investment.

4 Following the principle that the design segment determines technical classification and design speed, the length of a design highway segment should be long enough and technical parameters hall be kept in equilibrium.

5Geometric parameters in terms of highway alignment and profile and cross-section before and after an interface of different design segments shall be changed progressively from greater to smaller values as design speed shifts from higher to lower, or vice versa, to ensure a natural transition in running speeds. Neither minimum nor maximum values of horizontal and vertical indicators should be used adjacent to the interface.

9.1.4 Higher parameters for horizontal and vertical alignments shall be selected adjacent to junctions and crossings to ensure good visibility.

9.1.5 Checking by operating speed shall be executed on all classified highways to check the combined horizontal and vertical alignment designs, coronation and consistency of technical criteria, sight distances, and visual continuity on the route, based on which the geometric design shall be optimized in terms of technical criteria, and traffic control and safety devices.

9.2 Horizontal Alignment Design

9.2.1 Horizontal alignment design shall apply with the requirements as follows.

1Horizontal alignment shall be direct, continuous, in equilibrium, adaptable to terrain, and harmonized with the surrounding environment.

2 Where a long tangent has to be placed in an area constrained by the environment, effective technical measures shall be adopted in accordance with local conditions.

3 Proper ratios of radii shall be adopted for successive circular curves.

4 For all classified highways, a curve shall be placed at an intersection of two alignments no matter how small it is. A large radius should be selected as a priority. Where a deflection angle is comparatively small, a short circular curve shall be avoided.

5 A tangent of sufficient length shall be placed between two circular curves in the same direction. A short tangent between two curves in different directions shall be avoided.

6 For class-1 arterial highways with six or more lanes, the length of a tangent between two circular curves, either in the same direction or in opposite directions, shall conform to the provisions for transition rate of superelevation at the outer edge of the roadway.

7 On two-lane highways with a design speed less than or equal to 40km/h, two reversed circular curves may be connected directly where neither widening nor superelevation is required; a tangent section not less than 10m long for a widening transition shall be inserted in between where only widening but not superelevation is required; a tangent section not less than 15 m long shall be inserted for widening/superelevation transition where both widening and superelevation are required even in difficult segments constrained by terrain.

8 On two-lane highways with a design speed less than or equal to 40km/h, the alignment with successive sharp curves shall be avoided. In a case where such an

alignment is inevitable due to difficult terrain conditions, a tangent with a specified length or a spiral shall be inserted in between.

9.2.2 The application of tangents shall conform to the following requirements.

1 The application of a tangent shall be consistent with terrain and local environment. Very long tangents shall be avoided.

2 Tangent alignments should be selected in level terrain where farmland and irrigation waterways are well laid out in squared shapes, and in suburban areas where town layout plans are in straight-line styles.

3 Tangent alignments should be adopted in sections with special structures such as long or extra-long tunnels, the bridge as a special structure, and the sections before or after junctions or crossings.

4Tangent alignments should be adopted in sections with passing lanes on a two-lane highway.

9.2.3 The application of circular curves shall conform to the following requirements.

1Circular curves shall relate to terrain, and radii corresponding to 2%-4% superelevation should be selected.

2 The values greater than or close to the ‘normal values’ of the minimum radii of circular curves may be adopted in the places that are constrained by terrain conditions. ‘Limiting values’ may be adopted only in the places where the terrain conditions are extremely difficult and no other option is feasible.

3 A circular curve shall be well coordinated with the segments to which it links in terms of horizontal and vertical alignment elements to form a continuous and balanced curvilinear alignment. The alignment of which a small radius-curve overlaps steep grades shall be avoided.

4 A curve with a sufficient length shall be placed where the deflection angle at an intersection point has to be smaller than **7°**

9.2.4 The application of spiral curves shall conform to the following requirements.

1 Where the design speed is higher than or equal to 60km/h, spirals shall be considered as one of the alignment options. The length of every curve on a respective spiral–circular–spiral curve alignment should be approximately similar. The two spirals may be designed in an asymmetrical arrangement with different parameters in accordance with terrain conditions. However, the ratio of the spiral lengths, A_1:A_2, shall not be greater than 2.0.

2 The parameters of a spiral shall be determined in accordance with terrain conditions and the requirements for alignment, and shall be harmonized with the radius of the circular curve.

1) where R is smaller than 100m, A should be greater than or equal to R;

2) Where R is approximately 100m, A should be equal to R;

3) Where R is slightly larger than or close to 3,000m, A should be equal to R/3；

4） where R is larger than 3,000m, A should be smaller than R/3.

3 In the cases where two circular curves in opposite directions are directly connected or the length of a tangent between these two curves is not long enough, two spiral curves may be placed between the circular curves in opposite directions, and combine them into an S-curve.

1) Two spiral parameters, A_1 and A_2, should be the same.

2) Where different spiral parameters are adopted, the ratio A_1/A_2 should be less than 2.0, or less than 1.5 wherever possible. Where $A_2 \leqslant 200$, the ratio A_1/A_2 shall be less than 1.5;

3) The ratio of radii of two circular curves should not be too large but $R_1 / R_2 \leq 2$ (where R_1 refers to the radius of the larger circular curve, R_2 is that of the smaller one).

Where two circular curves in the same direction are directly connected or by a tangent in between would not be long enough, a spiral shall be placed to connect these two circular curves and combine them into an oval-curve (which is a circular-spiral-circular curve).

1) The spiral parameters of an oval-curve should be selected in the range of $R_2/2 \le A \le R_2$ (where R_2 is the radius of the smaller circular curve).

2) The ratio of two radii of circular curves should be $R_2/R_1 = 0.2 \sim 0.8$;

3) The spacing between two circular curves should be $D/R_2 = 0.003 \sim 0.03$(where D is the minimum spacing between two circular curves).

4 In areas constrained by terrain conditions, two spirals in the same direction may be directly connected at the same curvatures and combined into a spiral-spiral curve.

Generally, spiral-spiral curves may be used only in areas where the highway route is strictly constrained by terrain conditions and the curvature radius at the connecting point is large.

1) The spiral parameters of a spiral-spiral curve and the curvature radius at the connecting point shall conform to the criteria for allowable minimum spiral parameters and the minimum radii of circular curves respectively. .

2) The cross slopes within a segment equivalent to 0.3v in length (where length is measured in meters; v is design speed in km/h) to the connecting point shall maintain the same as that determined by the curvature radius at the connecting point.

6 In areas constrained by terrain conditions, two circular curves in the same direction with different radii may be joined by two or more spirals that connect each other at the points of the same curvature, which form a compound curve. The ratio of any twospiral parameters of a compound curve should be smaller than 1.5.Compound curves may be adopted in design only in places constrained by terrain or at interchange ramps.

7 In areas constrained by terrain or other special conditions, the spirals in between two circular curves in the same direction may be directly connected at the points of zero-curvature, and thus form a C-curve (which is a special circular-spiral-(zero curvature)-spiral-circular curve).

C-curves may be only adopted in extremely difficult places constrained by terrain.

9.3 Vertical Alignment Design

9.3.1 Vertical alignment design shall conform to the provisions as follows.

1 A vertical alignment shall be smooth and flowing, with continuous visibility and matched to the surrounding environment.

2 Highway grade design shall consider earthwork balancing of cut and fill. The material from a cutting shall be used for nearby filling or backfilling as far as possible to lessen the impact on natural ground slopes and environment.

3Large radii of vertical curves shall be adopted where the algebraic difference of gradients in adjacent sections is small.

4 For segments with continuously long and steep grades, the requirements for highway capacity shall be satisfied in the upgrade direction while traffic safety shall be the major concern in downgrade direction. Checking by operating speeds shall be executed for the capacity on the upgrade and the traffic safety on downgrade.

5 The grades either before or after a route intersection shall be gentle.

6 Steep grades shall not be used on segments in areas susceptible to freezing and snow cover.

9.3.2 The selection of values of grades shall conform to the requirements as follows.

1 Terrain conditions along the highway shall be fully considered in vertical alignment design. Gentle gradients should be adopted; however, the minimum gradient should not be less than 0.3%. Specific drainage designs should be conducted for road sections on a flat grade or with a gradient less than 0.3%.

2The maximum gradients and maximum lengths of grades should not be used on any classified highway unless for the purpose of taking advantages of terrain for elevation or avoiding difficult construction conditions.

9.3.3 Design of highway grade shall conform to the provisions as follows.

1 The grades in level terrain shall be uniform and gentle;

2 The grades in rolling or hilly terrain shall avoid large fluctuation in vertical alignment due to over-compensation of the terrain.

3 The grades of a ridge-crossing highway route shall be in equilibrium. The gradients equal to or close to the maximum gradients should not be used if possible. The vertical alignments, which consist of a few of short reduced grade sections inserted in continuous steep grades at their maximum lengths, should not be adopted if possible.

Gentle grades shall be used whenever possible on hillside highway routes or ridge highway routes unless a steep grade has to be used because of difficult terrain conditions.

9.3.4 A vertical curve design shall conform to the following requirements:

1 For highways with design speeds that are equal to or higher than 60km/h, the combination of long vertical curves and long gradients should be adopted. The values listed in Table 9.3.4 should be used for radii of vertical curves wherever feasible.

Table 9.3.4 Minimum Radii Visually Required for Vertical Curves

Design Speed (km/h)	Radius of Vertical Curve (m)	
	In crest	In sag
120	20 000	12 000
100	16 000	10 000
80	12 000	8 000
60	9 000	6 000

2 Large radii shall be selected for vertical curves. In areas constrained by environmental conditions, the radii used should be greater than or close to the ‘normal values’ of minimum radii of vertical curves. The ‘limiting values’ of minimum radii of vertical curves may be used only under extremely difficult terrain conditions and no other options are feasible.

2 If a gradient equal or close to the minimum length of grade is to be inserted between two vertical curves, especially the sag ones, in the same direction, such a gradient and two vertical curves should be merged into a simple curve or combined into a compound curve.

4 On a two-lane segment with demands for overtaking, the requirements for overtaking sight distance shall be considered, and large radii shall be selected for crest vertical curves and relevant signboards and road markings shall be placed.

9.4 Design of Cross-section

9.4.1 Design of a highway cross-section shall reduce the height of an embankment as far as possible, reduce the impact on eco-environment along the route, protect the environment and keep the highway in harmony with nature as far as possible. In a case where a high fill or deep cut is inevitable due to difficult terrain, options of bridge, tunnel or separate roadways shall be considered and assessed.

The arrangement of roadway cross-section shall be designed by considering ground cross slope, natural environment, and geotechnical conditions along the highway route. For motorways, an integral roadway cross-section should be selected where the natural land slopes are flat or gentle, or separated roadway cross-sections should be adopted where the natural land slopes are steep with complicated geotechnical conditions,.

9.4.3 A uniform median width on an integral roadway should be maintained. Where the median width needs to be widened or narrowed, the alignment design for each roadway shall be executed individually. In the case where constrained by terrain conditions and the change of median width is less than 3.0 m, a transition section may be adopted with a transition rate not greater 1/100.

9.4.4 Where an integral roadway splits into two separated roadways or two separated roadways merged into an integral roadway, a transition sections shall be placed if the width of median increases or decreases, and should be placed on a circular curve with a large radius.

9.4.5 Attention shall be paid to the roadside safety and the details in terms of median, speed changing lanes, shoulders, channelization facilities, left (right) turning lanes, and traffic islands. In areas or segments where possible, wide median, low embankment, flat side slopes and wide-shallow side drains are encouraged.

9.4.6 The design of a highway median shall conform to the requirements as follows:

1 Form of central dividing strip: a depressed form may be used where the width of a central dividing strip is greater than or equal to 3.0 meters; raised form may be the choice where the width of a central dividing strip is less than 3.0 meters, and flush form should be used for sections susceptible to windstorms and snow.

2 Curbs of central dividing strip: flush curbs should be used where the central dividing strip is greater than or equal to 3.0 meters, or on the segments susceptible to windstorms, snowstorms or both; flush curbs or inclined curbs may be used where the width of central dividing strip is less than 3.0 m. Vertical curbs are not allowed on motorways and class-1 highways.

3 Surface treatment of central dividing strip: turf may be placed where the width of central dividing strip is greater than or equal to 3.0 meters; shrubs or full-pavement may be provided where the central dividing strip is narrower than 3.0 meters.

9.4.7 The drainage within a highway cross-section shall be designed as a self-functioning system. The table drains beside the roadway should be in ditch forms or free flow mode, or shall be provided with cover slabs if trapezoid-shaped or rectangular-shaped trenches are used.

9.4.8 In segments that are susceptible to snow in winter, the roadway and subgrade may be appropriately widened to improve travel conditions.

9.5 Alignment Combination Design

9.5.1 The following policies shall be adhered to in an alignment combination design.

1 In an alignment combination design, all technical parameters shall not only comply individually with the criteria specified for horizontal and vertical alignments, but also take the effects of cross-section on alignment combination and driving safety into account. A combination of the least favorable values of highway alignment, profile and cross-sections shall always be avoided.

2Individual parameters refer to those relatively independent from each other. Determination of an individual parameter of alignment and profile shall consider the equilibrium and continuity of an individual parameter not only in a specific segment but also between the adjacent segments.

3 In a combination design, the alignment elements shall not only interior maintain coordination in terms of equilibrium of various elements and changing effects of each element, but also harmonization with the natural landscape and local geologic conditions.

4 A highway alignment shall be able to provide drivers with visual guidance and maintain sight continuity.

9.5.2 An alignment combination design shall conform to the provisions as follows.

1 Horizontal and vertical alignments should correspond to each other and usually a horizontal curve should be slightly longer than its corresponding vertical curve. Where the radii of a horizontal curve and a vertical curve are both small, the level of

correspondence to each other shall be strict. The larger the horizontal and vertical radii, the lower the level of correspondence to each other will be necessary. If both radii are large, correspondence may not be required.

2 A long tangent should not be combined with a short vertical curve either on the steep grade or with a small radius.

3A long horizontal curve should not contain multiple vertical curves; a short horizontal curve should not be combined with a short vertical curve.

4 Neither beginning point nor ending point of a small-radius circular curve should be placed at or close to the top of a crest vertical curve or the bottom of a sag vertical curve.

5 A small-radius horizontal curve should not be placed within a long vertical curve.

6 Neither the top of a crest vertical curve nor the bottom of a sag vertical curve should be placed at the point of reverse curvature of a horizontal reverse curve.

7 Checking by operating speed shall be executed for safety if the non-superelevated, left turning curve is a compound curve or S-curve.

8 A small-radius circular curve shall not be connected to the end of a long downgrade, a long tangent or a large-radius circular curve.

9.5.3 For highways that have design speeds greater than or equal to 60km/h, special attention shall be paid to the design of horizontal and vertical alignment combinations. The requirements in Clause 9.5.2 may be used as reference for the highways with design speeds less than or equal to 40km/h,

9.5.4 For motorways with six or more lanes, attention shall be paid to the configuration of tangents, curves (both horizontal and vertical) and their combination. A spiral or tangent with sufficient length shall be placed in between horizontal curves in order to provide a smooth transition and effective road surface drainage.

9.5.5 A large radius shall be selected for a horizontal curve on road sections with high fill embankment supplemented with visual guiding facilities for traffic control.

9.6 Coordination of Alignment of Bridges and Tunnels

9.6.1 The geometric design of bridges and bridge approaches shall conform to the requirements as follows.

1 The positions and alignment of a bridge and its approaches shall be harmonized with the highway route alignment and provide wide sight and good visual guidance. The technical parameter selected shall conform to the highway route layout and the design policies set out in the overall design.

2 On motorways, class-1 highways and class-2 arterial highways, the alignments of bridges shall be continuously and smoothly matched with the highway route alignment.

3 The horizontal and vertical alignments at the connections of a bridge, culvert, or other man-made structure to a road sections shall conform to the relevant requirements for highway route layout.

9.6.2 The alignment design for tunnel sections shall conform to the following requirements.

1 The position of a tunnel and its approach roads shall be in harmonization with the alignment of the highway route in order to ensure driving comfort and traffic safety. All technical criteria of tunnel sections shall conform to the relevant provisions for highway route layout and the overall design of a highway route.

2 Radii that do not require superelevation should be used for a tunnel which is placed on a curve. Where a tunnel is placed on a superelevated horizontal curve, the superelevation should not be greater than 4% and checking by operating speeds should be executed. The radii of horizontal curves requiring pavement widening shall be avoided in any circumstances.

3 The alignments approaching tunnel portals and inside of the tunnel shall be kept in consistence. Both horizontal and vertical alignments shall be in coordination over a range of distances traveled at design speed for 3s at both inside and outside of a tunnel portal. Subject to approval of specific assessment, a spiral curve may be placed outside the tunnel portal supplemented by reinforced alignment guiding facilities. A constant grade should be adopted in the sections at tunnel portals or a large radius should be adopted if a vertical curve is to be used.

4 Where two individual tunnels are used for divided traffic on a motorway or class-1 highway, the link roads to tunnel portals shall be in harmonization with the overall highway route alignment, while the intermediate crossover connections should be placed at appropriate locations outside the tunnel portals. .

5 The connection of a tunnel to the road section at a portal shall conform to the relevant criteria for highway route layout. Where the roadways inside and outside a tunnel portal are different in width, a transition section shall be placed outside of the entrance portal with a length not less than the distance travelled at the design speed for 3 seconds or 50m, whichever is longer.

9.7 Configuration of Roadside Facilities

9.7.1 The configuration of roadside facilities such as toll stations, service areas, rest areas, and transit bus stops shall be taken into account in a highway geometric design.

9.7.2 Main route toll plazas should be placed on tangents or non-superelevated curves. Toll plazas or toll booths shall not be located in the middle or bottom of sag vertical curves.

9.7.3 The configuration of traffic signs and road markings shall be taken into account in a highway route design. Traffic safety devices shall be designed where required by the geometric design. Protection facilities shall be provided in the segments where roadside design is constrained.

9.8 Environmental Fitness of Highway Alignment

9.8.1 The impacts of traveling speeds on driver's sight design shall be fully taken into account during geometric design. The highways or highway segments with higher design speeds shall require higher environmental fitness.

9.8.2 Highway alignment design shall take advantage of the terrain, conserve natural landscapes, and minimize alterations to surrounding land features, terrain, natural forests and local architectures, integrate the highway as part of nature and protect the environment as far as possible.

9.8.3 Highway protection shall combine engineering solution with ecological conservation to minimize the negative impacts on the natural landscape, enhance the capability of reinstatement to ensure that the highway works in harmony with the natural environment.

9.8.4 The side slopes in cuttings should be appropriately gentle and flat. The slope changing points should be trimmed into well-rounded shape to fit the natural ground and improve the highway appearance.

9.8.5 The green belts along both sides of a highway shall be specifically designed and implemented as visual cues, a part of the landscaping and a measure of nature reform.

10 AT-GRADE JUNCTIONS

10.1 General

10.1.1 The positioning of an at-grade junction shall conform to the provisions as follows.

1 The location of an at-grade junction shall be carefully selected and properly positioned in accordance with the functions and technical classifications of the intersecting highways, existing situation and planning of the regional road network, and terrain and land features around the junction.

2 At-grade junctions of class-1, class-2, class-3 and class-4 highways shall be positioned in compliance with the criteria in Table 10.1.1.

Table 10.1.1 The criteria for at-grade junction positioning

Main route / Intersected route	Class-1 arterial	Class-1 collector-distributor	Class-2 arterial	Class-2 collector-distributor	Class-3 and Class-4
Class-1 arterial	Strictly limited	—	—	—	—
Class-1 collector – distributor	Strictly limited	Limited	—	—	—
Class-2 arterial	Strictly limited	Limited	Limited	—	—
Class-2 collector – distributor	Strictly limited	Limited	Limited	Allowed	—
Class-3 & Class-4	Strictly limited	Limited	Limited	Allowed	Allowed

10.1.2 Design of at-grade junctions shall follow the policies below.

1 The location of at-grade junctions shall be selected in accordance with the status and planning of highway networks, terrain, ground objects and geologic conditions, and economic and environmental factors, and should be positioned in flat terrain with adequate sight.

2 The type of an at-grade junction shall be selected in accordance with various factors including highway functions, technical classes, traffic volumes, traffic management modes, land acquisition and construction costs of the intersecting highways. The type

selected should be able to ensure the traffic on the main highway or the mainstream traffic to move smoothly with few traffic conflictspots and smaller conflict zones.

3 Traffic management modes and the layout of relevant traffic facilities shall be taken into account in the geometric design of at-grade junctions.

4 Technical alignment parameters ofintersecting highways within the functional area of an at-grade junction shall be able to accommodate the requirements for sight distances.

5 Highway segments in the functional area of an at-grade junction should be on tangents. Where a curve has to be used, the radius of such a curve should be greater than the specified radius without superelevation. Vertical grades should be as flat as possible, of which the radius of vertical curve shall be greater than the minimum value required for sight distance.

6 At-grade junctions shall be designed in accordance with predicted traffic volumes. The traffic volume used in design shall be the directional design hourly traffic (DDHV).

7 The facilities for people crossing over an at-grade junction, such as pedestrian crossings, pedestrian overpasses, or pedestrian underpasses, should be designed in accordance with pedestrian flow, highway classifications and traffic management mode.

8 Traffic signs, road markings and traffic signals at an at-grade junction shall be considered and arranged in combination with the geometric design. Reflection mirrors may be placed at small sized at-grade junctions depending on specific local conditions.

9 For upgrading of existing at-grade junctions, in addition to the traffic volumes, the traffic delay, the number, severity and causes of traffic accidents and other data about the operation of the existing junction shall be investigated and collected.

10 An at-grade shall be able to accommodate the requirements for traffic capacity of the design vehicles on the intersecting highways. For special traffic requirements, verification on the traffic conditions at the at-grade junction shall be executed in accordance with the actual vehicle types on the highways.

10.1.3 Based on the highway function, classification and traffic volumes, at-grade junctions may be divided into threetraffic management modes, i.e. main road priority junctions, non-priority junctions, and signalized junctions, that shall conform to the provisions as follows.

1 Main road priority mode shall be adopted where significant differences in highway functions, classifications, and traffic volumes between two intersecting highways or for the T junctions with large traffic volumes.

2 Non-priority mode shall be adopted where both or all of the multiple intersecting highways have fairly low traffic volumes.

3 Signalized mode shall be adopted for the following situations where:

1) Both intersecting highways have large traffic volumes, similar functions and classifications, and‘main road priority’ modeis not applicable.

2) Even though a main road and minor road can be identified, both of the intersecting highways have large traffic volumes (i.e. dual traffic on the main road equal to or more than 750 pcu/h, while one-way traffic on the minor road is greater than or equal to 300 pcu/h), which would cause frequent traffic accidents and serious traffic delays if ‘main road priority’ mode is applied.

3) A large traffic volume on the main road (larger than or equal to 900 pcu/h) while the traffic volume on minor road is not large, buttraffic delay could be unacceptable due to limited opportunities for the traffic on the minor highway to enter into the dense and busy traffic stream on the main road, or could be very dangerous to enter into the insufficient traffic gaps on the main road if ‘main road priority’ mode is applied.

4) Traffic volumes on both intersecting highways are not large, butthe traffic delay, congestion or traffic accidents may occur due to a large number of pedestrians and non-motorized vehicles passing through the junction.

5) Many traffic delays occur due to large traffic volumes at the entrances to a roundabout junction.

6) The at-grade junctions on urban highway sections.

10.1.4 Determination of design speeds for an at-grade junction shall conform to the provisions as follows.

1 Design speed of main road in the functional area of an at-grade junction should be the same as that of the highway segments.

2 Where the functions, classifications, and traffic volumes of the intersecting highways are similar to each other, design speeds of through traffic lanes in the area of an at-grade junction may be appropriately reduced, but shall not be lower than 70% of the design speed of the highway segment.

3 Where the minor road is re-located due to deflection angle or other reasons, or lower alignment criteria are used due to restrictions because of the environment, the applicable design speed may be appropriately reduced.

4 The design speeds for turning lanes shall be determined in accordance with the design speed, traffic volume, mode of junction, traffic management mode and land acquisition.

10.1.5 The intersection angle and number of legs of an at-grade junction shall be determined in compliance with the rules as follows.

1 Intersection angle of an at-grade junction should be a right angle. In the case of a skew intersection, the acute angle shall not be smaller than 70°, or 45° if constrainedby terrain or other special conditions.

2The number of legs of an at-grade junction shall not be more than four, otherwise a roundabout shall be considered.

3 The number of legs in a roundabout should not be more than five. Where the 'give way' rule is feasible in practice, a yield controlled roundabout shall be adopted.

4 A new highway shall not directly join into an existing junctionwith 4 or more legs.

Channelization design of at-grade junctions must be conducted for motorways, Class-1 and Class-2 highways. It should be conducted for Class-3 highways, and may be conducted for Class-4 highways. Channelization of an at-grade junction, including widening of turning curves, widening of approaching legs, placing turning lanes and dividing islands, shall be designed in accordance with type of junction, traffic management mode, turning traffic volumes and design speeds.

10.1.7 The spacing of at-grade junctions shall be controlled in compliance with the provisions as follows.

1 The spacing of at-grade junctions shall be determined in accordance with the highway functions, technical classifications and their impacts on traffic safety, capacity, and delay.

2 Minimum spacing of at-grade junctions on aclass-1 or class-2 highway shall conform to the criteria in Table 10.1.7.

Classified Highway	Class-1			Class-2	
Highway Functions	Arterial		Collector-Distributor	Arterial	Collector-Distributor
	Normal Value	Limiting Value			
Spacing（m）	2 000	1 000	500	500	300

3 The traffic on arterial highways shall have priority by mitigating or eliminating longitudinal and transversal interferences. The spacing of at-grade junctions shall be large enough. Grade separated junctions may be placed if necessary.

4 On class-1 and class-2 collector-distributor highways, at-grade junction shall be positioned properly. The number of at-grade junctions shall be reduced through merging local roads and other measures.

10.1.8 The level of service of at-grade junctions shall conform to the provisions as follows.

1 The level of service of at-grade junctions on a class-1 highway shall not be lower than LOS-3; the level of service of at-grade junctions shall not be lower than LOS-4 for class-1 collector-distributor highways, class-2 highways and class-3 highways.

2 Analytical verifications shall be performed on the capacity and level of service of at-grade junctions on a class-3 or higher highways.

10.2 Highway Alignment at At-grade Junctions

10.2.1 Horizontal alignments at at-grade junctions shall be designed in compliance with the requirements as follows.

1 In the area of influence of an at-grade junction where two highways intersect at a right angle or approximately at right angles, the horizontal alignments shall be on tangents or large-radius curves, but circular curves requiring superelevation should be avoided.

2 Where a new highway intersects with anexisting highway of lower classification at an intersection angle smaller than 70^{o}, the minor highway shall be relocated within a certain range before and after the junction.

10.2.2 Design of vertical alignment of at-grade junctions shall conform to the provisions as follows.

1 In the area of influence of an at-grade junction, the vertical alignments of intersecting highways should be flat or gentle. The vertical alignment shall accommodate stopping sight distance.

2 The gradient of the main highway at an at-grade junction shall be between 0.15% and3%; while the minor highway approaching the at-grade junction shall be at an ascending gradientbetween 0.5% and2%.

3 Where the main highway is superelevated within the area of influence of an at-grade junction, the gradient of the minor highway shall follow the cross-slope of the main highway.

10.2.3 Vertical alignment of at-grade junctions shall be designed in compliance with the requirements as follows.

1 The profile of common area and the cross slopes of approaching sections of two intersecting highways shall be determined in accordance with the functions, classifications, horizontal and vertical alignments, and traffic management modes. Under ‘main road priority’ mode, the cross-section of the main road shall be maintained to dominate the at-grade junctions while the profile of minor road shall be adjusted to fit the cross-section of main highway. In case where such a profile adjustment on a minor road is difficult, the cross-sections of both roads shall be adjusted interactively.

2 The elevation and cross slope of every point on channelized right-turn lanes or auxiliary right-turn lanes shall accommodate the profilein the common area and adjacent areas, superelevation required for turning curves and the needs for surface drainage and road appearance in area of the junction.

3 One of the main factors that shall be considered in profile design is to ensure free and efficient road surface drainage. Any part of the road surface, including painted islands, in an at-grade junction must be free of ponding water.

10.3 Sight Distance

10.3.1 Approach sight distance at an at-grade junction shall conform to the requirements as follows.

1 Approach sight distance shall be provided on every leg at an at-grade junction, as shown in Fig. 10.3.1.

2 An approach sight distance is equivalent to stopping sight distance in value, of which however the criteria for determining the value is slightly different: the height of sight is 1.2m, and the height of an object is 0 m. The approach sight distances and minimum radius of crest vertical curves are shown in Table 10.3.1.

Design Speed（km/h）	100	80	60	40	30	20
Approach Sight Distance（m）	160	110	75	40	30	20
Minimum Radius of Crest Vertical Curve（m）	10 700	5 100	2 400	700	400	200

Curve

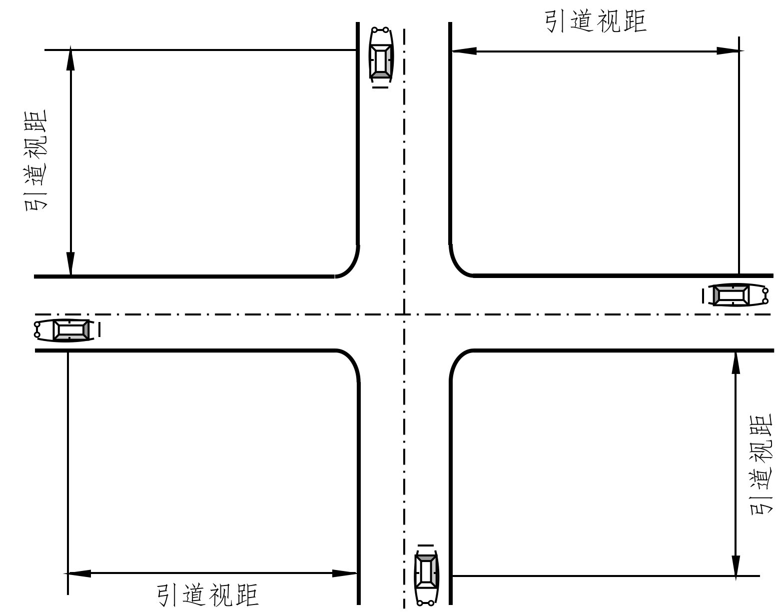


Fig. **10.3.1 Approach Sight Distance**

10.3.2 The sight distance of sight triangle shall conform to the requirements as follows.

1 Any object that may limitdrivers' inter-sightdistance must not exist in the sight triangledefined by two respective stopping sight distances onthe intersecting highways, as shown in Figure 10.3.2-1.

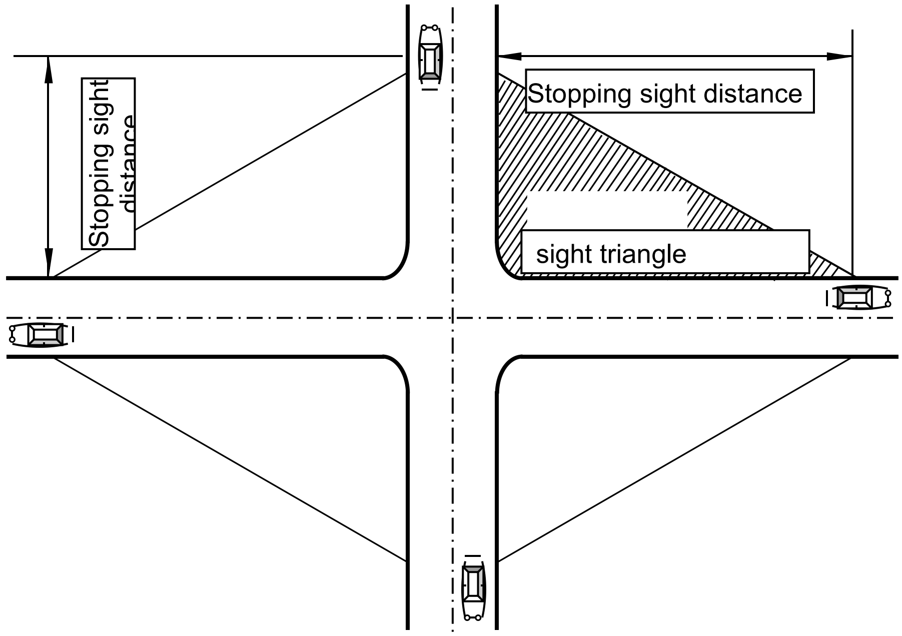


Fig. 10.3.2-1 Sight Triangle

2 Where the sight triangle defined by stopping sight distances cannot be satisfied due to restrained conditions, a corner sight distance, which is a sight triangle consisting of the stopping sight distance for safe crossing of main road as one leg and a 5m～7m long section on the minor road from center line of the main road as the other leg, shall be ensured as shown on Figure 10.3.2-2. The corner sight distances for safe crossing shall conform to the values in Table 10.3.2

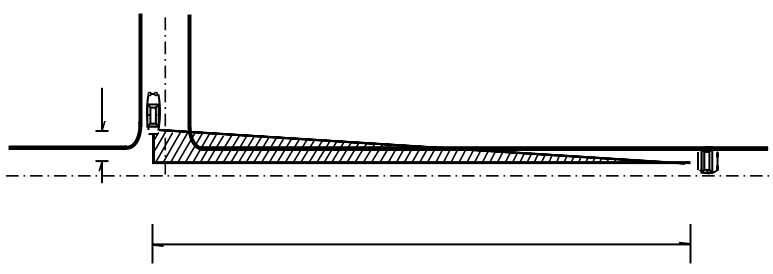


Fig. 10.3.2-2 Sight Triangle of Stopping Sight distance for Safe Crossing

Design Speed（km/h）	100	80	60	40	30	20
Stopping Sight Distance (m)	160	110	75	40	30	20
Stopping Sight Distance for Safe Crossing（m）	250	175	115	70	55	35

10.4 Turning Roadway Design

10.4.1 Alignment and roadway width of a turning curve at an at-grade junction shall be determined in accordance with the wheel tracks of design vehicles on turning.

10.4.2 Design vehicles and design speeds used for turning curves shall conform to the requirements as follows.

1 Turning design of a classified highway shall be conducted in accordance with the wheel path of the design vehicles corresponding to the classified highway. Verification on widening and turning clearance shall be executed wherever necessary.

2 Design of left-turn curves shall be controlled by the tracks of trucks.The design turning speed should be between 5 to 15 km/h. In the case of low proportion of large vehiclesor constrained conditions, truck tracksof a design speed of 5 km/h may be applied for design of left-turn curves, but radius of 自助 inner edge curve of a left-turn shall not be below 12.5 m.

3 where separated right-turn lanes are placed, the design speed for turning should not higher than 40km/h; where design speed of the main highway is lower than or equal to 60km/h, the design speed for right-turning should not be lower than 50% of the design speed. Specific lanes for right-turn may not be placed if the highway classification is low and traffic volumes are small.

10.4.3 The minimum radius of circular curve and alignment at the inner edge of a turning roadway shall conform to the provisions as follows.

1 Minimum radius of circular curves at inner edge of a turning roadway shall be determined shall be determined by referring to Table 10.4.3 and in accordance with

Design Speed (km/h)	≤15	20	25	30	40	50	60	70
Minimum Radius (m)	15	20（15）	25（20）	30	45	60	75	90
Min. Superelevation (%)	2	2	2	2	3	4	5	6
Max. Superelevation (%)	Normal value: 6; Limit value: 8							

turning speed.

Note: The values in brackets may be used where are restricted by the environment.

2 The edge alignment of a turning roadway shall conform to the wheel track of turning vehicles, for which the design shall conform to the requirements as follows.

1) For the right-turn lanes at a channelized at-grade junction, the inner edge of the turning roadway shall be in a three-centered compound curve; for inner edge of a left

turning roadway, the edge alignment of divisional islands shall be controlled by a simple circular curv.

2) Where wheel tracks of articulated trailersare used in design, the compound curve in match may be takenas the edge alignment of the turning roadway. .

3) The circular curve with a 15-m radius may be used as the alignment of pavement edge of an un-channelizedat-grade junction.

10.5 Auxiliary Lanes and Traffic Islands

10.5.1 Design of right-turn auxiliary lanes shall conform to the provisions as follows.

1 Either speed-deceleration to diverge lanes or speed-acceleration to merge lanes shall be added to the main highway which design speeds are higher than or equal to 60km/h.

2 Channelized right-turn lanes shall be placed where two class-1 highways intersect with each other, or where oneclass-1 highway intersects with one class-2 highway accommodating large traffic volumes.

3 At an at-grade junction on a class-1 or class-2 highway, a right-turn lane shall be placed in the circumstances as follows.

1) where intersection angle is or close to 70^{o}.

2）where traffic volumes are rather large and right turning traffic may cause unreasonable delays.

3) where right turning traffic contains large truck population;

4) where the running speeds of right turning vehicles are higher than 30km/h;

5) where the right turning traffic at the at-grade junctions of an interchange is quite large.

10.5.2 Design of left-turn auxiliary lanes shall conform to the provisions as follows.

1 left-turn lanes shall be placed at at-grade junctions except those where left turning traffic is very small and cause neither congestions nor delays to through traffic.

2 On class-2 highways, left-turn lanes shall be placed in the circumstances as follows.

1) at the at-grade junction that connects to the ramp of an interchange on a motorway or class-1 highway.

2) at the at-grade junctions that accommodate large non-motorized traffic but no slow traffic lanes are placed.

3) where left turning traffic may cause congestion or accidents.

3 A left-turn lane comprises a tapered transition section, speed reduction section and awaiting section. The length of an awaiting section shall not less than 30m and may not be considered only if the left turning traffic volume is very small.

10.5.3 Design of speed-change lanes shall conform to the provisions as follows.

1 The length of a speed-change lane shall be determined in accordance with the classification, design speeds and conditions for speed changing, and by referring to

Importance of intersecting highway	Design speed (km/h)	Length of deceleration lane (m)			Length of acceleration lane (m)		
		Departure speed (km/h)			Approaching speed		
		0	20	40	0	20	40
Main highway	100	100	95	70	250	230	190
	80	60	50	32	140	120	80
	60	40	30	20	100	80	40
	40	20	10	—	40	20	—
Minor highway	80	45	40	25	90	80	50
	60	30	20	10	65	55	25
	40	15	10	—	25	15	—
	30	10	—	—	10	—	—

Table 10.5.3-1.

Note: Transition section lengths are excluded in the value listed in the above table in terms of length of a speed-change lane.

2 The design of transition section in a speed-change lane shall conform to the requirements as follows.

1) an additional length of transition section as listed in Table 10.5.3-2 shall be added to the speed-change lane with an equal-width.

Design speed (km/h)	100	80	60	40
Length of transition section	60	50	40	30

2) if the speed-change lanes is in unequal widths, its length shall not be less than calculated value of the lateral movement for lane changing at a speed of 1.0m/s during deceleration or 0.6m/s during acceleration.

3） where the design speeds are higher or equal to 80km/h and through traffic volumes is large, the equal-width speed change section plus a tapered transition shall be used as the speed-change lane for right turn lane. Otherwise, unequal-width speed-change lane should be used.

4) Where the capacity of trough lanes is surplus or the full length of an acceleration lane is impossible due to environment constraints, a slightly shorter acceleration lane with tapered width may be adopted.

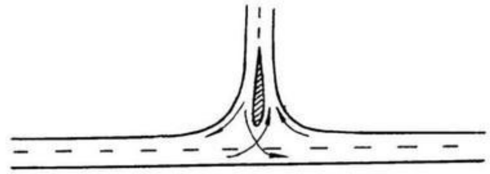
10.5.4 Placement of channelized traffic islands shall conform to the provisions as follows.

1 Splitter islands shall be placed where specific right-turn lanes are required.

2 At signalized at-grade junctions with two left-turn lanes, splitter islands should be placed in between left-turn lanes and through lanes.

3 Divisional islands shall be placed in between left-turn lanes and opposite through lanes.

4 In a T-junction, a splitter island shall be placed on the minor highway leg to guide left-turning vehicles.



Note: the above figure is added in En version only

5 Splitter islands shall be placed between traveled ways to provide pedestrian with refuge zones during crossing over, or where posts of signals or signs are to be installed.

10.5.5 The types of traffic islands shall be selected in compliance with the provisions as follows

1 Curb enclosed physical islands shall be selected where two or more than two lanes are to be separated or only one lane to be separated but has been widened for by passing troubled vehicles, or signal and sign posts need to be installed.

2 A shadow island should be delineated on pavement surface with road marking where the area of an island is too small or a physical island is neither necessary nor suitable.

3 a plate island, which is abutted by the wider-than-0.5m marginal strips of a through-passing roadway and a left-turn roadway, should be placed where the area of an island is quite large.

10.6 Reconstruction of at-grade junctions

10.6.1 The data about the existing at-grade junctions, such as traffic management mode, current and forecast traffic, geometry, current state of facilities, and the rate, types, level and causation of traffic accidents, shall be collected prior to reconstruction so as to develop reconstruction program accordingly.

10.6.2 In the case of insufficient capacity or unsure traffic safety, following improvements shall be arranged.

1 increase the number of lanes, such as adding turning lanes, speed-change lanes, and slow-moving lanes.

2 upgrade the channelization design.

3 relocate the horizontal alignments of some junction legs

4 improve sight distances.

5 improve vertical alignment of approaching sections and profile arrangement.

6 improve turning curves.

7 change traffic management mode, and re-design or re-arrange signs, road markings, and signal facilities.

8 designate the crossing locations for pedestrian and non-motorized traffic, upgrade pedestrian crossing-over facilities, place refuge islands, and build overpasses or underpasses.

10.6.3 For the highway segments with dense at-grade junctions, apart from the improving measures, some of the existing at-grade junctions may be eliminated by rearrangement of local network nodes, cutting off the intersections with some of the minor highways or building grade-separated junctions.

10.6.4 If the capacity and traffic safety still cannot be fully ensured by various improving measures, replacing the existing at-grade junction with a new interchange shall be considered.

11GRADE-SEPARATEDJUNCTIONS

11.1 General

11.1.1 Highway-highway grade-separated junctions include grade separations and interchanges.

1 A grade-separated junction must be adopted where a motorway intersects with another classified highway.

2 A grade-separated junction shall be adopted where a class-1 highway intersects with another classified highway that accommodates large traffic volumes.

3 Grade-separated junctions should be adopted for class-2 and class-3 highways intersecting one another if through traffic volumes are large or in a place where is favorable.

11.1.2 An interchange shall be placed at one of the following circumstances.

1 Where two motorways intersect each other or a motorway intersects with a class-1 highway.

2 Where a motorway or class-1 highway intersects with another major highway connecting with the cities above county level or important political or economic centers.

3 Where a motorway or class-1 highway intersects with a major highway connecting with important industrial and mining zones, seaports, airports, railway stations or tourist attractions.

4 Where a motorway intersects with a major highway that accommodates significant traffic flows which serves as one of the link roads to and from the motorway.

5 Where two class-1 arterial highways intersect with each other or a class-1 highway intersects with another classified arterial or collector-distributor highway.

6 On a class-1 highway where the capacity of an at-grade junction cannot accommodate the traffic flow, or is susceptible to frequent crashes.

7 Where an interchange has higher benefits than other junction solutions in considering terrain, land, and other conditions.

11.1.3 Grade separations shall be adopted in the following circumstances:

1 Where a motorway intersects with another classified highway unless an interchange has to be adopted to accommodate turning traffic volumes.

2 Where a class-1arterial highway intersects with another classified highway, except where an interchange has to be provided for turning traffic, for the purpose of reducing the number of at-grade junctions but not cutting off the intersected highways.

3 A grade separation may be placed for any two of class-2, class-3 and class 4-highways intersecting one another if through traffic volumes are large, terrain conditions are in favor, and turning traffic does not have to be considered.

11.1.4 Interchanges are categorized as hub interchanges and general interchanges. Their placement shall conform to the requirements as follows.

1 The interchanges between two motorways, or two class-1 arterial highways, or one motorway and one class-1 arterial highway shall be regarded as hub interchanges.

2 The interchanges between one motorway or class-1 arterial highway and one class-1 collector-distributor highway or other non-arterial, lower classified highway shall be regarded as general interchanges.

11.1.5 The spacing of interchanges shall conform to the requirements as follows.

1 On motorway segments near large cities or important industrial zones, the average spacing of two successive interchanges should be between 5 and10 km.

2 The minimum spacing of two successive interchanges on a motorway, which is measured from the end of the acceleration lane of one interchange to the starting point of the deceleration lane of next interchange, should not be shorter than 4km. In places restricted by the highway network structure or other special conditions, the spacing of

two successive interchanges may be reduced subject to the approval of specific investigation. In such a case, a specific traffic engineering design shall be executed that will include effective signs, road marking, alerting devices and visual guiding facilities, but the spacing must not be shorter than 1,000m. In a case where the spacing is shorter than 1,000m, the two successive interchanges shall be combined into one compound interchange.

Spacing between adjacent interchanges on a motorway shall not be greater than 30km in general, or 40km in a desert, steppe or sparsely populated mountainous areas. If this spacing is exceeded, a grade-separated U-turn facility shall be placed.

4 The minimum spacing of adjacent interchanges on non-motorways (classified highways but not motorways) should be determined by referring to the above guidelines. In the case where restricted by environmental conditions, the spacing may be appropriately reduced subject to the approval of the analysis and verification of the capacity of weaving sections.

11.1.6 Spacing between interchanges and other facilities with accesses or tunnels shall conform to the requirements as follows.

(1)Spacing between an interchange and a roadside facility, such as service area, rest area or a bus stop, shall be sufficient for installation of exit information signboards. In places that are restricted by environmental conditions, the spacing may be reduced to a minimum of 1,000m from the end point of an entry access to the start point of exit access at the next interchange. In case the spacing is shorter than 1,000m, the two adjacent interchanges shall be combined into one compound interchange.

(2)Distance from a tunnel exit to the interchange ahead shall be sufficient for the installation of exit information signboards. At locations that are restricted by physical conditions, the distance from the tunnel exit portal to the start of an exit to an interchange shall be not less than 1,000m; otherwise, the information signboards shall be placed before the tunnel entrance portal or inside the tunnel.

3 Distance (in meters) from the end of tapered section of an acceleration lane to the tunnel entry portal ahead should not be less than the numerical value of the design speed (km/h).

11.1.7 An interchange shall be located in a suitable place for intersecting highways in terms of alignment, terrain, geological conditions and environment based on the status and development plan of the highway network. The highways linked by an interchange shall be in compliance with the requirements as follows:

1 The classification of intersecting highways at an interchange shall not be lower than secondary arterial highways or collector-distributor highways in terms of functions in a road network, and shall not have lateral interference.

2 The highway capacity shall be able to accommodate both passing-through traffic and collected-distributed traffic.

3 The link road to major traffic sources shall be short and efficient.

4 The traffic volumes distributed to nearby highways in the highway network shall be moderate and avoid causing congestion on these highways or segments of these highways.

5 A reconstruction design shall be conducted in the case that an existing highway is selected as part of the layout of the highway network but incapable to serve as the proposed link road to an interchange.

11.1.8 The type of an interchange shall be selected in accordance with various factors including the functions and classifications of the intersecting highways, design speeds of ramps, terrain, ground conditions, land acquisition, traffic volume, construction cost and possible tolling facilities.

11.1.9 The geometry of a main highway route at an interchange shall conform to the criteria in Table 11.1.9.

Table 11.1.9 Alignment Criteria of Main Route at Interchange

Design speed (km/h)			120	100	80	60
Minimumradiusofcircular curve (m)		Normal value	2000	1500	1100	500
		Limiting value	1500	1000	700	350
Minimumradiusofvertical curve (m)	Convex	Normal value	45 000	25 000	12 000	6 000
		Limiting value	23000	15000	6000	3000

	Concave	Normal value	16000	12000	8000	4000
		Limiting value	12000	8000	4000	2000
Maximum longitudinal grade (%)		Normal value	2	2	3	4.5(4)
		Limiting value	2	3	4(3.5)	5.5(4.5)

Note: The grade of the main road shall not be greater than the values in the brackets in the case where the main road enters on a steep downgrade into an interchange and the connected deceleration lane is on a downgrade, and followed by a ramp with small alignment parameters.

11.1.10 The length of a weaving section in a compound interchange shall not be shorter than 600mand may be connected to the interchanges by one of the following three ways:

1 by means of auxiliary lanes to provide the two interchanges with direct access;

2 by means of a separated ramp or frontage road to provide connections for all of the exits and entrances on one side of the main route;

3by means of separated lanes to form non-weaving connection between the two interchanges.

11.2 Sight Distance

11.2.1 Good visibility shall be provided in the area of an interchange

11.2.2 A decision sight distance ahead of an approach nose shall be ensured. The decision sight distances shall conform to the criteria in Table 7.9.5, and shall be 1.25 times greater than the stopping sight distance on the main route.

11.2.3Over the full length of a ramp, the stopping sight distance shall not be shorter than the values specified in Table 11.2.3.

Design Speed (km/h)	80	70	60	50	40	35	30
Stopping Sight Distance (m)	110（135）	95（120）	75（100）	65（70）	40（45）	35	30

Note: In areas subject to snow and freezing, the values shall not be smaller than indicated in brackets.

11.2.4 A sight triangle shall be ensured ahead of an approach nose.

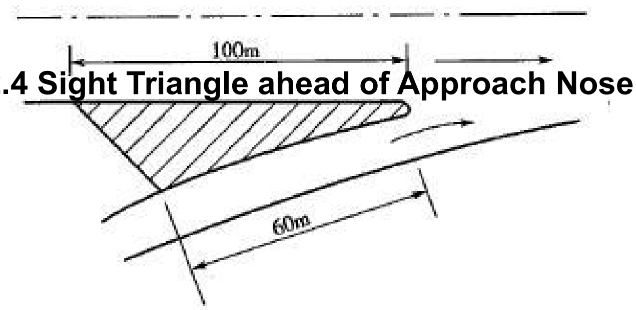


Fig. 11.2.4 Sight Triangle ahead of Approach Nose

11.2.5 The location of ramp exits shall be visible and identifiable. An approach nose should be placed ahead of the overpass; where it is placed behind an overpass, the distance from ramp exit to the overpass shall not be shorter than 150m.

11.3 Design of Ramps

Type of Ramp		Direct	Semi-direct	Loop
Design Speed on Ramp（km/h）	Hub Interchange	80、70、60、50	80、70、60、50、40	40
	General Interchange	60、50、40	60、50、40、	40、35、30

11.3.1 Design speeds of interchange ramps shall be conform to the criteria in Table 11.3.1.

Note: 1 upper or mid values should be used for right-turn ramps;

2 upper or mid value should be used for left-turn directional or semi-directional ramps.

11.3.2 Design of ramp roadway shall conform to the requirements as follows.

1Dimensions of each element of a ramp roadway are as follows:

1) Lane width is 3.50m in general, and 3.75m where the design speed on the ramp is higher than 60km/h;

2) Width of marginal strip is 0.50m;

3) Width of left hard shoulder (including marginal strip) is 1.00m; or may be 0.75m where a turnout is provided at right shoulder of a one-way, two-lane ramp.

4) Width of hard right shoulder (including marginal strip) should be3.00m where the hard shoulder is also used for emergency stopping; width should be 1.50m where it is

constrained by difficult conditions, 2.00m for divided two-way, two-lane ramps; or shall be 1.00m if the hard shoulder is not used for emergency stopping.

5) Width of an earth shoulder is 0.75m; or may be 0.5m where constrained by the environment, and no roadside barriers are installed.

6) Width of a central dividing strip shall not be less than1.00m.

2 A ramp roadway cross-section shall be one of the four types shown in Fig. 11.3, and shall be selected in compliance with the following requirements.

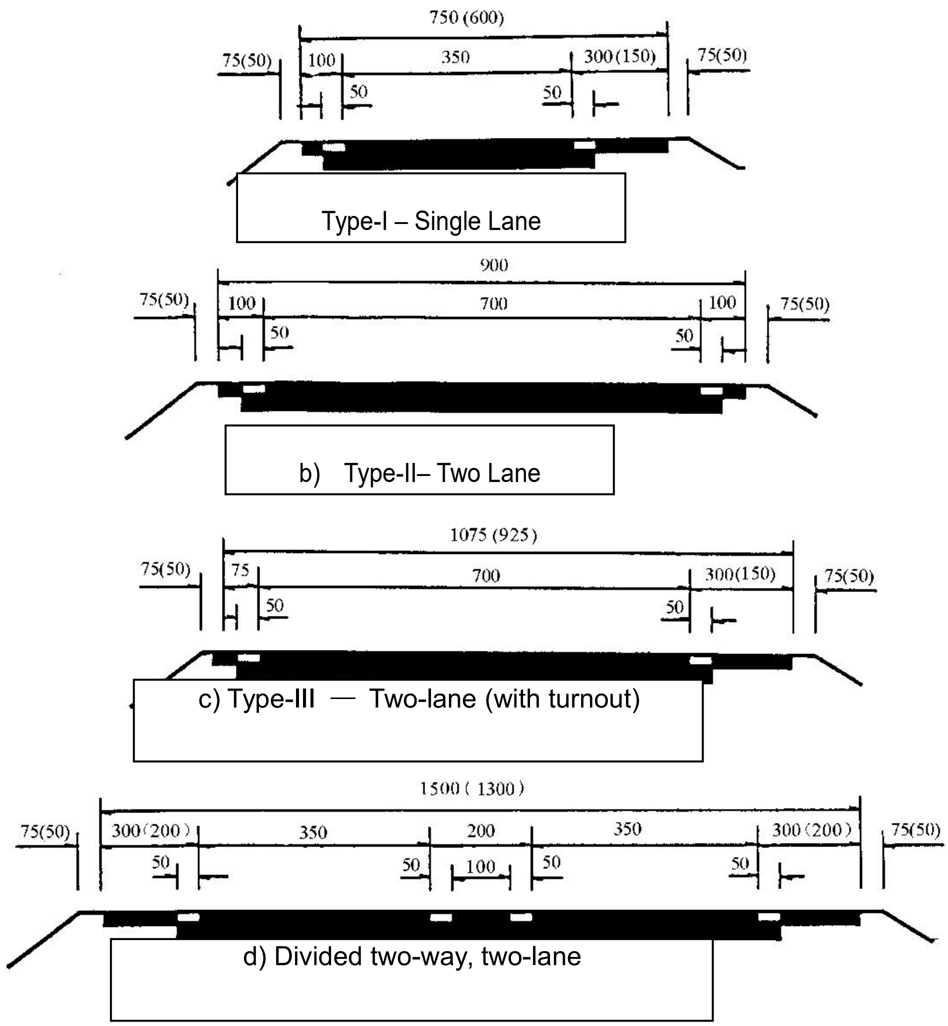


Fig. 11.3.2 Basic Ramp roadway Cross-sections

Note: widening on curve is not included.

1) Type-I shall be adopted where the traffic volume is less than 100pcu/h, or where traffic volume is greater or equal to 100pcu/h but less than 1 200pcu/h and where the length of the ramp is less than or equal to 500m.

2) Type-II, with single-lane at an exit and entrance, shall be adopted for the demands of overtaking where the traffic volume is greater than or equal to 100pcu/h but less than 1 200pcu/h, and the length of ramp is greater than 500m.

3) Type-II shall be adopted where the traffic volume is larger than or equal to 1,200pcu/h, but less than 1,500pcu/h.

4) Type-III shall be adopted where the traffic volume is larger than or equal to 1,500pcu/h.

5) Type-IV shall be adopted for divided two-way, two lane ramps. However, where the design speed is less than or equal to 40km/h, Type-II may be adopted for undivided two-way, two-lane ramps on the non-motorway side.

6) The number of lanes in each direction and the arrangement of the roadway of a divided ramp should be determined in accordance with the criteria for the basic type and dimensions of ramp roadways.

7) Single lane ramps shall be adopted for loop ramps with a design capacity between 800 and 1,000pcu/h.

3 For a multilane ramp merging or diverging from the main route, the widths of ramp lanes and hard shoulder shall be same as that of the main route.

11.3.3 The horizontal alignment of a ramp shall be determined in accordance with the ramp design speed, type of intersections, traffic volume, terrain, land acquisition availability, construction cost and other relevant factors, and shall be designed in compliance with the requirements as follows.

1 For ramps, minimum radii of circular curves and minimum radii for non-superelevated circular curve shall conform to the criteria in Table 11.3.3-1

Table 11.3.3-1 Minimum Radius of Circular Curves and Minimum Radius for Non-superelevated Circular Curves on Ramps

Design speed on ramp		80	70	60	50	40	35	30
Minimum Radius of Circular Curve on Ramp (m)	Normal value	280	210	150	100	60	40	30
	Limiting value	230	175	120	80	50	35	25
Minimum Radius for Non-superelevated Circular curves(m)	Cross slope ≤2%	2500	2000	1500	1000	600	500	350

2 Design of horizontal alignment for a ramp shall conform to the following requirements.

1) In the section from exit or entrance to the section with a tight horizontal alignment, the radius of the curve shall fit the various speeds of the vehicles on the section.

2) Higher horizontal criteria shall be adopted for right-turn ramps, left-turn directional ramps, or semi-directional ramps.

3) In directional interchange ramps, the horizontal alignments before and after a crest vertical curve shall be kept consistent with one another; otherwise, good visual cues shall be provided. It is forbidden that a crest vertical curve with small radius is immediately followed by a horizontal reverse curve.

4) The horizontal alignment of a ramp shall fit the traffic volume. Higher horizontal criteria shall be used for the ramp with higher traffic volume.

5) Unnecessary reverse turning shall be avoided wherever possible.

6) The length of each alignment elements should not be less than the distance traveled during 3s at the design speed.

3 Where a curve is placed within a ramp and its end section, the parameters and length of such a curve should not be lower than the criteria listed in Table 11.3.3-2. The length of a spiral curve shall not be less than the length required for a superelevation transition.

Table 11.3.3-2 Parameters and Length of Spirals on Ramp

Design speed on ramp (km/h)	80	70	60	50	40	35	30
Parameter of Spiral A (m)	140	100	70	50	35	30	20
Length of Spiral (m)	70	60	50	40	35	30	25

4 At an approach nose, the minimum curvature radii of ramps are listed in Table 11.3.3-3. The radius of circular curve on ramp (R), which connects to the spiral at the approach nose (A), shall be greater than the normal value of minimum radius

Design Speed of Main Route (km/h)		120		100	80	60
Design Speed at Approach Nose (km/h)		80	70	65	60	55
Min. Curvature Radius (m)	Normal Value	450	350	300	250	200
	Limiting Value	400	300	250	200	150

corresponding to the ramp operating speed at the connecting point.

Note: For general interchanges, the design speed at the approach nose may be reduced by 5km/h and the specified

Table 11.3.3-3 Minimum Curvature Radius of Ramp Horizontal Curve at Approach Nose

values are then used.

5 In a compound curve, the ratio of the large radius to the small radius shall not be greater than 1.5. Otherwise a spiral curve shall be inserted between the circular curves.

11.3.4 Vertical alignment of ramps shall conform to the requirements as follows.

Design Speed on Ramp (km/h)			80、70	60、50	40、35、30
Max. Grade （%）	Exit Ramp	* Upgrade	3	4	5
		Downgrade	3	3	4
	Entrance Ramp	Upgrade	3	3	4
		* Downgrade	3	4	5

1 Maximum ramp grades shall conform to the criteria in Table 11.3.4-1.

Note: The maximum longitudinal grade may be increased by 1% in difficult terrain or limited land space. In the regions where do not have freezing or snow, the gradients may be increased by 2% if the local condition is particularly difficult.

2 Minimum radii and minimum lengths of vertical curves on ramps shall conform to the criteria in Table 11.3.4-2.

Table 11.3.4-2 Minimum Radius and Minimum Length of Vertical Curve on Ramps

Design Speed on Ramp (km/h)			80	70	60	50	40	35	30
Min. Radius of Vertical Curve (m)	Crest	Normal Value	4 500	3 500	2 000	1 600	900	700	500
		Limiting Value	3 000	2 000	1 400	800	450	350	250
	Sag	Normal Value	3 000	2 000	1 500	1300	900	700	400
		Limiting Value	2 000	1 500	1 000	700	450	350	300
Min. Length of Vertical Curve		Normal Value	100	90	70	60	40	35	30
		Limiting Value	75	60	50	40	35	30	25

3 Vertical alignment of a ramp shall conform to the following criteria:

1) Ramp gradients shall be gentle or flat, and shall avoid reversed grades.

2) Vertical alignment shall be continuously smooth at the interconnection of the ramp and the main route. Abrupt changes in alignment shall be avoided.

3) Exit ramp should be on upgrade.

4) Flatter grades shall be adopted for upgrade acceleration ramps or downgrade deceleration ramps. Maximum values shall be avoided.

5) Where toll booths are placed on a ramp, the grades of the approach road sections to the toll booths shall be gentle and flat. Steeper grades for approaches to toll stations are not allowed.

6) A large radius vertical curve shall be placed at the end of a ramp where the grade changes. A crest curve shall have a larger radius where an opposite grade is inevitable, especially if it is followed by a reverse horizontal curve, or a ramp for traffic diverging or merging.

11.3.5 Superelevation and superelevation transition shall conform to the requirements as follows.

1 If the radius of the circular curve on a ramp is smaller than the radii of non-superelevated circular curves as listed in Table 11.3.3-1, the superelevation shall be placed in accordance with the relevant provisions stated in Section 7.5 of these specifications.

2 On a ramp, a superelevation transition section shall be placed between a tangent and a superelevated circular curve, or between two circular curves with different superelevations. The length of a superelevation transition section shall be determined in accordance with design speed, type of roadway, the position of the axis of rotation, rate of transition and other relevant factors. The transition rate of the superelevation on a ramp shall conform to the criteria in Table 11.3.5-1.

3 Where the cross slope is almost flat, the transition rate of superelevation shall not be less than the criteria in Table 11.3.5-2

Design speed (km/h)	Type of Roadway and Position of Axis of Rotation			
	One-way single lane ramp		One-way two-lane and two-way two-lane ramp	
	Outer edge of left marginal strip	Centerline of traveled way	Outer edge of left marginal strip	Centerline of traveled way
80	1/200	1/250	1/150	1/200
70	1/175	1/235	1/135	1/185
60	1/150	1/225	1/125	1/175
50	1/125	1/200	1/100	1/150
≤40	1/100	1/150	1/100	1/150

Type of Cross-section		One-way Single Lane	One-way two-lane, two-way two-lane
Position of Axis of Rotation	Centerline of Traveled Way	1/800	1/500
	Outer Edge of Marginal Strip	1/500	1/300

11.3.6 The widening of the ramp roadway on a circular curve shall conform to the criteria in Table 11.3.6.

Table 11.3.6 Widening Value of Ramp Pavement on Circular Curve

Single Lane Ramp (Type-I)		One-way Two-lane or Two-way Two-lane (Type-II)	
Radius of Circular Curve (m)	Widening Value (m)	Radius of Circular Curve (m)	Widening Value (m)
25～<27	2.25	25～<26	3.25
27～<29	2.00	26～<27	3.00
29～<32	1.75	27～<28	2.75
32～<35	1.50	28～<30	2.50
35～<38	1.25	30～<31	2.25
38～<43	1.00	31～<33	2.00
43～<50	0.75	33～<35	1.75
50～<58	0.50	35～<37	1.50
58～<70	0.25	37～<39	1.25
⩾70	0	39～<42	1.00
—	—	42～<46	0.75
—	—	46～<50	0.50
—	—	50～<55	0.25
—	—	⩾55	0

Note: 1. The widening values in the Table above refer to the amounts added to the width of the standard roadway as shown in Figure 11.3.2a). In the case of special cross-sections, the widening values shall be adjusted so that the overall width after widening shall be consistent with the standard values.

2.Each lane of a type-IV ramp shall be widened depending on the corresponding curve radius.

3. The widening of a type-III ramp is calculated such that the widening values of type-II minus the difference of the shoulder widths in Type-II and Type-III.

11.3.7 The exit and entrance of a ramp shall conform to the requirements as follows.

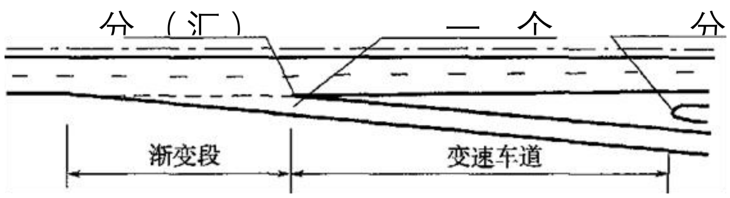
1 Except for high-speed ramps, the exit and entrance ramps shall be placed at right side of the main route roadway.

2 Offset widening shall be placed on both sides of an approach nose at an exit ramp end; on the main route side, the width of hard shoulder or the offset width after widening, C_1, should be in a range from 2.5 to3.5m; on the ramp side, the offset width abutting to left hard shoulder C_2 should be in a range from 0.6 to 1.0m, or take the value from Table 11.3.8-1.

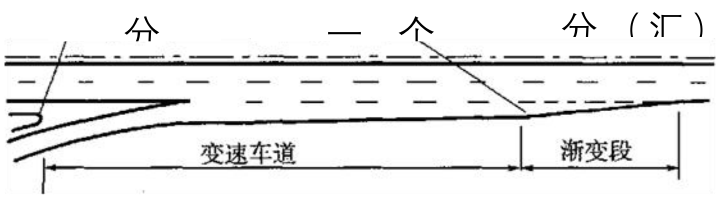
11.3.8 Design of speed-change lanes shall conform to the requirements as follows.

1 Cross-section of speed-change lane shall comprise left marginal strip (shared with through-lane on main route), traffic lanes, right shoulder (including right marginal strip).

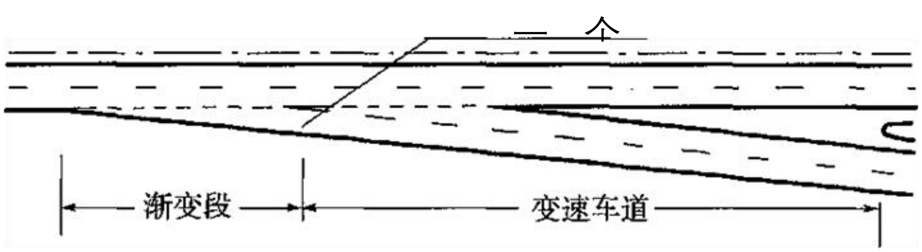
2 Speed-change lanes are categorized as directional type and parallel type, as shown in Figure 11.3.8-1. In the case of a single lane, directional type should be adopted for deceleration lanes while parallel type should be adopted for acceleration lanes. In the case of two-lanes, directional type shall be adopted for both deceleration and acceleration lanes.



a) Directional single-lane

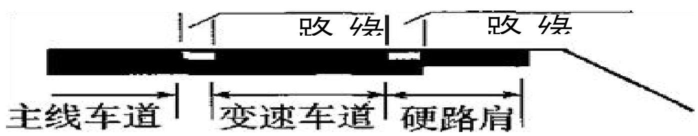


b) Parallel single-lane



c) Directional Two-lane

d) Directional Two-lane with Auxiliary Lane



e) Cross-section of single Lane

Fig. 11.3.8-1 Speed-change Lane

3 Where the main route offsets to the left and on a circular curve with radius close to the specified normal value of minimum radius, the deceleration lane on the left shall be a parallel type, and the length of transition section shall be reduced (the reduced length is given in the parallel section). Parallel type should be adopted where deceleration lane is connected with a small radius loop ramp.

4 The length of speed-change lanes shall not be less than the criteria in Table 11.3.8-1.

Table 11.3.8-1 Parameters of Speed-change Lane

Type of Speed-change Lane		Main Route Design Speed (km/h)	Length of Speed-change Lane (m)	Rate of Transition (1/m)	Length of Transition Section (m)	Main Route Hard Shoulder, C_1 (m)	Widening of Left Hard Shoulder at Nose, C2 (m)
Exit	Single - lane	120	145	1/25	100	3.5	0.60
		100	125	1/22.5	90	3.0	0.80
		80	110	1/20	80	3.0	0.80
		60	95	1/17.5	70	3.0	0.70
	Two – Lane	120	225	1/22.5	90	3.5	0.70
		100	190	1/20	80	3.0	0.70
		80	170	1/17.5	70	3.0	0.90
		60	140	1/15	60	3.0	0.60
Entrance	Single - lane*	120	230	—（1/45）	90（180）	3.5	~
		100	200	—（1/40）	80（160）	3.0	—
		80	180	—（1/40）	70（160）	2.5	—
		60	155	—（1/35）	60（140）	2.5	—
	Two - lane	120	400	—（1/45）	180	3.5	—
		100	350	—（1/40）	160	3.0	—
		80	310	—(1/37.5)	150	2.5	—
		60	270	—（1/35）	140	2.5	

Note: * In this table, single-lane entrance is parallel type; figures in brackets are for directional type. Additional 10m or 20m shall be added for single lane entrance of a two-lane ramp.

5 The length of a downgrade deceleration lane or an upgrade acceleration lane shall be

Average Grade on Main Route (%)	$i \leqslant 2$	$2 < i \leqslant 3$	$3 < i \leqslant 4$	$i > 4$
Correction Factor for Downgrade Deceleration Lane	1.00	1.10	1.20	1.30
Correction Factor for Upgrade Acceleration Lane	1.00	1.20	1.30	1.40

adjusted by using the correction factors in Table 11.3.8-2.

6 Speed-change lanes should be extended under the following circumstances.

1) where the design speed of the main route is lower than or equal to 100km/h and the parameters of the ramp alignment are low, the length corresponding to one level higher design speed should be adopted.

2) where the predicted traffic volume on both the main route and the ramp is close to their design capacity, or in the case of large proportion of trucks and large buses.

7 Where the main route is on a curve, the speed-change lanes shall conform to the requirements as follows.

1) The section of speed-change lanes parallel to main route shall have the same curvature as the main route.

2) In the case of two curves in the same direction, an oval or compound spiral curve shall be used from the change point, CP, (the point where the transition begins or ends) of alignment, as shown in Figure 11.3.8-2 a). In the case of curves in the opposite direction, S-shaped spiral curves should be used, as shown in Figure 11.3.8-2 c).Where the radius of a circular curve on the main route is larger than 2,000m, a full spiral curve may be used.

3) The whole directional speed-change lane up to the approach nose shall be on the same alignment as the main route.

4) In case the whole directional speed-change lane up to the approach nose cannot be on the same alignment as the main route because the superelevation on the main route is greater than 3% or for other reasons, S-shaped spiral curves may be used from the point where the spacing between outer edge of the main route and inner edge of the ramp is 3.5m to the nose point, as a transition section to the ramp alignment, as shown in Fig. 11.3.8-2 e).

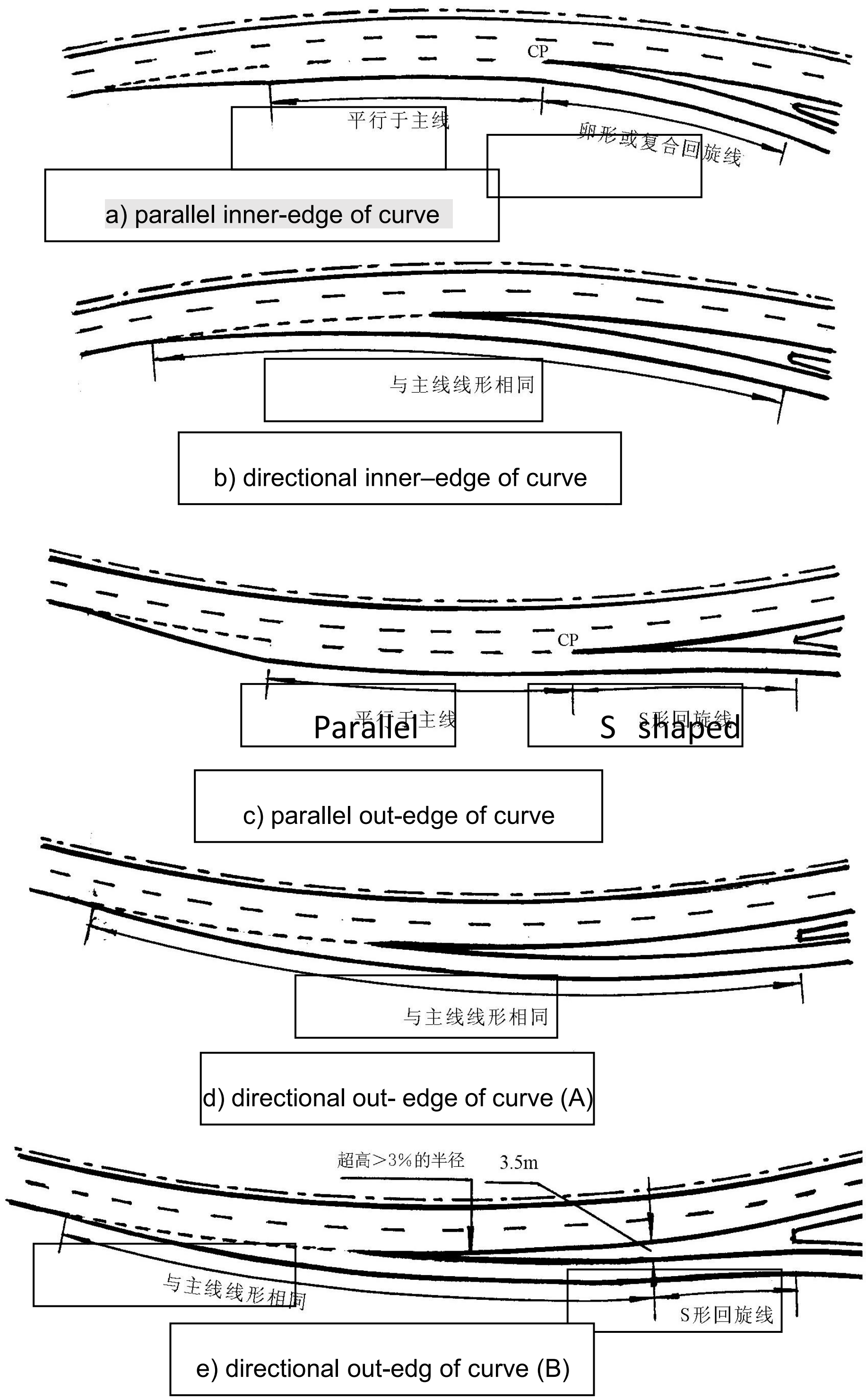


Fig. 11.3.8-2 Alignment of Speed-change Lanes

11.4 Basic Number of Lanes and Lane Balance

11.4.1 The basic number of lanes shall be kept constant over the whole length or a long segment between important network nodes of a motorway. The change in the number of lanes on a directional traveled way in two successive motorway segments must not be more than 1.

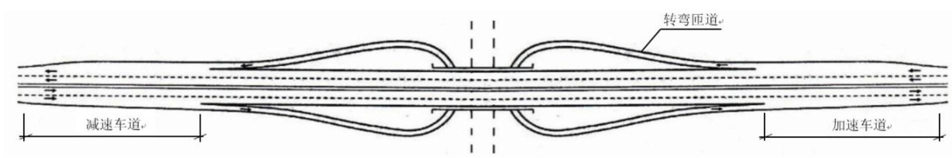
11.4.2 On a motorway, lane balance shall be maintained at the places where the main route and ramps are merged or diverged, as shown in Figure 11.4.2. The number of lanes on each part shall conform to the equation (11.4.2).

$$N_C \geq N_F + N_E - 1 \quad (11.4.2)$$

N_C —— Number of lanes on the main route before diverging or after merging;

N_F ——Number of lanes after diverging or before merging;

N_E ——Number of lanes on a ramp



a) diverge a) merge

Fig. 11.4.2 Lane Balance at Diverging or Merging

11.4.3 For the segments on a motorway with a constant number of lanes N_B, auxiliary lanes shall be placed where the number of lanes on ramp in an interchange $N_E > 1$, as shown in Figure 11.4.3.

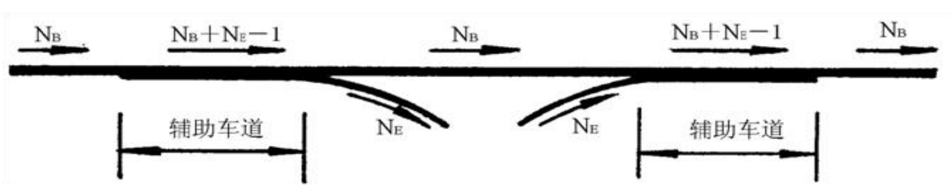


Fig. 11.4.3 Auxiliary Lanes at two-lane Exit/Entrance

辅助车道：auxiliary lanes

11.4.4 Design of auxiliary lanes shall conform to the requirements as follows.

Design Speed of Main Route (km/h)			120	100	80
Length of Auxiliary Lane (m)	Entrance		400	350	300
	Exit	Normal Value	580	510	440
		Limiting value	300	250	200
Length of Transition Section (m)	Entrance		180	160	140
	Exit		90	80	70

1 Length of an auxiliary lane shall conform to the criteria in Table 11.4.4.

2 Where the distance from the exit of one interchange to the entrance of the next interchange is less than 1,000m and at least one of them is designed with auxiliary lanes, the auxiliary lanes shall be continuous from the exit to the next entrance. In the case of large traffic volumes and a high incidence of traffic weaving, such all-through auxiliary lanes should be placed providing the spacing of the interchanges is no longer than 2,000m.

3 The lane width of auxiliary lanes shall be the same as the lane width on the main route. A marginal strip may not be placed between auxiliary lanes and the main route. The right hard shoulder of an auxiliary lane should be to the same width as the hard shoulder of the main route, but may be narrowed for saving land use and must not narrower than 1.50m.

11.5 Major Forks and Branch Connections on Main Routes vs. Diverges and Merges on Ramps

11.5.1 Designs of major forks and branch connections on main routes of a motorway shall conform to the requirements as follows.

1 A major fork on the main route refers to the design of a splitting section on a motorway where one of the traveled ways splits into two, of which one links to the multilane ramp of another motorway (labeled as A in Figure 11.5.1,) or that for one motorway splits into two motorways (labeled as A’ in Figure 11.5.1,).

2 A branch connection on the main route refers to the design for a combining section where two directional or semi-directional multilane ramps separated from one

motorway are merged into one traveled way of another motorway (labeled as B in Figure 11.5.1), or the directional traveled-ways from two motorways are merged into one traveled way of a motorway (labeled as B’ in Figure 11.5.1).

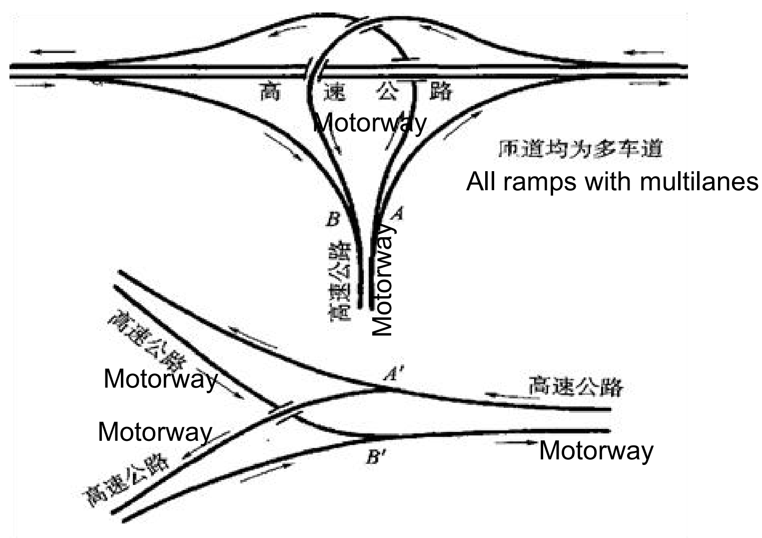


Fig. 11.5.1 Diverging and Merging of Main Route

11.5.2 The design of major forks and branch connections on main routes shall conform to the principle of lane balance.

11.5.3 The design of major forks and branch connections shall conform to the criteria as follows.

1 The width of a roadway shall vary linearly along the length of the transition section from the width before a divergence or after a convergence to the width of the roadway with an increase or decrease of one lane.

2 The rate of transition shall be 1:40 for major forks and 1:80 for branch connections.

3 The edge line of the transition section and the edge lines of the two-way segments shall be continuous in alignment.

11.5.4 The diverging and merging between ramps shall conform to the requirements as follows.

1 In the case that the number of lanes is in balance before and after diverging or merging, directional diverging or merging may be adopted, and a transition section

should be placed. The minimum length of transition sections for diverging or merging shall conform to the criteria in Table 11.5.4.

Table 11.5.4 Minimum Length of Transition Section for Diverging or Merging between Ramps

Speed at diverging or merging（km/h）	Minimum Length of Transition Section (m)	
	Diverging	Merging
40	50	70
60	60	90
80	80	120

2 In the case that the number of lanes is not in balance before and after diverging or merging, a section of auxiliary lanes shall be placed with a length not less than 150m and a transition section not shorter than 50m.

3 a two-lane ramp that is adopted only for the purpose of overtaking shall be reduced into a single lane before the merging operation. The transition section for the lane reduction shall not be less than 50m, as shown in Figure 11.5.4. Warning signs shall be installed before the start point of merging and road markings for merging shall be placed in the transition section.

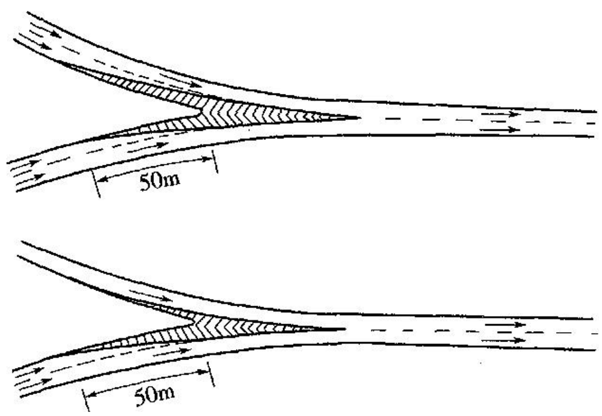


Fig 11.5.4 Lane Reduction before Merging

11.5.5 The spacing of adjacent exits and entrances shall conform to the criteria as follows.

1 On motorways, the distance of various exits and entrances from one to another, as shown in Figure 11.5.5, shall be not shorter than the values in Table 11.5.5.

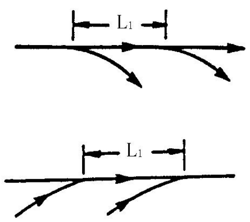
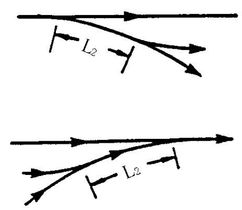
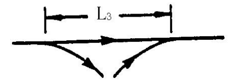
Successive exits or entrances on main route	Successive exits or entrances on ramp	Exit before entrance on main route
		

Fig.11.5.5 Spacing of Accesses

Design Speed on Main Route (km/h)				120	100	80
Spacing (m)	L_1	Normal Value		400	350	310
		Limiting Value		350	300	260
	L_2	Limiting Value	Hub Interchange	240	210	190
			General Interchange	180	160	150
	L_3	Normal Value		200	150	150
		Limiting Value		150	150	120

2 In the case that the spacing between exit/entrance on the main route cannot be ensured or the main route traffic flow is affected by the tight weaving of turning traffic, a collector-distributor ramp, which is separated from the main route, shall be placed to link the exits and entrances.

3 The roadway of a collector-distributor ramp consists of a traveled way and hard shoulder. A separating strip shall be placed between the collector-distributor ramp and the main route.

4 A collector-distributor ramp should have two-lanes. A single lane collector-distributor ramp may be adopted in a non-weaving section with low traffic volume. The width of the right hard shoulder of a collector-distributor ramp should be 2.50m, or may be reduced to 1.0m where the traffic volume on the two-lane ramp is not large or similar to that for a single lane.

5 The connections between collector-distributor ramps and the main route shall be regarded as exits or entrances on the main route, and shall be in compliance with the principle of lane balance. A two-lane ramp with single-lane exit or entrance may be adopted as long as the traffic volumes can be accommodated by single- lane access. The spacing between two successive exits or entrances on a collector-distributor ramp

shall conform to the criteria of the spacing between ramp exits and entrances. The distance from an entrance to the next exit shall accommodate the requirements for weaving.

11.6 The At-grade Junction between an Interchange Ramp and an Intersecting Highway

11.6.1 A channelization design must be conducted for any at-grade junction between an interchange ramp or link road and the intersected highway, which shall conform to the relevant provisions in Chapter 10 of these specifications.

11.6.2 The two at-grade junctions at the ends of ramps in a diamond or partial cloverleaf interchange should be visible from each other. If there is a crest curve between them, the stopping sight distance shall be ensured. The road section between these two at-grade junctions shall be long enough to accommodate two left-turn lanes and should not be provided with pedestrian crossings.

11.7 Grade Separations

11.7.1 Grade separations shall be designed in accordance with factors such as the functions of intersecting highways in the road network, development planning, operational safety, land acquisition, environment, and investment efficiency.

11.7.2 If a grade separation is planned for implementation as an interchange in future, the relevant engineering factors to be used in further development shall be properly arranged in advance in accordance with the principle of phase construction.

11.7.3 Design of grade separation shall conform to the criteria as follows.

1 Horizontal and vertical alignment of the main highway shall be kept uncomplicated, smooth and gentle. The placement of a grade separation must not cause any unreasonable curvature to the horizontal alignment or undue variation to the vertical alignment of either highway.

2 Two highways should intersect at or close to a right angle. The adjacent sections should be on a tangent or large-radius curve with no superelevation.

3 Where grade separation is adopted for a motorway or class-1 highway intersecting with an existing class-2, class-3 or class-4 highway, then the following is required:

1) The alignment and route location of the intersected highway shall be fully utilized. Relocation shall be considered and adopted in the case of a small intersection angle or poor parameters of alignment adopted in original design.

2）The criteria of intersected highway, such as the classification, roadway width, net span clearances of overpass, and vehicular loading shall be determined in accordance with the current requirements or approved planning.

4 Rainwater on the deck surface of an overpass in a grade separation shall be drained through drainage pipes into drainage tranches below and must not fall directly to the road surface beneath. Free drainage should be adopted for the highway section below an overpass.

5 Attention shall be paid to the architectural aesthetics of an overpass bridge. The shape shall be clear, simple and in harmony with the landscape. The span arrangement should provide visual security and fit for purpose.

11.7.4 The intersection mode, either by overpass or by underpass, in a grade separation shall be determined in accordance with the following factors and after comprehensive technical and economic assessment.

1 The combination of horizontal alignment and grade design shall minimize the construction costs, land use, and demolition costs.

2 under unfavorable geotechnical conditions, the main highway, especially a motorway, should pass under the other highway.

3 The highway with at-grade junctions in the vicinity or providing exits or exits to roadside motorists should pass under the grade separation.

4 The highway with the larger traffic volume should pass under the other highway.

5 A new highway should pass over street-like highways.

6 The design shall be in synchronization with terrain and existing development conditions, and in harmony with environment and landscape.

11.7.5 In the case of a main highway or motorway passing over other highways, the design shall conform to the criteria as follows.

1 The spans and span arrangement of an overpass must satisfy the requirements of an intersected highway, including the highway clearance profile, sight distance, and inter-visibility.

2 Thepier of an overpass bridge must not be placed in the middle or between opposite traffic lanes of a two-way two-lane highway beneath the overpass.

3 Where a pier of the overpass bridge is placed in the median of a multilane highway beneath, collision barriers with buffer spacing must be provided on both sides of the mid-pier. If a pier of the overpass bridge has to be placed on the underpass roadway with no median, such an underpass roadway section must be reconstructed to provide a median strip with sufficient length adjacent to the mid-pier, and sufficient width for collision barriers and buffer spacing on both sides of the mid-pier.

4 An overpass bridge must not restrict any part of the roadway cross-section beneath, or the spacing reserved for existing canals, telecom conduits and so on. Furthermore, sufficient space allowance shall also be provided.

5 If phased implementation is adopted for grade separation or intersected highways, the overpass bridges shall be constructed from the outset as planned.

11.7.6 In the case of a main highway or motorway passing under another highway, the design shall conform to the criteria as follows.

1 The alignment and location of an intersected highway shall be fully utilized. Relocation shall be considered and adopted in the case of small intersection angle or poor parameters of alignment adopted in the original design of the intersected highway.

2 The criteria of intersected highway, such as roadway width, net span clearances of overpass and vehicular loading, shall be determined in accordance with current status or approved plans.

3 The span and span arrangement of an overpass must satisfy the requirements of the main highway or motorway, including the highway clearance profile, sight distances and identification ahead of the highway and visibility. The main span should cross over

the whole cross-section of the main highway and side spans with proper lengths shall be arranged beside the main span.

4 Where an overpass bridge pier is placed in the roadway of a main highway or 4-lane motorway with wide median or other multilane motorway, collision barriers must be installed with sufficient buffer spacing on both sides of the pier. Partially changing the median width thus curving the roadway is not allowed.

5If there are outer-separation strips installed on the underpass roadways of a main highway or motorway beneath the overpass bridge, the mid-piers of an overpass bridge may be placed in the outer-separation strips. In case of insufficient width, the outer-separation strips shall be widened over a distance before and after the mid-pier and widening transitions shall be provided on the right side of the outer-separation strip.

6 If there is an exit, entrance or at-grade junction after an overpass bridge, additional side spans shall be provided for drivers to see through; or truck stopping sight distance shall be ensured where the main highway or motorway in on a curve.

7 Where an overpass bridge crosses over a road cutting, the bridge abutments shall be placed in the positions behind the top edge of the side slopes if the cutting is not very deep; or at or near the top edge of the side slopes if the cutting is deep or the side slope is gentle and long. The overpass abutments must not be placed at the toe of the side slope.

8 Where the main highway is a motorway,

1) Collision barriers and protecting nets must be placed on both sides of an overpass bridge.

2) Where overhead traffic signs are placed on the side of an overpass bridge, they shall not be over the full length above the traveled way of the highway beneath. The height of these signs shall not exceed the top edge of the barriers and the bottom edge of the side beam of the overpass bridge.

12 RAILWAY, FARMROAD AND PIPELINE CROSSINGS

12.1 General

12.1.1 The design of a highway-railway crossing is applicable where a highway crosses a standard gauge (1,435mm) railway.

12.1.2 The mode of a highway-railway crossing shall be determined in accordance with the classifications, traffic volumes (annual volumes of both passenger and cargo transportation), and other factors such as safety and economics. Usually, a grade separation is preferred.

12.1.3 A highway-railway crossing shall conform to the design lives of the railway and the highway in the crossing. For projects being planned, the space and conditions shall be reserved based on the approved plan for further development.

12.1.4 The provisions for highway-farm road crossings applicable to the design of junctions where classified highways cross various roads and streets in villages and farmlands for farmers and their farming vehicles to pass through.

12.1.5 Provisions for highway-pipeline crossings are applicable to the design of crossings where classified highways cross10,000kV and lower overhead electrical power lines, and inland oil or gas pipelines in terms of intersection angles, clearances, etc.

12.1.6 Optimization shall be conducted for the design of facility crossings based on the engineering characteristics of each facility, to identify the most favorable location, mode and structure for the proposed crossings.

12.1.7 Facility crossings shall follow highway functions and highway operational requirements, coordinate the interfaces with railroads, farmroads, power transmission, oil and gas transportation, and deal with the conflicts and problems caused by construction or upgrading works.

12.2 Grade-separated Highway-Railway Crossing

12.2.1 Where a highway crosses a railway, grade-separation crossing shall be selected as apriority for a new highway or railway project.

12.2.2 A motorway or class-1 highway must cross railways by grade separations.

12.2.3 A high-speed railway, intercity railway, or railway for passenger trains with design running speed higher than or equal to 140km/h must cross highways at grade separation.

12.2.4 A grade separation shall be placed for one of the following circumstance:

1 Where a Class I railway crosses highways;

2 Where a railway section for which the design running speed of passenger trains is higher than or equal to 120km/h crosses a highway;

3 Where a railway crosses a class-2 highway;

4 Where a railway shunting operation may seriously delay the vehicles on a highway;

5 Where due to terrain restrictions, an at-grade crossing, if so adopted, would endanger the safety of vehicles on the highway;

6. Where the condition of terrain or structural works are advantageous to adopt a grade separation for the highway-railway crossing.

12.2.5 The horizontal and vertical alignment of a highway-railway crossing shall conform to the requirements as follows:

1. A highway-railway grade separation should be located where both highway and railway are on tangents or on the curves with good horizontal and vertical alignments and with good visibility.

2 A highway-railway grade separation should be at right angle. If a skew intersection has to be adopted due to the constraints of terrain or other conditions, the skewed intersection angle should be as large as possible.

3 For a motorway orclass-1 highway crossing a railway, besides the railway requirements on the placement of overpass bridges, the location of the grade separation shall conform to the overall layout of the highway alignments to keep it continuous, uniform, and smooth. None of the technical criteria in this section shall be reduced.

4 For the upgrading of an existing highway-railway grade separation, the highway classification and the location of the crossing shall be determined in accordance with highway network plan. Where highway relocation is required for improving the intersection angle or moving the crossing location, the horizontal and vertical geometry

of the highway section must not be lower than the normal values of the adjacent highway sections. Limiting values are not to be used.

5 No highway at-grade junction shall be placed on the highway approach section to a highway-railway grade separation.

6 The requirements for sight distances at a highway-railway grade separation: motorways and class-1 highways shall provide stopping sight distance; class-2, class-3 and class-4 highways shall provide passing sight distance.

12.2.6 Where a highway passes over a railway, the design shall conform to the criteria as follows.

1 The span and clear height of highway overpass must conform to the specified structure gauges for 1,435mm standard gauge railway.

2 The spans and span arrangement of a highway overpass shall be determined in accordance with terrain, geology, clearance beneath bridge, drainage system of the railway, and layout of a pipeline along the railway.

3 Where a highway crosses over an electrified railway, the highway overpass bridge shall be such that it will neither interrupt electrical power transmission during construction nor negatively affect the safety of highway construction and railway operation.

4 The drainage system of highway overpass and its approaches shall be independent and comprehensive. The rainwater on the bridge deck must not directly drain onto the railway track beneath.

5 Where a four-lane or more than four lane highway crosses over a railway, the horizontal curves, gradients, skew angle and superelevation of the highway and the railway shall be taken into account, and the structure gauges at four extreme points of the highway overpass bridge shall be checked for size.

6 Collision barriers and netting to catch falling objects shall be installed on a highway overpass bridge crossing over railway.

12.2.7 Design of railway overpass bridges crossing over highways shall conform to the criteria as follows.

1 The spans and clear heights of a railway overpass bridge must conform to the specified highway clearance profiles.

2 It is forbidden to place any piers of a railway overpass bridge on the traveled way of a class-2, class-3 or class-4 highway. None of the piers of a railway overpass bridge must be placed in the median of a four-lane motorway or class-1 highway. Where any of the piers of a railway overpass bridge has to be placed in the median of a six-lane motorway or class-1 highway, barriers must be installed on both sides of the pier with sufficient safety spacing for collision buffering.

3 The span of a railway overpass bridge that crosses over a highway shall include the width of the standard traveled way and the widths of auxiliary speed-change lanes, climbing lanes, and side drains.

4 The spans and span arrangement of a railway overpass bridge shall provide sufficient lateral clearance allowances, must not placethe piers or abutments in highway side drains or drainage trenches, and accommodate highway sight clearance and the requirements for service road identification. Side spans shall be added where the sight distance on the underpass roadway is insufficient.

5 Protection netting against falling objects shall be installed on railway overpass bridges crossing over highways.

6 The drainage system of a railway overpass bridge and its approaches shall be independent and appropriate. Rainwater on the railway bridge deck must not drain directly onto the highway clearance profile beneath.

12.3 Highway-Railway At-grade Crossings

12.3.1 The intersection of a railway crossing a highway at-grade should be at right angles. Where a skew intersection is unavoidable, the intersection angle shall be greater than 45^{o}.

12.3.2 A railway at-grade crossing shall be placed where corner sight distance is greater than the value specified in Table 12.3.2 and conform to the requirements as follows.

Table 12.3.2 Vehicles'Corner Sight Distance

Design Speed of Passenger Train at Crossing (km/h)	120	100	80
Vehicle's Corner Sight Distance (m)	400	340	270

1 A railway at-grade crossing must not be placed in vicinity of a rail yard, rail track switch, bridge approach, tunnel portal, and any railway section available for shunting operation.

2 A flagman must be assigned at the railway at-grade crossing where the corner sight distance is less than the value specified in Table 12.3.2 due to terrain or other restrictions. Corner sight distance is defined as the distance in either direction of the rail track that a motorist can see from his vehicle stopped 5 m before the near rail.

12.3.3 The railway sections along both sides of a highway-railway at-grade crossing should be on tangent alignment. The highway sections approaching the highway-railway at-grade crossing should be on tangent alignment, of which the tangent length from the nearest rail on either side of the highway-railway at-grade crossing shall not be less than 50 meters.

12.3.4 The length of a level section (excluding vertical alignment) from the nearest rail on either side of a highway-railway at-grade crossing shall not be less than 16m for a classified highway and not be less than 10m for a farm road. The grade of the road section adjacent to the level section shall not be greater than 3%; or not be greater than 5% in difficult terrain or other special conditions. The downgrade of the road section on which there are heavy trucks approaching to the level section of a highway-railway crossing shall not be greater than 3%.

12.3.5 A highway-railway at-grade crossing shall be paved with a stone pitched layer that should be durable, flat, stable and easy to replace. The length of the stone pitching shall be extended 2.0m from the nearest rails on either side of the at-grade crossing. This is followed by a further length of asphalt or cement concrete paved section up to 20m away from the nearest rails on each side of the at-grade crossing. The width of a railway crossing surface and its highway approaches on both sides shall not be less than the width of roadway of the intersecting highway.

12.4 Highway-Farm Road Crossings

12.4.1 The design of highway-farmroad crossings shall be included in an overall design of highway junctions and crossings for integrated planning and overall layout. The modes, locations, and spacing of highway-farm road crossings shall be determined in accordance with the demands for farming equipment in the overall land utilization plansof the county or village where the crossingsare located. However,the existing and planned farmroads and field tracks shall be properly regulated and combined where feasible.

12.4.2 The placing of highway-farm road crossings shall conform to the requirements as follows.

1 Grade separations, either overpasses or underpasses, must be used where a motorway crosses a farm road.

2 Grade separations, either overpasses or underpasses, should be used where a Class-1 highway crosses a farm road.

3 An at-grade crossing shall be used where a class-2， class-3 or class-4 highway crosses a farm road. Alternatively, grade separation, either underpass or overpass, may be used where the terrain is favorable and the traffic volume on the main route is large.

4 A farmroad shall be upgraded to the standards of a class-4 highway for a given length before and after it crosses a class-2, class-3 or class-4 highway.

5 Pedestrian overpasses or underpasses should be placed at sections of a motorway, class-1 highway or class-2 highway in densely populated areas or in the vicinity of schools.

12.4.3 At highway-farm road crossings, relocation of the farm road shall be designed for one of the following circumstances, for which the horizontal and vertical geometry after relocation shall not be lower than that of class-4 highways.

1 Where the intersection angle is at an acute angle less than 60^{o}.

2 Where the crossings have been combined or the location of the crossing is shifted in accordance with local land planning or the overall design of junctions and crossings.

3 Where the terrain, geology, sight distances, or the horizontal alignment of the existing farm road at the proposed location is not suitable for placing a crossing.

4 The construction volume would be significantly increased if redesign or reconstruction of the existing at-grade crossing takes place.

12.4.4 An underpass design shall conform to the following criteria.

1 The spacing of underpasses should be 400 m, but may be increased in highly mechanized farming areas or sparsely populated areas.

2 The intersection angle of an underpass should be 90°. Where a skew underpass is inevitable, the acute angle shall not be smaller than 60°. Where constrained by terrain or other conditions, the skew angle shall not be smaller than 45°.

3 The horizontal alignment of an underpass farm road should be on a tangent, and the length of such a tangent on each side of the crossing shall not be less than 20 m.

4 The vertical alignment of an underpass farm road should be at tangent grade not less than 3%. An underpass tunnel must not be placed at the bottom of a sag vertical curve. Free flow drainage shall be adopted for underpass structures.

5 The minimum clear height shall comply with the values given in Table 12.4.4 and may be increased if necessary.

Table 12.4.4 Clearance of Underpass

Clear Height	For farm tractors and animal drawn carts	⩾2.70m
	For farmtrucks	⩾3.20m
Clear Width	To be selected according to traffic flow and type of farming equipment	⩾4.00m
	For extra-long underpass or irrigation canal crossing	May be extended depending on the situation

12.4.5 Design of an overpass bridge shall conform to the criteria as follows.

1 Overpass bridges may be placed in sections in cut or other favorable terrain. The intersection angles should be at right angle, the clear widths should not be less than 4.50 meters and the other technical parameters may follow the criteria for class-4 highways.

2 Lane loading of an overpass bridge shall not be lower than Highway-II vehicular loading. Loading limit signs shall be placed at the overpass bridge.

3 Collision barriers and netting for falling objects shall be placed on the overpass farm road bridges crossing over motorways and class-1 highways.

4 Rainwater on an overpass bridge deck must not directly drain onto the highway surface beneath.

12.4.6 The design of a pedestrian underpass shall conform to the criteria as follows.

1 The clear height of a pedestrian underpass shall not be less than 2.20m, the clear width shall not less than 4.00m.

2 Where a pedestrian footpath underpasses a motorway or class-1 highway, illumination shafts shall be placed in the median strip.

3 In addition to steps, slope ramps may be placed and the gradient shall not be steeper than 1:8.

4 Drainage for a pedestrian underpass must be properly designed to ensure the passage free from standing water.

12.4.7 Design of a pedestrian overpass bridge shall conform to the criteria as follows.

1 The clear width of a pedestrian overpass bridge shall not be less than 3.00m.

2 Pedestrian loading shall not be less than $3kN/m^2$ in general, and not be less than $3.5kN/m^2$ in densely populated areas.

3 In addition to steps, slope ramps shall be placed where possible with a gradient less than 1:4.

4 Protection netting against falling objects shall be placed on pedestrian overpass bridges crossing over motorways and class-1 highways.

12.4.8 The design of an at-grade crossing shall conform to the criteria as follows.

1 Intersection of an at-grade crossing should be at right angles. Where a skew intersection is inevitable, the acute intersection angle shall not be smaller than 70^{o}; or 60^{o} where constrained by terrain or other special conditions.

2 The farm road sections approaching a highway-farm road crossing shall be on a tangent with a length not less than 20m on either side of the crossing.

3 The farm road sections approaching an at-grade crossing shall be in level terrain or gentle grade with a length not less than 10 meters on each side of the crossing. The gradient of such a level or gentle grade section shall not be greater than 2%, while the gradient of the approaches to the level or gentle sections shall not be greater than 3% under normal conditions, or 6% in difficult conditions.

4 The drivers on the farmroad approaching an at-grade crossing shall be able to identify any vehicles 20m before the crossing, in either direction along the crossing highway, over a distance greater than the stopping distance for a class-2 or class-3 highway and not shorter than50m.

5 Where farm machines with crawler tracks frequently use the crossing, the pavement shall be reinforced over a length including full roadway width of the highway at the at-grade crossing and a 10m long section on either side of the highway.

12.5 Highway-Cable Line and Highway-Pipeline Crossing

12.5.1 Overhead electrical transmission lines should cross a highway at right angles. Where a skew crossing is inevitable, the acute angle shall be larger than 45^{o}.

12.5.2 Where overhead electricity-transmission lines cross over a highway, the minimum vertical distance between the lines and the highway surface must not be less than the values specified in Table 12.5.2.

Table 12.5.2 Minimum Vertical Distance from Overhead Electrical Lines to the Surface of Highway beneath

Nominal Voltage of Overhead Electrical Line (kV)	35～110	154～220	330	500	750	1000		±800 ±800 DC
						Single circuit	Double circuit in reverse phase sequence	
Min. Vertical Distance to Highway Surface beneath (m)	7.0	8.0	9.0	14.0	19.5	27.0	25.0	21.5

12.5.3 The vertical distance from the overhead electrical power transmission lines to the surface of highway beneath shall be determined in accordance with the maximum sag and the maximum wind swing. The maximum sag refers to that either under the condition of the operating temperature of the electrical lines or the condition of ice covered and no wind, whichever is greater; the maximum wind swing refers to that under conditions of maximum wind speed or maximum ice covering, whichever is greater.

12.5.4 Where overhead electrical power transmission lines cross over or are parallel to a highway, the distance between electrical line posts and highway side drain shall conform to the criteria in Table 12.5.4.

Table 12.5.4 Distance from Overhead Electrical Line Post (Tower) to Highway Side Drain

Nominal Voltage (kV)		35～110	220	330	500	750	1000	±800 DC
Crossing over(m)		8				10	15	15
Parallel	Open Area (m)	Max. Height of a Post (Tower)						
	Confined Area (m)	5	5	6	8 Motorway 15	10 Motorway 20	Single circuit 15 Double circuit 13	12

Note: The value for 1,000kV or ±800kV DC electrical lines parallel to a highway is the horizontal distance from the nearest post to the outer edge of the highway side drain.

12.5.5 The intersection of a highway crossing an oil or gas pipeline should be at right angles. Where a skew intersection is inevitable, the acute angle should not be smaller than 30^{o}.

12.5.6 Underpassing facilities such as tunnels, culverts, or conduits shall be placed foroil or gas transmission pipes crossing classified highways.

12.5.7 Subject to the relevant industrial standards and specifications, the overburden depth above an underpass passage shall conform tothe prevailing *JTG D60General Specifications for Design of Highway Bridges and Culverts*, calculated and verified for the vehicle loading of the highway passing over. The depth from the top of a conduit to the bottom of highway subbase shall not be less than 1.0m.

12.5.8 The pipelines for toxic, flammable, explosive, high pressure substances, and high voltage electrical power transmission cables are strictly prohibited on highway bridges crossing a river. The river crossing of such a pipeline shall be at least a distance of 100 meters awayfrom any extra-large, large or medium highway bridge; or at least 50 m away from any small highway bridge.

12.5.9 The pipelines of toxic, flammable, explosive, high pressure substances, or high voltage electrical power transmission cables are strictly prohibited in a highway tunnel.

12.5.10 All and any pipelines crossing over a highway must not intrude into the highway clearance profile, must not interfere with highway traffic safety, must not damage any highway facilities, and must not endanger the highway and highway facilities.

13HIGHWAY ROADSIDE FACILITIES

13.1 General

13.1.1 Roadside facilities and the accesses to and from them shall be located in accordance with the overall design of the highway and service functions of the facilities at locations that accommodate preferred alignment parameters of the main route, satisfactory visibility and adequate distances to nearby interchanges, tunnels or extra-large bridges.

13.1.2 The scope of a roadside facility shall be determined by a wide-ranging evaluation of the highway functions, service functions of the roadside facility, and traffic volumes. Adequate spacing shall be kept between roadside facilities and interchanges, tunnels, super-large bridges or other special structural works.

13.1.3 The geometric design of roadside facilities such as toll plazas, service areas, rest areas, bus bays, and U-turns shall be properly designed in accordance with the relevant provisions of this Chapter of the Specifications.

13.2 Toll Station

13.2.1 The geometry of a toll plaza shall meet the following requirements:

1 Toll plaza on main route: the parameters of horizontal curves shall conform to the requirements for the main route at an interchange. The parameters of vertical curves shall not be less than the normal values specified in Table 8.6.1 *Minimum Radius and Length of Vertical Curve*. The gradient of a road section over at least100m before and after the centerline of the toll plaza shall not be greater than 2%.

2 Toll plaza on ramp: the radius of a horizontal curve shall be greater than 200m, while the radius of a vertical curve shall be greater than 800m. The gradient of a road section over a distance greater than 100m each before and after the centerline of toll plaza should not be greater than 2%; or shall not be greater than 3% in difficult conditions.

3 The cross-slope of a toll plaza should be 1.5%, or may be 2.0% if required for drainage purpose.

13.2.2 Design of a toll plaza shall conform to the requirements as follows.

1 No toll plaza shall be placed at the bottom of a vertical sag curve.

2 The layout of a toll plaza is shown in Figure 13.2.2-1.The lengths of concrete pavement before and after tollbooths, L_o, shall conform to the criteria in Table 13.2.2-1.

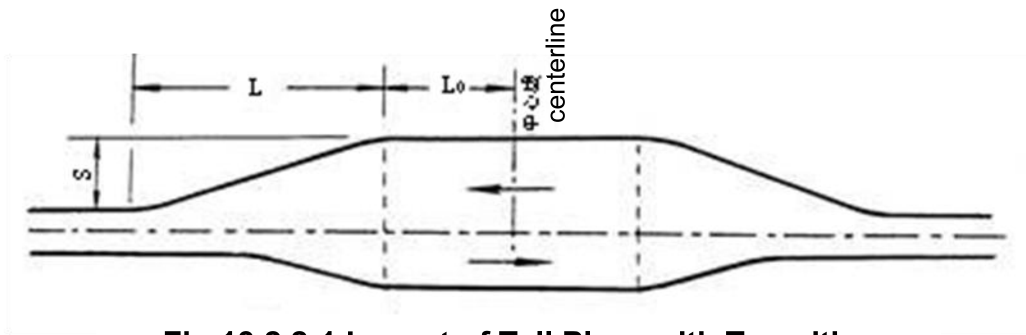


Fig.13.2.2-1 Layout of Toll Plaza with Transition Sections

Table 13.2.2-1MinimumLength of Concrete Pavement either before or after Toll Booth

Location of Toll Plaza		On ramp	On main route
Tolling Mode	One-way	30	50
	Two-way	25	40

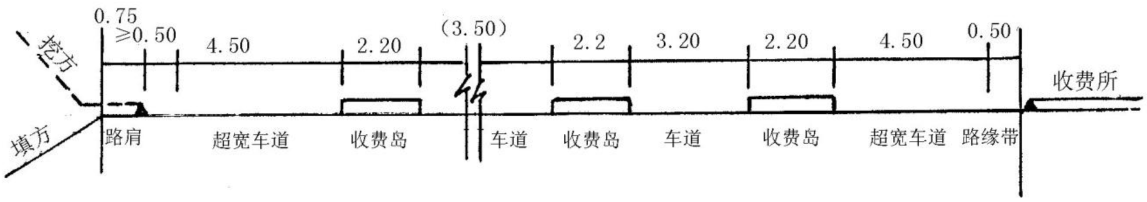
3 The transition sections at both ends of a toll plaza shall conform to the criteria in Table 13.2.2-2.

Table 13.2.2-2 Rate of Width Transitions of Roadway at Both Ends of Toll Plaza

Location of Toll Plaza	On ramp	On main route
Rate of Width Transition of Roadway (L/S)	**4～6, limiting value 3**	**6～8**

4 Toll plaza on ramp: the distance from the centerline of toll plaza to the splitting point of the ramp should normally not be less than 100m or 75m as a minimum. The distance from the centerline of toll plaza to the at-grade junction on the intersected highway should not be less than 150m. Otherwise, a waiting lane should be placed.

5 The roadway of a toll plaza shall include toll lanes, toll islands, and shoulders (or marginal strips). The width of a toll lane at a tollbooth should be 3.2 m, that of an ETC lane shall be 3.5 m, and that of the lane for over-wide vehicles should be 4.5 m. The width of a toll island should be 2.2 m. The width of a hard shoulder shall not be less than 0.5 m. The typical roadway cross-section of a toll plaza is shown in Figure 13.2.2-2



挖方 In cut							
填方 In fill	露肩 shoulder	超宽车道 Over-wide lane	收费岛 Toll booth island	车道 ETC Through lane		路缘带 Marginal strip	收费所 Toll admin. office

Fig.13.2.2-2 Roadway Cross-section at Centerline of toll plaza

13.3 Service Areas and Rest Areas

13.3.1 The spacing of service areas and rest areas shall conform to the criteria as follows.

1 The spacing ofservice areas should be 50 km. The distance from one rest area to the next rest area or service area should be 15km to 25km.

2 The spacing between a service area or rest area and an interchange or tunnel should be greater than 2km; or may be determined by referring to the relevant requirements for interchange spacing in places constrained by terrain or other conditions,

13.3.2 The alignment parameters of the main highway route near a service area shall conform to the requirements for the main route alignment for interchanges. The stopping sight distance shall conform to the criteria in Table 13.3.2.

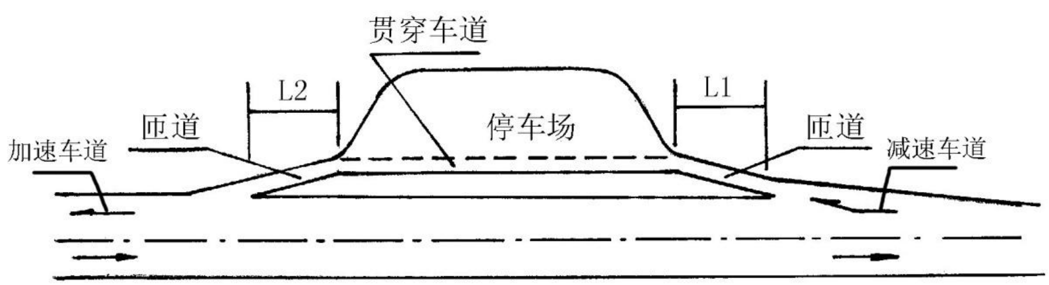
Table 13.3.2 Criteria for Main Route Alignment at a Service Area

Design Speed（km/h）		120	100	80	60
Min. Radius of Circular Curve（m）	Normal value	1500	1000	700	500
	Limiting value	1200	850	600	400
Min. Radius of Crest Vertical Curve（m）	Normal value	45000	25000	12000	6000
	Limiting value	23000	15000	6000	3000
Min. Radius of Sag Vertical Curve（m）	Normal value	16000	12000	8000	4000
	Limiting value	12000	8000	4000	2000
Max. Grade（%）	Normal value	2	3	4	4.5
	Limiting value	3	4	5	5.5

Note: Grades steeper than the normal values above should be used in normal circumstances, and the limiting values may be adopted in special circumstances.

13.3.3 Overall layout of a service area or rest area shall conform to the criteria as follows.

1 The layout of a service area or rest area shall include acceleration lanes, deceleration lanes, connecting ramps, passing through lanes and parking lots, as shown in Fig.13.3.3.



加速车道 Acceleration lanes	匝道 ramp	贯穿车道 Passing through lanes	停车场 Parking lots	匝道 ramp	减速车道 Deceleration lanes

Fig. 13.3.3 Layout of a service or rest area

2 Design speeds of the ramps at a service area or rest area should be 40km/h in general, and shall not be lower than 30km/h in difficult conditions.

3 The length of a connecting ramp in a service area or rest area shall conform to the criteria in Table 13.3.3.

Table 13.3.3

Design Speed of Main Route (km/h)	120	100	≤80

Deceleration side lanes L_1 (m)	Normal Value	110	90	80
	Limiting value	80	70	60
Acceleration side lanes L_1 (m)	Normal Value	80	70	60
	Limiting value	60	60	60

4 The geometric design of ramps and speed-change lanes shall conform to the relevant requirements for interchanges.

5 The geometric design of a passing-through ramp shall conform to the criteria as follows.

1) Design speed of a passing-through ramp should be 30km/h.

2) The roadway of a passing-through ramp shall be one-way, single-lane ramp, with a width of the traveled way of 3.5m, while the left and right marginal strips are 0.50 m respectively.

3) The elevations of parking lots and the needs for drainage shall be taken into account in the profile design of a passing-through ramp.

13.3.4 For the service areas, rest areas, and scenic overlooks along a class-2 highway, either a typical layout or a simplified layout may be adopted in accordance with their functions, traffic volumes, site conditions and so forth. Typical layout is to place exit and entrance ramps, deceleration and acceleration lanes, while simplified layout is a widening of the roadway of the main route with no separate ramps. A simplified layout of a service area, rest area or a scenic overlook shall conform to the requirements as follows.

1 The grade of the main route section near a simplified service area, rest area or scenic overlook shall not be steeper than 2.5%. A side separating strip or road markings shall be provided between the main route and the parking lot.

2 A deceleration section and an acceleration section with the same length shall be placed before and after the parking lot. The layout of these sections shall refer to Figure 13.4.4 for a bus bay while their length shall be determined based on the width of the separating strip and the transition rates given in Table 13.4.4.

3 The length of a parking lot along main route should be greater than 30 m.

13.4 Transit Bus Bays

13.4.1 No transit bus bays shall be placed on the main route of motorways.

13.4.2 The maximum grade of the main route section at which a bus bay is located shall not be greater than 2% in general, and shall not be greater than 3% in difficult terrain. The horizontal and vertical curves of the main route shall conform to the criteria in Table

Table 13.4.2 Alignment Criteria of Main Route at Bus Bays

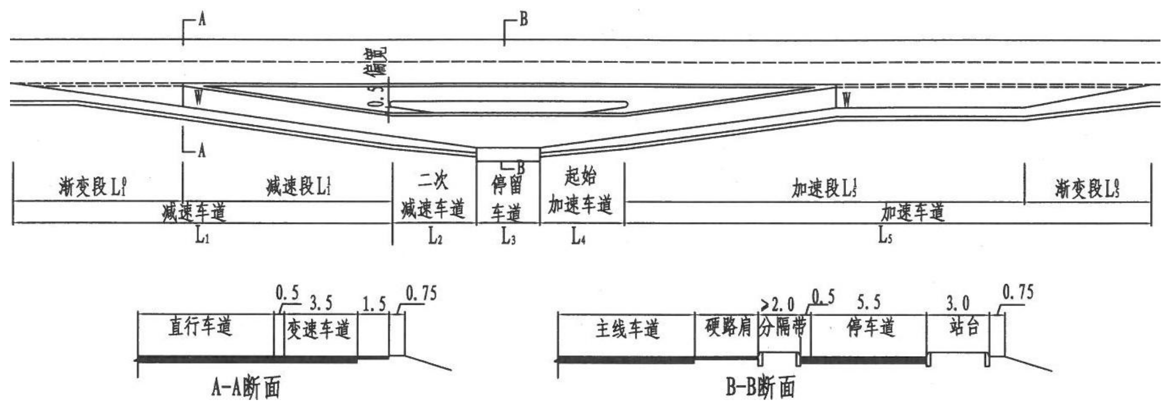
Design Speed (km/h)	100	80	60	≤40
Min. Radius of Circular Curve (m)	800	500	250	150
Min. Radius of Crest Vertical Curve (m)	10000	4500	2000	1000
Min. Radius of Sag Vertical Curve (m)	4500	3000	1500	1000

13.4.3 The layout of a transit bus bay at the roadside of the main route of a class-1 highway shall include tapered sections, acceleration (deceleration) lanes, and the stop bay, as shown in Figure 13.4.3, and shall conform to the criteria as follows.

1 The bus bay and the right hard shoulder of the main route must be separatedfrom each other by an outer separation or a roadside barrier.

2 The length of a speed-change lane and itstapered section,and the length of a bus stop shall not be less than the criteria in Table 13.4.3.

3 The width of an outer separation shall not be narrower than 2.0m, the width of a right hard shoulder shall be 1.5m, the width of a bus stop shall not be narrower than 5.50m, and the width of the bus platform shall be 3.0m.



偏宽 Offset width						
渐变段 Taper	减速段 deceleration	二次减速车道 Second deceleration	停留车道 Bus stop	起始加速车道 Initial acceleration	加速段 Acceleration	渐变段 Taper
减速车道 Deceleration lane					加速车道 Acceleration lane	

直行车道 Through lane	变速车道 Speed-change lane	主线车道 Through lanes	硬路肩 Hard shoulder	分隔带 Separating strip	停车道 Bus stop	站台 Platform
A-A 断面 Section A-A		B-B 断面 Section B-B				

Fig. 13.4.3 Transit Bus Bay on Class-1 Highway

13.4.4 Roadside transit bus bays on the main route of a Class-2, Class-3 or Class-4 highway shall include the sections of acceleration (deceleration) and the bus stop, as shown in Fig.13.4.4 and shall conform to the criteria as follows.

1 A bus stop shall be separated by road markings from the through lanes of the main route.

2 A speed-change lane shall be placed before and after the transit bus stop with its length in compliance with the criteria in Table 13.4.4.

3 The length of a bus bay is 15 meters.

4 The widths of a marginal strip (road marking) of the through lane at the edge, the bus

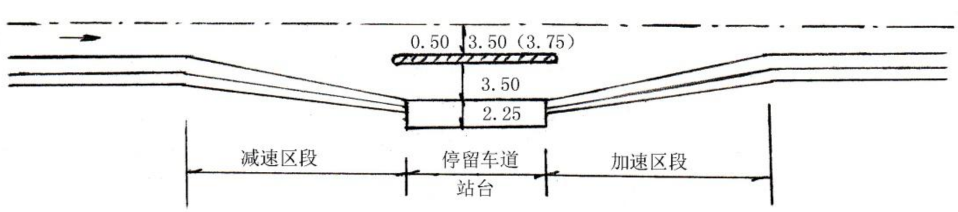
Table 13.4.3 Length of Speed-change Lanes and Bus Bay on Class-1 Highway

Design Speed of Main Route (km/h)		100	80	60
Length of deceleration Lane L_1	Tapered length L_1^0	70	70	70
	Deceleration section L_1^1 (m)	100	90	70
Second deceleration lane L_2 （m）		50	50	40
Length of Bus Bay L_3 （m）		30	30	20
Initial acceleration lane L_4 （m）		40	40	30
Length of acceleration lane L_5	Acceleration section L_5^1 （m）	130	110	80
	Tapered section L_5^0 （m）	65	60	50

Table 13.4.4 Tapered Section of Speed-change Lane for Class-2 or lower Highways

Design Speed of Main Route (km/h)	80	60	40	30	20
Transition Rate	1/15	1/12.5	1/10	1/7.5	1/5
Length of Acceleration (Deceleration) lane	60	50	40	30	20

bay and the awaiting platform are 0.5m, 3.5m, and 2.25m respectively.



减速区段 Deceleration	停留车道 Bus stop	加速区段 Acceleration

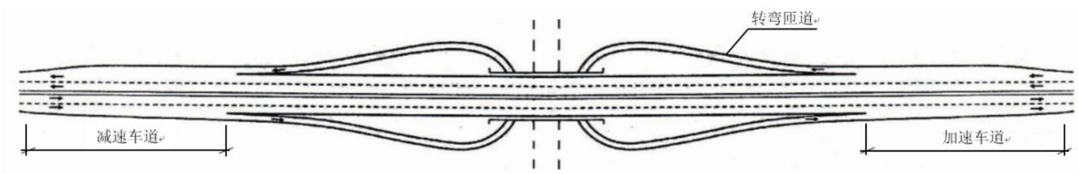
section		section
	站台 platform	

Fig. 13.4.4 Bus Bay on a class-2, class-3 or class-4 Highway

13.5 U-turns on Motorways

13.5.1 U-turns shall be provided where the spacing of interchanges is greater than 30km or in desert, steppe, or other sparsely populated areas.

13.5.2 A U-turn should be provided for both traffic directions with aconfiguration ofacceleration and deceleration lanes and U-shaped turning ramps, as shown in Figure 13.5.2.



减速车道 Deceleration lane	转弯匝道 turning ramp	加速车道 Acceleration lane

Fig.13.5.2 Layout of U-Turn

13.5.3 U-turns shall be placed by taking advantage of bridges on the main route, or by building a U-shaped flyover or an underpass tunnel according to the needs.

13.5.4 The design of the U-turn accesses to and from main route and the acceleration and deceleration lanes shall conform to the relevant provisions on interchanges. Design speeds of U-turn ramps should not be lower than 20km/h.

13.5.5 The ramps of a U-turn should be one-way, single-lane with a right hard shoulder 1.50m wide. The roadway width of a U-turn ramp is 7.50m.

Background to Provisions

1 GENERAL PROVISIONS

1.0.2 The scope of application of these specifications, as defined by *Technical Standards for Highway Engineering (JTG B01-2014)* (hereinafter referred to as JTG B01-2014), covers the design of highways to be newly built or those to be upgraded or reconstructed.

According to the nationwide survey and the instructions of the highway administration of the Ministry of Transport, this edition of the Specifications for Highway Geometric Design follows previous editions and primarily addresses the geometric design of highways. In the process other design specifications such as those for bridges, tunnels and traffic engineering are considered, and furthermore guided by the perspective that 'geometry is the key to highway design'. This edition embodies and emphasizes the requirements for substantial coordination of the overall design with related engineering activities, and adds the section on 'highway roadside facilities' to match the main works so as to encompass a comprehensive engineering system of a highway project and to serve the holistic objectives for safety, environmental protection and sustainable development.

1.0.3 At the present time the national highway network has been substantially constructed. The focus of highway development in China is shifting from new construction to maintaining and improving the network to provide t*wo coexisting and mutually complementary highway systems* (that is, a toll highway system and a non-toll highway system). JTG B01-2014 emphasizes the principle that the technical classification shall be determined by highway function while the decisive role of traffic volume in determining highway technical criteria need to be gradually changed. Designers shall first verify the highway function, based on which technical classification shall be determined, and followed by major technical criteria to be selected in accordance with traffic volumes, terrain and other factors.

1.0.4 In this edition, the concept of highway overall design has been extended from the previous 'design of highway geometry' to 'design of highway project', which covers the design of the highway route and includes all technical considerations related to highway survey and design, or those aspects that need to be considered but are not covered in the relevant technical specifications.

1.0.5 Route corridor selection involves utilization of land that is not a regenerating resource. It shall be carefully planned with systematic layout, considering long-term and short-term requirements and implemented for sustainable development. Highway route positioning in the highway corridor shall be determined based on thorough investigations and studies conducted during the project feasibility study. During the route design stage, the connections and links between the highway and other transportation modes shall be identified and planned as early as possible. Furthermore, the connections between the new works and the existing works shall be properly planned and programmed. In determining the highway classification, the designer shall deal with the relationship of the highway to the other works in such a way that it shall be based on the proposed highway function considering regional development and provide allowance for anticipated needs and demands in future so that the highway corridor can be utilized effectively.

1.0.6 Highway route is the core of geometric design. An overall design shall examine various design speeds and their impact on the local environment. If there are several options available, a comparison and assessment of the details shall be conducted individually and collectively.

1.0.7 Investigation of the geotechnical environment and other natural conditions are critically important for determining the highway route location, which considers the major horizontal and vertical geometrics to be selected.

Regional characteristics of climate shall also include 'local climate along the route', i.e. the foggy areas, wind corridor, and storm center, etc.

1.0.8 Environment protection and effective utilization of land are important national policies. The impact of highway projects on the environment and natural landscaping shall be minimized. Environmental quality along highways shall be ensured and continuously improved. The design of motorway or class-1 highways shall pay special attention to visual guidance of alignment, alignment continuity and harmonization with the local environment so as to increase driving comfort and safety.

1.0.9 Most of individual indicators for alignment design are the minimum values specified for the design speed of the corresponding classified highways. The overall design, after taking various factors into account, shall conform to the provisions in Chapter 9, *Alignment Design*. Optimization shall be applied in alignment design in accordance with the site conditions such as terrain, geology, technical difficulties and construction quantities. A good design does not mean a simple adherence to all parameters as specified in the specifications. In fact, using the lower limit values of design parameters does not necessarily mean a saving of project size or cost, which a comprehensive and creative combination of various design parameters will. The quality of a design primarily depends on the appropriateness to environmental conditions, the matching of indicated design combinations and effective solutions to specific issues.

A highway is a belt-shaped three-dimensional object. As a result of technical developments, the approaches to simulation modeling of highway operation and environment, based on operational speeds, 3-D modeling and driving simulation may be applied to the examination, analysis and assessment on highway alignment design.

1.0.10 The highway traffic safety assessment based on operating speed has been gradually introduced in China since the methodology of checking by operating speed and traffic safety assessment were included in *JTG B01-2003* and in The 2006 edition of these specifications, and especially after *the Guidelines to Assessment of Highway Development Project Safety* came into force in 2004. By using the operational speed assessment system, the practice suggests that it is crucial to optimize highway geometric design, traffic engineering facilities and safety measures since safety hazards or problems in highway design, implementation and operation could be efficiently detected and identified at an early stage.

The traffic safety assessments mentioned in this clause refer to the activities carried out by the designers or a third party in accordance with prevailing *Specifications of Safety Assessment for Highway Project (JTG B05)* to analyze and assess highway geometric design, relevant specialist designs and their coordination. The design of a highway shall be optimized based on safety assessment and appropriate safety facilities will be provided accordingly.

1.0.11 A phased implementation program refers to a holistic overall design and implementation plan, which is prepared based on current and long-term traffic volume and funding.

Lessons learnt from the early stage of motorway development in China included phasing of a project by dividing the roadway transversely, due to limited experience and economic constraints, is not feasible. That was the reason why the 2006 edition of these specifications stipulated that, based on highway network planning or traffic volume, motorways shall be built in longitudinal sections or in project phases. It also emphasized that a section of a four-lane motorway with integral subgrade must not be constructed in phases by dividing the roadway transversely.

1.0.12 Since starting to develop motorways in the 1980s, China has built over 130,000-km motorways until the end of 2016; most of these early highways were four-lane motorways. As a result of rapid economic growth， traffic volume shave been increasing significantly while the level of service of these motorways has been falling with an increase in congestion. Over the last 10 years a number of motorways have been implemented, which has provided extensive practical experience together with continued research results. This edition of the Specifications accommodates the most recent findings including the timing, methods and indicators of the upgrading and reconstruction projects from relevant research such as the *Research on Technical Policies of Highway Upgrading and Reconstruction*. This research emphasizes the general principles to be followed for upgrading and reconstruction projects, and stipulates the provisions for development program verification, technical class selection, and so forth.

1.0.13 Besides these specifications, highway design shall comply with relevant provisions in prevailing national and industrial standards.

2 HIGHWAY CLASSIFICATION AND CLASS SELECTION

2.1.1 According to the requirements as stated in *JTG B01-2014* that highway function shall be emphasized in the selection of highway classification, this clause clarifies the categories of highway function: highways are divided by function into three categories: arterial highways, collector-distributor highways, and local highways. Arterial highways are further divided into primary arterial highways and minor arterial highways, while collector-distributor highways are further divided into main collector-distributor highways and minor collector-distributor highways.

1. Primary arterial highways

1) link to or between the large and medium cities with populations over 200,000, transportation network hubs, major ports and terminals, and localities with military strategic importance.

2) provide long distance, high volume and high speed transportation service for inter-provincial or inter-city movement.

2 Secondary arterial highways

1) link to or between cities with populations over 100,000 and regional economic centers.

2) provide moderately long distance, moderately high volume and moderately high speed transportation within a region or for intra-provincial movement.

3 Main collector-distributor highways

1) link to and between the counties (towns) with a population over 50,000, major industrial or agricultural production bases, main economic development zones, famous tourist sites, and large trade centers.

2) provide average distance, medium volume and medium speed transportation services.

3) connect counties (towns) to arterial highways over average distances.

4 Minor collector-distributor highways：

1) connect the counties (towns) with a population over 10,000, relatively large villages and other sources of trip generation.

2) provide relatively short distance, relatively low volume and relatively low speed transportation services.

3) connect local highways to arterial highways and main collector-distributor highways, distribute the traffic from arterial highways and collect traffic to local highways.

5 Local highways

1) Mainly provide a service function and link to trip origin of road-users.

2) Connect to collector-distributor highways to provide connecting service and access service for the trips within a specific region.

The function category of a highway can be determined by procedures as follows.

1 to conduct the zoning in terms of administrative jurisdiction, land attributes, and travel needs; and then to define the zones as abstracted nodes.

2 to determine the node significance. Node significance is a quantitative indicator measuring relative importance of each node in terms of total population, gross industrial production, per capita income and so forth. Table 3-2 shows the hierarchical structure of the network nodes. A highway shall be identified as a primary arterial if its main control points are recognized as A-level nodes; or, it shall be a secondary arterial if the main control points are B-level nodes; or, it can be a main collector-distributor highway if the main control points are C-level nodes; or, a minor collector-distributor highway if the main control points are D-level nodes; or, while the highway shall be a local highway if the main control points are E-level nodes.

Table2.1 Hierarchical Structure of Nodes

Level	Central Node	Main Nodes
A	Beijing	Capitals of provinces or autonomous regions, metropolitan and special administrative regions
B	Capital of a province or autonomous region	Administrative centers of district or municipal governments
C	Administrative center of the district or municipal government	Administrative centers of county(city)governments
D	Locality of county administration.	Localities of township administrations
E	Locality of township administration	Administrative villages

3 to add the highway network and to identify the functional category of each highway by referring to node significance;

4 to calculate highway kilometers and traffic volume of each functional category and to plot the cumulative curves of network kilometer coverage – ratio of vehicle-kilometers;

5 In the case of two or more highways that have similar main control points in one zone, the functional classification of these highways shall be determined in accordance with the service index of the road network.

The service index of a road network is the ratio of vehicle kilometers to kilometer coverage. The larger the service index of the road network, the higher the functional category of the highway. The calculation of the service index is that: for n highway routes in the zone, then the ratio of vehicle kilometer R_{VMT_i}, the ratio of kilometers R_{k_i} and service index of road network R_i of the ith (i = 1, 2 ...,n) highway shall be calculated by using equations (2.1), (2.2) and (2.3) .

Vehicle kilometer ratio:	$R_{\mathrm{VMT}_i} = \frac{VKT_i}{\sum_i VKT_i} \times 100\%$	(2.1)
Kilometer coverage ratio:	$R_{k_i} = \frac{K_i}{\sum_i K_i} \times 100\%$	(2.2)
Service index of road network:	$R_i = \frac{R_{\mathrm{VMT}_i}}{R_{k_i}}$	(2.3)

where	VKT_i	——the vehicle-kilometer of the ith highway (pcu •km) in the zone, determined by multiplying the number of vehicles on the given highway by the average length of their trips measured in kilometers;
	$\sum_i VKT_i$	——the sum of all vehicle-kilometers (in pcu·km）;
	K_i	——the length (in km) of the ith highway;
	$\sum_i K_i$	——the total length(in km) of all highways in the zone under study.

6 The indicators for functional classification of a highway include a number of qualitative and quantitative indicators such as zonal hierarchy, network continuity, traffic flow character and the characters of the highway itself. Regional economic development level and differences in terrain and topography directly affect the selection of the factors for classification. Designers may make selection at their own discretion in accordance with the real situation of the local zone. Recommended quantified indicators for highway functional classification are listed in Table 2.2

Table 2.2 Indicators of Highway Functional Classification

Functional	Functional Classification

Classification Indicators	Primary arterials	Secondary arterials	Main collector-distributor	Minor collector-distributor	Local highway
Locality and network continuity	Cities with populations over 200,000	Cities and counties with populations over 100,000	Cities and towns with population over 50,000 or connection to arterials	Connections to arterials or local highways	Direct to trip origin
Network service index	≥15	10～15	5～10	1～5	<1
Speed expected	Over 80km/h	Over 60km/h	Over 40km/h	Over 30km/h	Not required
Access control	Full control	Partial control or access management	Access management	Lateral interference control where warranted	No control

2.1.2 Consistent to JTG B01-2014, the revisions have been made to this clause for the basic elements for technical classification and the design traffic volume for motorways.

(1) Technical Classification

The factors considered in this edition are vehicle operating mass, control of access, number of lanes, and whether or not the lanes are specific for motorized vehicles.

。

Motorway is the highway of the highest mobility, which shall be provided with at least two lanes in each direction, a median in the middle to separate opposing traffic flows, and all necessary facilities such as grade separated junctions to fully control the accesses and to eliminate either longitudinal or lateral interference to through traffic.

Class-1 highway shall be provided with at least two lanes in each direction, to which accesses are to be controlled at appropriate levels depending on actual needs. For the Class-1 highways serving as arterials, partial control of access is adopted under which grade separations are provided for all types of access and at-grade junctions are only allowed for those specifically selected highways where isolation facilities are provided to prevent entry of pedestrians, slow moving vehicles, non-motorized vehicles and animals. For the Class-1 highway serving as a collector-distributor where longitudinal and lateral interference are high, access management measures shall be applied to control locations, number and types of accesses between the highway and abutting land development so as to enhance the travel safety while preserving the level of service.

Class-2 highway is a two-way two-lane highway for motor vehicles travelling on the roadways. In the case of a high volume of slow-moving vehicles and dense urbanization in adjacent areas, slow lanes may be added by widening the hard shoulders in order to reduce longitudinal or lateral interference and preserve traffic safety.

Class-3 or Class-4 highway is a two-way two lane highway (a Class-4 highway could be a two-way single lane in the case of low traffic volume) shared by mixed traffic. The roadway is not only for motor vehicles but is also used by slow-moving vehicles such as farm tractors and non-motorized vehicles.

(2) Design Traffic Volume

As in JTG B01-2014, this edition replaces the term accommodated traffic volume with ‘design traffic volume’, and made adjustment to the range of design traffic volumes for motorways and Class-1 highways, which are affected by multiple factors such as the number of lanes, design-hour factor, directional split, road conditions, etc. The level-of-service has been extended from four levels to six levels, that is, previous Level 2 is split into the new Level 2 and Level 3 while the previous Level 4 is split into the new Level 5 and Level 6. The purpose is to represent the proactive design policy that the level-of-service shall be selected based on highway function and regional features.

For multi-lane highways, the Annual Average Daily Traffic under various levels of service for a future year shall be calculated by equation (2.4) as follows:

$$\mathrm{AADT} = \frac{C_D N}{KD} \qquad (2.4)$$

Where: AADT – Annual Average Daily Traffic, pcu/day;

K——Design hourly volume factor, to be determined from observation data；

C_D— directional design hourly volume per lane under specific level of service

D —— directional split；

N—— number of lanes in one direction。

In the light of the principle that highway functions determine technical classifications, the service level of arterial highways is raised from LOS-3 to LOS-2, and the most unfavorable values are taken for both design hourly factor and directional split for arterial highways. This is based on 15000pcu/day as the minimum AADT for motorway or Class-1 highway design.

Capacity and design volume of two-way, two-lane highways are subject to multiple factors including directional splits, overtaking sight distance, management level, and roadside interference. Therefore, design hourly traffic for a Class-2, -3 or -4 highway shall be that of the whole roadway other than an overlap in scope of design capacity and design volume. The annual average daily traffic shall be calculated by the equation (2.5):

$AADT = C_D \times R_D / K$ （2.5）

Where	AADT ——Annual Average Daily Traffic (pcu/day);
	C_D— The design capacity of a Class-2, Class-3, or Class-4 highway；
	R_D — Correction coefficient of directional split for a Class-2, Class-3 or Class-4 highway；
	K— Design hourly volume factor, to be determined from observed data

According to the equation, the upper limit volume recommended for two-lane Class-2 highway design is 15,000pcu/day, which can be taken as the threshold traffic volume between two- and multi-lane highways. Referring to the current highway development strategy, the continuity in terms of AADTs for classified highways, the annual average daily traffic for a single-lane Class-4 highway shall be below 400 pcu per day. Table 2.3 gives the annual average daily traffic for Class-2, -3, and -4 highways.

Table 2-3 Annual Average Daily Traffic factors for Class-2, Class-3, and Class-4 Highways

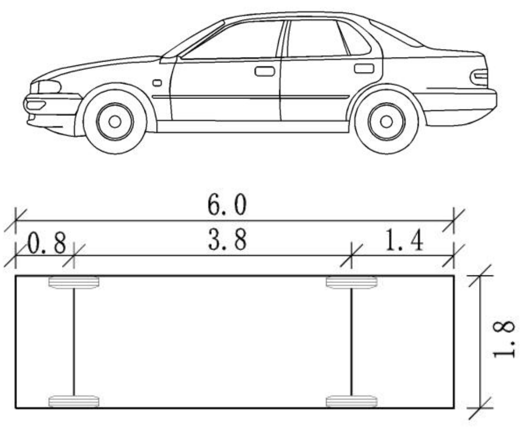
Highway Class	Design speed （km/h）	Design capacity （PCU/day）	Correction coefficient of directional split (R_D)	Design hour factor (k)	Annual average daily traffic （PCU/day）
Class-2	40～80	550～1600	0.88～1.0	0.9～0.19	5000～15000
Class-3	30～40	400～700	0.88～1.0	0.1～0.17	2000～6000
Class-4	20	<400	0.88～1.0	0.13～0.18	<2000

2.1.3 The outline dimensions, loading mass and engine performance of highway design vehicles are the main elements for determining the geometric criteria. According to investigations and research, a number of vehicles currently operating on highways exceed 16m in length. Some of them are 18m, 20m long or even 26m over-long vehicles. Taking the highway investments and the operational safety into account, in accordance with The Limits of Outline Dimensions, Axle Loads and Mass of Road Vehicles(GB 1589-2004), and in compliance with the requirements of 100% coverage for the standard vehicles in operation, two additional types of design vehicle, bus and articulated bus, were added. Meanwhile, the “truck-trailer” as mentioned in previous editions has been renamed as “articulated trailer” with standard over-all length of 18.1 m and width of 2.55 m.

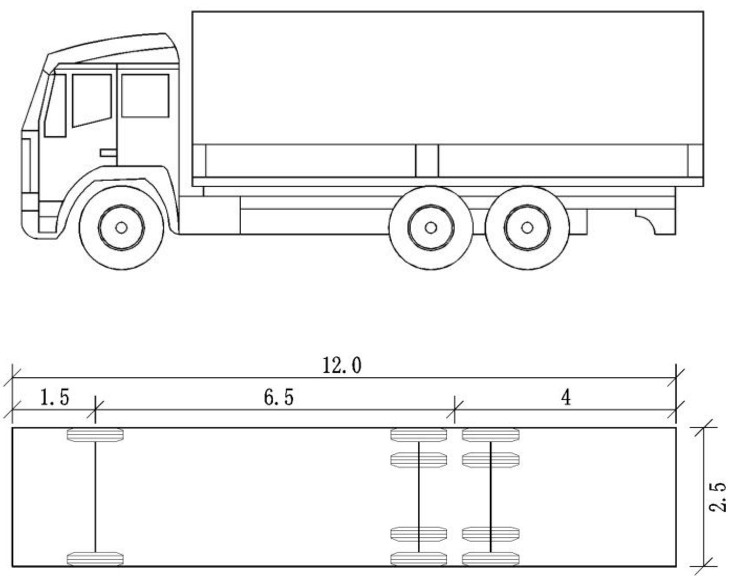
The highway project designer shall select and determine the design vehicles in accordance with highway function and traffic composition, and carry out the geometric design by using various design parameters such outline dimensions, turning path and overall performance of the design vehicles so that the highway main route and its junctions and accesses will accommodate the normal movement of the design vehicles.

In the light of highway functions, five types of vehicles, namely passenger car, large bus, articulated bus, single-unit truck and articulated trailer shall be selected as the design vehicles for arterial highways and main collector-distributor highways; passenger car, large bus, and single-unit truck shall be selected as the design vehicles for minor collector-distributor highways; and passenger car and large bus shall be selected for local highways. For the highways with special purposes， the design vehicles may be selected based on specific evaluation.

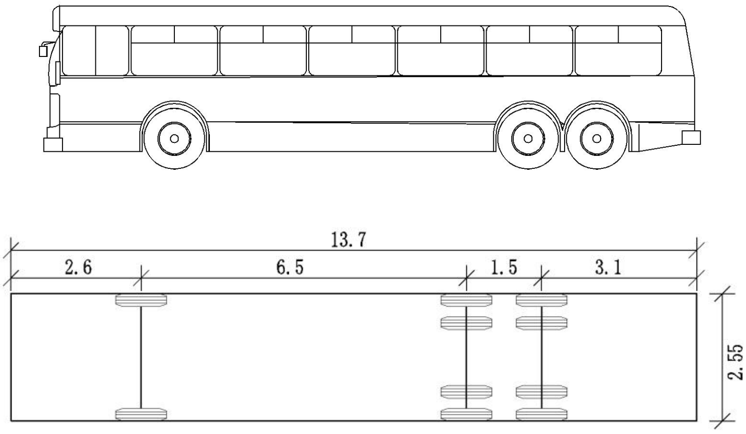
Outline dimensions of five typical types of design vehicles are shown in Figure 2.1.



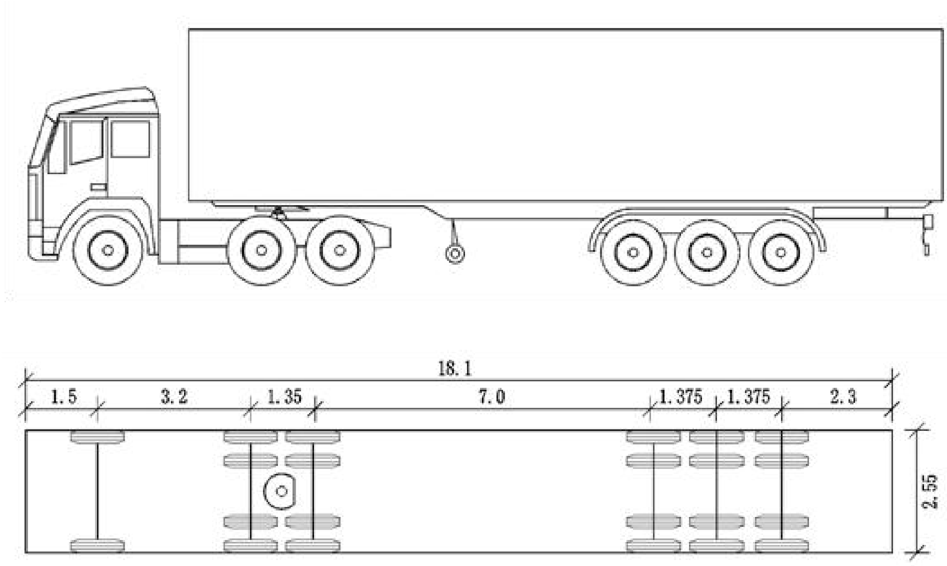
Passenger car



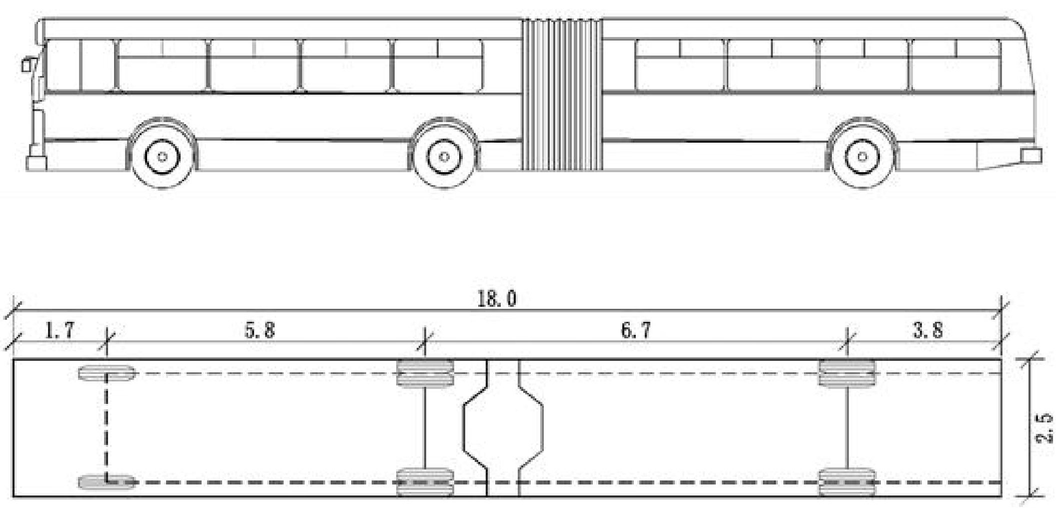
Single-unit truck



Large bus



Articulated trailer



Articulated bus

Figure 2.1 Representative Outline Dimensions of Design Vehicles

2.2.1The design period is one of the major elements in traffic prediction. A new highway or an existing highway to be upgraded or reconstructed shall consider not only the existing traffic volume but the future volume growth as well. Determining the service period of a highway is a difficult task because the actual service lives (periods) of different highway structures are different. For instance, the service period of subgrade could be 50 or 100 years, pavement could be 15 to 30 years, and bridges could be 25 to 100 years. These prediction periods are based on the assumption of normal maintenance and no abandonment of structures. The service life of a bridge may vary with accumulated frequency of heavy loading, while the life of pavement depends on the pavement structure and accumulated axle loads.

The length of the period taking for predicting traffic volume affects cost effectiveness. On one side, a long prediction increases initial investment and maintenance cost, which may result in in-effective use of funds and under-utilization of facilities. On other side, a short prediction may cause traffic congestion and premature demands for upgrading, which in turn has negatively impact on traffic and increases construction cost. Although a highway may continue its service for some time after the design life, the level of service will be low and operating speed would be slow and drivers will not be able to travel at the desired speed.

There are two major considerations in highway design life prediction; one is the accommodation of traffic demands for a certain period, and the other is the highway investment and the design lives of various structural elements. Therefore, different classified highways shall have different design lives. A too long design life may cause large error in predicted volume which may mean that facilities are under-utilized due to the uncertainty of many prediction factors. In accordance with the experience in China and other countries, this edition of the specifications stipulates that the prediction period for the design life shall be 20 years for motorways and Class-1 highways, and 15 years for Class-2 and Class-3 highways. Because of a comparatively low traffic volume, the prediction period of design life of a class-4 highway may be determined by the actual situation with reasonable adjustments.

Highway function is a known factor for determining technical classification. Therefore it is closely related to prediction. In other words, the higher the function, the longer the prediction period shall be and the greater the need for long term planning and effective utilization of land. In JTG B01-2014, highway function is mentioned and linked with prediction period; thus, for convenience, the prediction period is specified in terms of highway classification. However, highway classification shall be based on traffic volume, which shall be predicted only after the prediction period is determined. Therefore, for practical application, it is recommended that designers take two successive prediction periods and carry out volume prediction respectively, and then select the highway classification in accordance with the highway function and by taking terrain and other physical conditions into account.

2.2.2 This clause highlights the reasoning for selecting highway classification in accordance with highway functions and advocates influences from economic development, geological and topographical features. Considering unbalanced regional transportation development, highways with the same functions shall not only adopt one corresponding technical classification in order to reflect the differentiation. Meanwhile, the highway serving a particular function should not only be assigned to one single classification. In selection of a technical classification, the highway function shall be determined at first in accordance with the highway network program, regional features, traffic characteristics and so forth, and then determine highway class in accordance with highway function and traffic volume verification.

1 According to the paragraph 2, Clause 3.1.2 of JTG B01-2014, all primary arterial highways shall be motorways. This provision is reconfirmed in this edition of the specifications, which reflects the differentiation in traffic volume and regions in conjunction with the factors for highway technical classification. This clause stipulates that a motorway classification shall be selected under normal circumstances where AADT is over 15,000 pcu/day or roadside interference is severe. Otherwise, Class-1 or class-2 highways may be selected for special circumstances such as low urbanization, limited non-motorized traffic and pedestrian traffic, and AADT below 15,000pcu/day. However, necessary facilities for interference control shall be provided to ensure the arterial functions. For example, for Class-1 highways, partial controls of access must be provided. ForClass-2 highways, connection controls must be provided and passing lanes may be added to mitigate transverse interference in segment with high truck mix. However, motorway shall be the choice in the circumstances where neither partial control of access nor access control is efficient to serve the highway function.

Partial control of access: Preference is given to full control of access connections, except under special circumstances (such as low traffic volume on main route and design hourly volume of the intersected highways less than 60 pcu) where a limited number of at-grade junctions are acceptable. Partial control of access is mainly applicable for Class-1 arterial highways.

Access management: In order to ensure the driving safety on the main route, access management could be applied to the number, mode and spacing of accesses to limit interference to the traffic on main route. Access management is mainly applicable to secondary arterials and Class-1 or class-2 collector-distributor highways.

2 According to JTG B01-2014, paragraph 3, Clause 3.1.2, Secondary arterials shall become Class-2 or higher classified highways. This provision has also been retained in this edition of the specifications. The selection of highway classification shall be based on highway function and in conjunction with the traffic volume, and the capability of interference control. It is stipulated in this clause that for a secondary arterial highway, if the AADT reaches 10,000 pcu while the longitudinal and transverse interference along the highway is severe, a Class-1 highway should be selected and control management should be planned and implemented accordingly. According to the basic criteria for a Class-2 highway, the maximum traffic volume to be served shall be 15,000pcu under the standard level of service. However, if the maximum traffic volume

under the standard level of service falls to 10,000 pcu/day due to high longitudinal and transverse interference, which means that traffic volume capacity drops to a lower level and hardly serves as a secondary arterial highway, upgrading would be required only after a short period if a Class-2 highway were selected. Therefore Class-1 highway is recommended for such a situation.

Where the traffic volume of a secondary arterial highway is less than 10,000 pcu/day and the land adjacent to the road is still under-developed and minimal mixed traffic influence, , intermittent passing lanes could be adopted to mitigate longitudinal interference and assure highway mobility. Research suggests potential safety risks for intermittent passing lanes onClass-2 highways due tan absence of physical separation as drivers do not obey lane markings. Therefore, many countries adopt physical median barriers for divided highways, which are believed to improve traffic safety and could increase low capacity by 15%.

2.2.3 Design speed is one of the basic elements used for harmonizing geometric design indicators. Once the design speed is selected, all the relevant parameters such as radii of horizontal curves, sight distance, super-elevation, grades and vertical curves shall fulfill the requirements so as to achieve a balanced design. Currently the design methodology based upon design speed has been generally understood and practiced by designers, thus this edition of the Specifications maintain those in JTG B01-2014.

1 For the benefit of safety and comfort, the design speed of a motorway should be kept above 100km/h. The operational experience of motorways in China and abroad suggests that accidents are caused when the design speed is lower than that anticipated by drivers. Furthermore, motorways usually remain in the same highway corridor and it would be difficult to upgrade the geometric parameters to a higher design speed to meet economic development demands. Therefore, a minimum design speed of 80 km/h is required for motorways.

3 For sections of a motorway or Class-1 arterial highway passing through extremely difficult terrain, the lower design speed of 60km/h may be selected subject to the approval of a thorough comparison and assessment of technical, economic, safety, environmental and social aspects. It is emphasized that only if confirmed by the evaluations, a section can be recognized as extremely difficult and should be limited to a length shorter than a typical design section, i.e., 15 kilometers. However, this limitation of section length may be relaxed to the length between two successive interchanges with special attention to be paid to the alignment coordination and layout of roadside facilities.

The principle that is applied throughout this edition of the Specifications is that a higher design speed shall be selected as priority for the highway in a higher functional category while a lower design speed should be adopted for the highways in a lower functional category. In other words, for Class-1, Class-2 and Class-3 highways, the design speed shall be selected for the service functions to be served by these highways in a road network, and may be lowered by one level, i.e., 20km/h, only where restrained by terrain and/or geological conditions.

2.2.4 Design segment is the segment for which the same technical class is assigned and the same design speed is selected. Based on service purpose, function and predicted traffic volumes, a highway route may be divided into sections for which different technical classes may be selected. A classified highway or highway section can be further divided into several segments for each of which a specific design speed may be selected. In such a way, the highway will better adapt to various environmental conditions in terms of terrain, landscape, geology and so forth. In all cases the eco-environment protection should conform to the national strategy of building a resource saving society. However, frequent changes in design speeds are one of the causes of traffic accidents. Therefore, design speeds shall not be changed frequently and the segment of a design speed shall not be too short. From experience in construction and operation, the length of a design segment should not be less than 15km for a motorway; and 10km for Class-1 and Class-2 highway.

According to the principle of uniform operating speeds, the change in operating speeds shall be less than 20km/h before and after the connection between two design segments with different design speeds. The operating speed shall be changed progressively to allow drivers to change their driving speed accordingly when design speed changes from one design segment to another. This requires that the highway alignment, before and after the interface of design segments, shall change progressively as the terrain changes. A lower value of the alignment indicator shall be used for the design segment with higher design speed; while for the other side, a high value shall be used, to keep alignment parameters in equilibrium with no abrupt changes.

The interface of two design segments with different design speeds and different classes shall be selected at the locality where the traffic volume changes, or somewhere the highway users are able to judge the needs of speed changing in front. Such connecting locations should be placed at interchanges or at-grade junctions of a motorway or Class-1 highway, and at at-grade junctions, bridges, tunnels, and the places where are near villages or terrains are significantly different for a 2.2.5 Checking by operating speeds for the technical parameters of a highway design has been found to be harmonized and consistent in theory and methodology and confirmed by engineering practice over many kilometers of highways. Therefore, this edition of the Specifications stipulates that the highway designed by design speeds shall be verified by operating speeds, to ensure the harmony and consistency of operating speeds on adjacent highway segments and thus enhance the operational safety and service quality of highways.

Class-2, Class-3 orClass-4 highway.

2.2.6 Speed limits were previously decided by a highway traffic administration in accordance with design speeds, which were significantly different from the road user's expectation and was thus questioned. This edition of the Specifications advocates the use of the operating V85 (85th percentile speed) as the basis for determining the speed limit while taking the safety records and roadside environment of the highway section into account. Such an approach should be more realistic than that adopted previously.

2.3.2 Control of access is to control the numbers, locations, and approaches of accesses to the main route, aiming to eliminate horizontal and transverse interference to through traffic, improve service quality, operating speed, capacity, and traffic safety. Control of access includes full control and partial control of access.

Control of access is to provide accesses only to selected highways that are intersected, urban roads or service facilities. Full control of access includes five basic measures: firstly, having rights to apply limits on the vehicles allowed to enter into the highway, mitigating the speed differentials and eliminating longitudinal interference; secondly, placing median barriers to separate traffic in different directions to avoid interference and incidents from opposing traffic flows; thirdly, providing each direction of the traffic with at least two traffic lanes to facilitate overtaking, so as to enhance driving speeds and highway mobility; fourthly, providing grade-separated junctions wherever other highways, railroads, urban roads pass over or under, for no at-grade junction is allowed; fifthly, placing isolation installation to avoid roadside interference by pedestrians, animals or other means. Partial control of access uses similar control measures except that a few at-grade junctions are allowed for specific conditions.

Motorways are highways with full control of access. The control of access shall be applied and placed at relatively large spacing to exploit fully the advantages of fast moving traffic, safe travelling and comfortable driving. Collector-distributor highways approaching cities or economic zones and all two-way two-lane highways are highways with no control of access.

2.3.2 Class-1 highway serves one of the two highway functions, either arterial or collector-distributor. A Class-1 highway is characterized as a highway with divided traffic flow, high capacity, high design speed, but not with full access control. When a Class-1 highway is considered, the designers shall decide the range of access control based on the highway function, service objective and in conjunction with the determination of design speed and cross-section arrangement.

Where a class-1 highway serves as arterial, a higher design speed shall be adopted and the needs for control of access shall be identified. On highway sections with low traffic volume, some local roads shall be merged by means of the highway network and at-grade junctions may be placed only if the design hourly traffic volume of an intersected highway is less than 60 pcu. The layout design shall include turning lanes for the at-grade junction. Where the class-1 highway serves as a collector-distributor, connection access management shall be applied. The designer shall study the locations, number of accesses, method of the access between the highway and the surrounding areas to minimize the influence on the through traffic, while considering the type and arrangement of the cross-section for accommodating the traffic. For an at-grade junction design, the lower value of design speed should be selected, while traffic channelization and traffic control devices shall be carefully planned and properly arranged in accordance with traffic flow and other conditions, thus minimizing longitudinal and transverse interference with through traffic.

Control of access is a different concept from reducing interference. In a broad sense, reducing longitudinal and transverse traffic interference has the effect of preventing entry and plays positive role on driving speed, highway capacity and traffic safety. However, there is substantial difference between the types of control of access (either full or partial control of access). “Control of access” is to apply full control on the vehicles entering or exiting the highway, including the number of the vehicles, location of the access and the mode of connection with the highway, which is to eliminate the effects of interference. This is not possible by reducing longitudinal and transverse interference.

For the design of an at-grade junction on class-1 arterial highways, reference has been made to American Association of State Highway and Transportation Officials Geometric Design Manual which states that:

2.3.4 On a highway with control of access, emergency exits shall be placed at such localities where the facilities for emergency rescue, fire-fighting or medical care are available and shall be specifically used by special-purpose vehicles. The emergency exits shall be located at places with good visibility and easy connection to external roads. Two emergency exits should be placed at one locality, one at each side of the highway.

The external road connecting to an emergency exit normally should not be lower than a class-3 highway or may be a higher class highway wherever possible. The length of the opening of an emergency exit is normally 15 meters and in trumpet shape connecting to an external road. Movable fence shall be placed on the external road at a place near the emergency exit, which shall normally be kept closed to prevent other vehicles from entering the main route.

3 HIGHWAY CAPACITY

3.1.1 Capacity analysis and level-of-service assessment includes two stages, one is the analysis for highway planning and design, the other is the analysis for operation.

The purpose of the analysis for highway planning and design is to determine the highway classification, to calculate the number of traffic lanes, the width of each traffic lane and the types of junctions, and to predict the impacts on the highway capacity and operational performance of the other design elements (such as the width of medians, the adjustment of the shoulder widths, the placement of climbing lanes). In other words, it is to determine the typical width of the highway cross sections for the required level-of-service in accordance with the predicted traffic volumes.

The purpose of the analysis for highway operation is to determine the operational status of the traffic flow and the level-of-service that the highway facilities is capable of providing, to calculate the capacity under actual conditions and determine the maximum through traffic flow that the highway facilities can serve. From the analysis, the operational status of the highway may be effectively assessed and basic information for traffic management can be provided so as to ensure the highway in a good operational status.

Passing through capacity, or capacity, refers to the maximum number of vehicles passing through a specific highway facility in a certain period (usually taken as 1 hour) under normal conditions of highway environment, traffic and driving behavior. By measuring the factors using level-of-service, the service volume under each level-of-service can be derived. Highway capacity reflects the capability of handling traffic flows that the highway facility may accommodate. It is one of the important parameters for highway planning, design and operation management. In terms of the performance characteristics and requirements, the highway capacity can be categorized into three types:

(1) Typical capacity: the maximum hourly flow rate sustainable for a specified period of time to traverse a specific cross section or uniform segment of a lane under typical geometric, traffic, control and environmental conditions, usually expressed as pcu/h/ln (passenger car units per hour per lane) or pcu/h(passenger car units per hour).

(2) Design capacity:the maximum hourly flow rate sustainable for a specified period of time passing through a specific cross section or anapproximately uniform segment of a lane in a selected level of service and under expected geometric, traffic, control and environmental conditions, which is usually expressed as pcu/h/ln (passenger car units per hour per lane) or pcu/h(passenger car units per hour).

(3) Actual capacity: the maximum hourly flow rate sustainable for a specified period of time passing through a specific cross section or a lane of the known highway facility under expected geometric, traffic, control and environmental conditions, which is usually expressed as veh/h/ln (number of any vehicles per hour per lane) or veh/h (number of any vehicles per hour). In other words, it is the hourly flow rate corrected in accordance with actual road and traffic conditions in terms of the traffic volumes accommodated at various levels of service (such as typical capacity and design capacity) when a specific highway segment is designed or assessed in accordance with the highway geometry, traffic condition and management level.

The three capacities defined above may not fully explain the relationship between traffic operation status and passing through capacity, but remain in use because they have been used in design practice for many years to match with the criteria of design traffic volumes stated in JTG B01-2014.

1. The types of highway facilities that need to be analyzed and assessed are identified in the light of their importance. Based on the experience in highway operation, the merge and diverge areas at interchanges and tolling areas on motorways are susceptible to traffic congestion. Therefore, it is recommended in this edition of the Specifications that these two types of facilities should be evaluated in terms of their capacity and level of service at equilibrium with adjacent sections. Designers shall assess the capacity and level of service of every segment of the highway, identify and analyze the differences of each other, and then make necessary geometrical adjustments or improvements in a systematic and holistic way to eliminate potential traffic bottlenecks as far as possible.

2 and 3 For class-2 highways and class-3 highways, and refer to the highway functional categories specified in JTG B01-2014, the analysis and assessment on capacity and level of service shall be conducted for the at-grade junctions on an arterial, or may be conducted depending on the real needs for the at-grade junctions on a collector-distributor. The analysis and assessment of the capacity and level of service of at-grade junctions shall follow recommended industry standard *Guidelines for Highway Capacity Analysis*.

3.1.2 Many factors, such as control of access, either single-type or mixed traffic, highway geometry, number of lanes, driving behavior and traffic regulations, affect traffic conditions and traffic mode and hence the capacity and level of service of highways. Highways under different environments and conditions shall be analyzed for capacity in different ways. On a motorway or class-1 highway, the traffic in each direction has its own and significant characteristics. Therefore, the analysis and assessment on capacity and level of service shall be conducted separately and individually for each traffic direction.

On class-2 and class-3 highways, directional traffic is not physically divided, and thus interferes to each other significantly. Therefore, capacity analysis and level of service assessment shall be conducted in an intergraded way by taking the traffic flows in both directions as whole.

There are significant differences in traffic flow because of road configuration, traffic rules, driving behaviors that exist on interchange ramps, merge, diverge and weaving segments. The capacity analysis and level of service assessment shall be executed separately and individually on these segments.

The continuous upgrades, where the speeds of large vehicles are much slower than passenger cars, are usually the segments of poor or even the poorest operational quality along a highway. Conventional passenger car equivalents (PCE) are not applicable and have to be increased. In addition, a climbing lane may need to be placed where design hourly volume on ascending grade exceeds the design capacity of the travelled way in the same direction. Therefore, individual and specific capacity analysis and level of service assessment are required for these specific grade segments.

3.1.4 Roadside inference factors are categorized into five groups, that is, local vehicles, roadside parking vehicles, pedestrians, non-motorized vehicles and urbanized roadsides. The highway designer shall describe the typical situations of these road influence factors based on the data of relevant roadside influencing events, roughly determine the level of roadside interference on the highway segment. Detailed analysis may be executed in accordance with *Guidelines for Highway Capacity Analysis*.

3.2.1 Capacity analysis aims to measure the quality of traffic operations. Therefore, capacity analysis and assessment shall be carried out simultaneously with the analysis and assessment for level of service. Level of service is the quality of operational conditions that vehicles will experience. It can be described and measured by driving speeds, traffic density, freedom to maneuver, traffic interruptions and the extent of comfort and convenience.

In order to reflect the highway traffic capacity, the level of service is categorized into six levels in terms of traffic flow regimes, which gives qualitative descriptions of the traffic spectrum from free flow, stable flow, saturated flow and congested flow. To assess the level of service, volume to capacity ratio (v/C) is used for motorways and class-1 highways, whereas the extent of delay and average operating speed are used for class-2 and class-3 highways. Vehicle delay is used for highway junctions.

At the Level of Service1 (LOS-1), the traffic is in a state of full free flow, reflecting low volume, high travel speed, low travel density, freedom of drivers to choose travel speed, and very little interference from other vehicles. This gives significant freedom to drive in the traffic stream and provide drivers, passengers and pedestrians with favorable comfort and convenience. The impact of minor traffic incidents or obstacles could be easily eliminated with no stops or delay in the section, and the level of service may be quickly reinstated.

At Level of Service 2 (LOS-2), traffic is maintained in a state of reasonable free flow. Drivers may choose desired traveling speed but shall pay attention to other road users. It gives a high degree of physical and psychological comfort to the drivers. The impact of minor traffic incidents or obstacles could be easily eliminated while the operating service conditions on these sections are slightly lower than that of Los-1.

At the Level of Service (LOS-3), traffic is in the upper half of stable flow regime, which creates larger interference among travelling vehicles, impact on speed selection from other vehicles, and extra attention shall be paid by drivers in changing lanes. The consequential impacts of minor traffic incidents can be eliminated but the quality of service may deteriorate significantly, and traffic is seriously impeded with queues forming and drivers become anxious.

At the Level of Service 4 (LOS-4), traffic is in the lower half of stable flow regime, under which the traveling vehicles are severely interfered by other vehicles, and the traveling speed and driving freedom are significantly constrained. Slight increases in traffic flow may cause a significant reduction in level of service and in driver’s comfort. Impact of even minor incidents may be difficult to eliminate and may cause long queues of vehicles.

At the Level of Service 5 (LOS-5), traffic is in the upper part of the congested flow regime, or approaching the maximum capacity. Any interference, such as vehicles entering from ramps or maneuvering to change lanes, will cause interference waves that may not be absorbed by the traffic flow. Any incidents will cause long vehicle queues and thus mobility of the traffic flow is extremely sensitive and constrained. The driver's comfort is at a very low level.

At the Level of Service 6 (LOS-6), traffic is in the lower part of a congested flow regime, or in general terms, the forced or breakdown flow. The demand of traffic exceeds the available capacity, and vehicles travel in queues and frequently stop and start. The operating regime is extremely unstable and inclined to change over a short distance.

Main parameters used for level of service assessment are different depending on the typed of highway facilities, as shown in Table 3.1 .

Table 3.1 Main parameters for Level of Service Assessment

Type of Highway Facility	Main Parameters for LOS Assessment
Motorway and class-1 highway Ramps and weaving segments in interchanges	Volume to capacity ratio and speed difference Volume to capacity ratio v/C and traffic density
Class-2 highways with design speed 80km/h and 60km/h	Extent of delay (%) and average speed (km/h)
Class-3 highway with design speed of 40km/h (incl. segment of 40km/h in mountainous terrain of class-2 highways)	) Extent of delay (%)
At-grade junctions（non-signalized）	Delay (s)
Toll plaza	Delay exponent

In China, most Class-3 highways in a highway network provide short-distance transportation accesses to villages or small towns, where there is no expectation for high average travel speed. Therefore, only the extent of delay is adopted for assessing level of service of the class-3 highways with low design speeds.

A highway plan and highway design shall not only ensure the quality of highway service and vehicle operations but also account for the cost and benefit of highway development. Considering that the annual 30thhighest traffic volume is taken as design hourly volume, a high level of service is not always necessary.' Nevertheless LOS-4 shall not always be used as design criteria as during long periods traffic would be in an unstable and congested flow regime. Therefore, in principle, LOS-3 shall be adopted for the design of a motorway or class-1 highway. By considering the difference in service functions, the level of service may be increased by one level higher for the design of a primary arterial motorway, and decreased by one level lower for the design of a class-1 colletor-distributor highway. Similarly, LOS-4 shall be adopted for designing a class-2 highway, a class-3 highway or at-grade junctions. Based on the same principle, the level of service may be increased by one level higher if the class-2 or class-3 highway is designed as an arterial highway.

Class-4 highways are feeder or local highways mainly providing an access service for short distance transportation. Therefore, the level of service of class-4 highways is not specified. Designers may use their discretion depending on the demands in terms of users, purpose and functions of the highway.

Design hourly volume is one of the important criteria used to determine highway classes and to evaluate highway operational status and level of service. The smaller the design hourly volume, the smaller shall be the scale of highway development and the lower the construction cost. However, an underestimate of the design hourly volume may result in a poor traffic environment, which in turn may cause more traffic accidents which will reduce the expected economic effectiveness. Ranking the hourly traffic volumes during a whole year in a descending order, the 30^{th} hourly volume is usually adopted as the design hourly volume, or a value may be taken between 20^{th} and 40^{th} hourly volumes based upon the results of a site investigation.

3.4.1 It is recommended that highway authorities establish their own database with the factors of design hourly traffic (K) for determining design hourly percentile and factors of design hourly traffic. In the case where there is a lack of observed data, the factor of design hourly traffic can be calculated by using equations (3.1), (3.2) and (3.3).

(1) Motorway

$K=[-4.105\,6\ln(AADT)+49.9271]\times(1+A)+\Delta$ (3.1)

(2) Class-1 highway

$K=[-2.428\,3\ln(AADT)+31.7670]\times(1+A)+\Delta$ (3.2)

(3) Class-2 or class-3 highway

$K=[-1.564\,81n(AADT)+23.1640]\times(1+A)+\Delta$ (3.3)

Where: K——factor of design hourly traffic;

AADT——annual average daily traffic (veh/d)

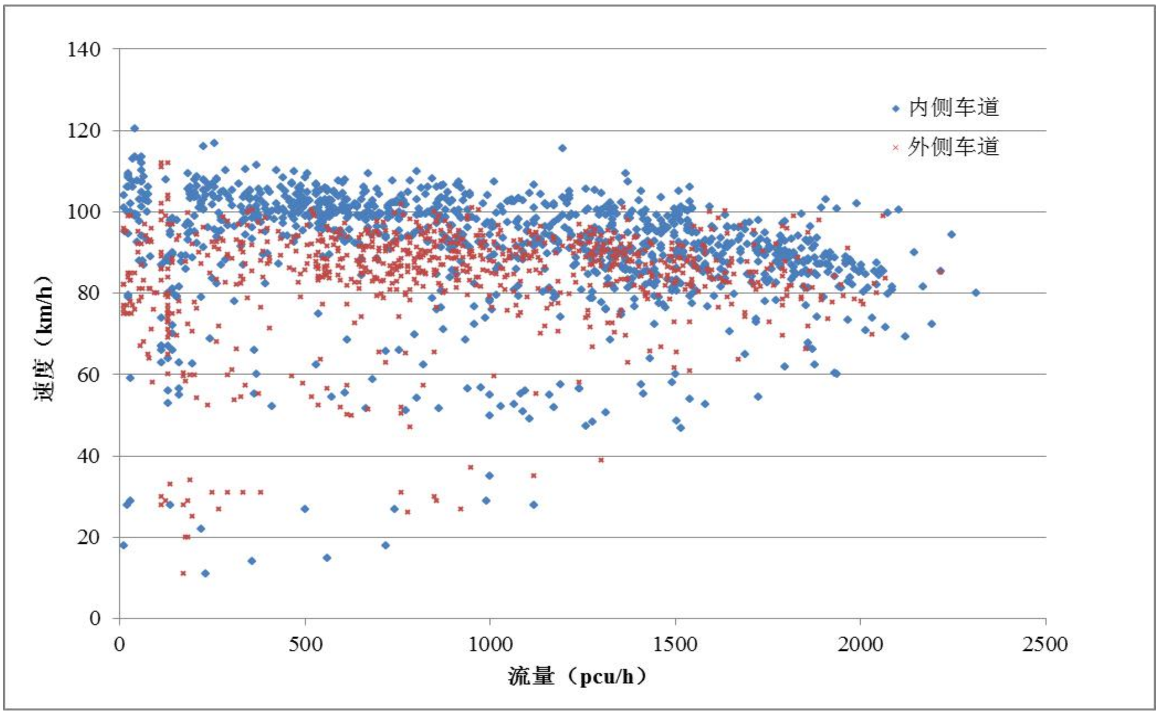
Δ——correction factor of highway location; taking 0 for suburban areas, and 4.0% for rural areas;

A——correction factor for regional climate, $-10\% \leqslant A \leqslant 10\%$; using larger value for significant changes in annual climate, and smaller value for minimal changes in annual climate. The average factor for northern, northeastern and southwestern China is -9.23%; the average in north-east China is 8.31%, the average in north-west China is 7.18%. Climate correction may not be necessary for east, central-south and south-west China.

3.4.2 Design capacity on segments of motorway and segments of class-1 highway may be calculated together though there is a small difference in capacities.

(1) Motorway

The motorway speed-volume relationship (as shown in Figure 3.1) has been established based on the data collected from 52 highway observation segments in Beijing, Guangdong, Zhejiang, Hebei, Henan, Liaoning, and other provinces or regions.



速度 Speed (km/h)	流量 Volume (pcu/h)

Fig. 3.1 Motorway speed-volume relationship

Main factors influencing capacity are quite different due to highway classifications and types of facilities. Though the main influences and relevant adjustments have been discussed in these specifications, the designer shall bear in mind that road surface quality, especially the surfacing evenness and friction coefficients have significant impacts on highway capacity; in addition there are impacts of climate conditions such as rain, snow, fog, etc. Because the extent of these kinds of impact varies significantly and there is little supporting data, the influences of road surface quality and climate are not included in these specifications. In other words, the relationship and parameters of capacity and level of service presented in these specifications are under normal road surface quality and fair climate conditions.

It is also noticed that the capacities of motorway segments and class-1 highway segments are combined and calculated as a whole, as is the adjustment factor for roadside interference. For motorways that are fully access-controlled, the roadside interference factor is 1.0.

(2) Class-1 highway

Class-1 highways are the highways for motor vehicles travelling in divided directions and on channelized traffic lanes with partial control of access and must be equipped with central dividing facilities. From the point of view of vehicle operation, the vehicles traveling on a class-1 highway do not interfere with each other, overtaking is completed by maneuvering to an passing lane in the same direction and may be constrained only when traffic in the same direction reaches a certain density. Therefore, on an ideal condition without farm tractors and other roadside interferences, the operational characteristic of a class-1 highway is similar to a motorway thus the method of capacity analysis and assessment for motorways can be used for a class-1 highway. However, the capacity of Class-1 highway is lower than motorways because of roadside interference that force vehicles to change lanes frequently, and the lateral clearances of a class-1 highway is narrower than that of a motorway. Therefore, the capacity of a class-1 highway takes the motorway as baseline and is adjusted by roadside interference factors.

In this edition, some minor factors have been deleted or reduced. For systematic and detailed analysis required by particular projects, reference shall be made to recommended industry standard *Guidelines for Highway Capacity Analysis*.

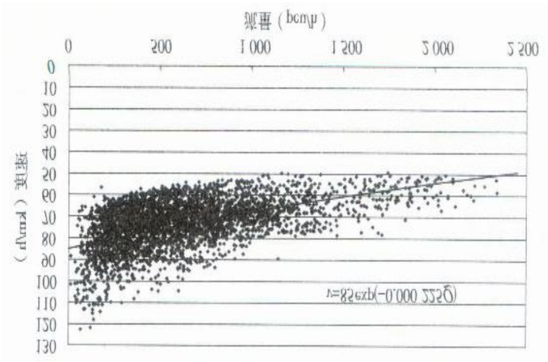
3.5.1 and 3.5.2 During motorway planning and design, capacity and level of service analysis and assessment shall be executed not only for motorway segments but for interchange ramps, merge areas, diverge areas, weaving areas and toll stations as well. This is to determine the capacity of the whole motorway, identify potential ‘bottleneck’ segments, and propose necessary engineering solutions so that the level of service can be kept consistent over the whole route of the motorway.

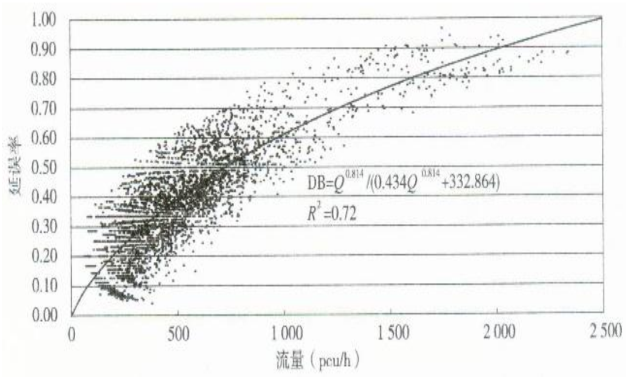
There are two kinds of highway facilities; one includes the ramps, toll stations and the merge, diverge and weaving areas at an interchange and the other is the at-grade junctions. These specifications provide only qualitative provisions on the capacity analysis and level of service assessment. For quantitative details of analytical methods and descriptions, reference shall be made to the recommended industry standard, *Guidelines for Highway Capacity Analysis*.

3.6.1 JTG B01-2014 uses the passenger car as the standard vehicle type. Therefore, two methods of analysis base on speed-volume respectively are adopted for determining the capacity of a 2 or class-3 highway under desirable conditions.

This conclusion is based on the research project during which the data on highway conditions and traffic status were observed and collected from seven provinces and one municipality in China. The actual travel speeds at each observation point were adjusted to the ideal travel speeds in terms of lane width, roadside interference, terrain conditions, and then a model of speed-volume relationship (fig. 3.2) and a model of delay-volume relationship (fig. 3.3) were established.

The values taken for a typical capacity of class-2 highway (using the design capacity of class-2 and class-3 highway) mainly reflect the effects of design speeds (80km/h, 60km/h, or 40km/h) and the effects of pavement widths. The percentage of no-overtaking zone reflects the differences in terrain. This means that though the design speeds of a class-2 highway and a class-3 highway are the same, say 40km/h, the percentages of no-overtaking zones may be significantly different from each other because the terrains are different. For instance, the geometric indicators of a 40km/h class-3 highway in plain or rolling terrain may be significantly higher than a 40km/h class-2 highway in mountainous or hilly terrain, which in turn results in a higher percentage of no-overtaking zones and larger volume-capacity ratio (v/C)， thus upper limits are taken for the design capacity of the class-3 highway, while lower limits are taken for the class-2 highway in mountainous or hilly terrain.





4 OVERALL DESIGN

4.1.1 In the light of the national strategy for highway transportation and the guiding policy for the updating of these specifications, this chapter has been extended in both depth and details to emphasize the importance of and encourage the execution of overall designs, which includes the aspects in terms of highway functions and technical criteria, implementation plan and scope of project, environmental stewardship and resource conservation, design verification and safety assessment. It covers various project stages and takes different professional point of views to provide key points for development an overall design.

Following the requirements for environmental and structural improvement of national highway networks, the conception is extended from previous ‘overall design of highway route geometry’ to ‘overall design of whole project’, which emphasize on embracing the gaps uncovered by various professional specifications and the coordination among specialist participants. In this sense, the coverage of these specifications has been somehow extended while the scope of application and guidance has been widened. Therefore, this edition of the specification is a systematic guide under the governing of JTG B01-2014, and covering various technical aspects and whole engineering process in terms of design and site investigation.

This Clause highlights the main tasks of an overall design. Highway functions are the baseline for determining technical classifications and major technical parameters of a highway project. Therefore, the first task of an overall design is to carry out an elaborate verification on the function positioning of the highway project.

4.1.2 It is emphasized that the highway geometric design is the key to all of the design works of a highway project. Attention shall be paid to the coordination between the geometric design with other specialist designs on one side, and to the internal and external connections of the project in order to formulate an integrated engineering system and realize the overall objective of transportation safety, environment protection and sustainable economy.

4.1.3 Every highway development project has its own conditions and characteristics. There is no one overall design that can cover all the conditions and characteristics for all projects. An overall design shall cover the complete investigation and design lifecycle for a highway project, and shall be subdivided and extended progressively during the design stages.

4.2.1 and 4.2.2 explicitly require that an overall design shall include the verification for determining function, technical classification, design vehicle types and the number of lanes of the highway, and shall indicate the basis of verification and issues to be further verified. Because the highway function has been determined in the early stage of the design, the scope of works shall be the first topic to be verified. Clause 4.2.2 specifies that a highway could be divided into several segments according to different functions and traffic volumes, and then different technical classifications can be assigned to different segments of the highway.

4.2.3 JTG B01-2014 gives outline dimensions of five representative vehicle types. In principle, the types of design vehicles shall be differentiated and characterized for projects assigned with different functions and classifications. Not all types of design vehicles equally suit all the projects. Arterial highways shall accommodate traveling requirements for all five types of design vehicles; the collector-distributor highways directly linked to arterial highways shall accordingly and appropriately account for the traveling needs of the arterial highways. Local highways shall mainly serve the needs of passenger cars and trucks.

4.2.4 Motorways and class-1 highways are multilane highways. The number of lanes in a normal segment shall be determined in accordance with highway function and design traffic volume. If the number of lanes needs to be increased, it should be done symmetrically for both traffic directions. Asymmetrical increase in the number of lanes may be allowed only in special circumstances after specific verification.

4.2.5 The natural environment, such as terrain and geology, is one of the major factors that influence highway design speeds. It is common sense that the selected design speeds shall fit the terrain, geology, and other natural conditions. Different from the traditional approach of one design speed for a very long segment as adopted in many previous projects, this clause requires that geometric parameters shall be closely related to design speeds in order to ensure the match of geometric design to terrain conditions along the highway and this shall be embodied in the early design stage when the highway is segmented for determination of design speeds. The change points of technical classification and design speeds shall be placed at proper localities to avoid design speed changes in normal segments. Item 2 of this clause gives recommended locations and positions for changing highway classification and design speeds. In addition, reference shall be made to the backgrounds of Clause 2.2.4 for design segments.

4.2.8 This clause indicates the overall principles for the selection of technical criteria and indicators of upgrading highways. Taking the characteristics of such projects into account, the design speeds and geometric criteria may be appropriately lowered in some of the segments subject to environmental constrains but their technical classifications shall not be lowered. For instance, a motorway segment, even though constrained by local environment, shall not be degraded to a class-1 or class-2 highway.

4.3.1 to 4.3.8 Based on the experience of highway development in China and the results of relevant research, this section summarizes the key points and tasks of highway projects under various environments and construction conditions, including:

the determination of the scope of the project

the selection of implementation method of a highway project

the connection modes of the project to the local road network and major traffic sources,

the selection of the roadway cross-sections,

the determination of the positions and modes of intersections,

the selection of geometric elements,

the layout of traffic devices and roadside facilities， and

the verification of upgrading or reconstruction

‘Implementation plan’ mentioned in these specifications refers to the method of implementation in sequential phases, roadway by roadway or segment by segment adopted depending on specific conditions.

4.3.4 The requirements in relation to ‘the building control areas’ of a highways shall refer to Regulations of Protection for Highway Safety (the Decree of State Council of the People’s Republic of China, No. 593).

4.3.5 Where the segment or segments of class-1 or lower class highway are near or through a city or town, the locations and modes of intersections shall be properly arranged based on environment, traveling needs and safety considerations. Isolation facilities shall be placed if it is necessary to reduce random crossing of pedestrian and non-motorized vehicles.

4.3.6 This clause gives the guidelines, including rules of placement, configuration criteria and scope of works, for traffic control devices and roadside facilities. It emphasizes that traffic control devices and roadside facilities are important components of a highway and shall be designed, implemented and operated along with the main works. Furthermore, the design of traffic control devices and roadside facilities shall follow the overall design strategies, account for relevant controlling and influencing factors, and be effectively combined with geometric design into a cohesive system. However, if the predicted traffic volumes in early stages are comparatively small, the roadside facilities may be implemented progressively in several phases under a holistic and once-for-all plan subject to specific assessment.

4.3.8 According to the results of relevant research projects and the nationwide investigations on upgrading and reconstruction of existing highways, this clause gives the basic principles to be followed in an overall design and the main points for determining traffic management, by-pass roads and flooding frequency. The utilization of existing highway subgrade, bridges, and tunnels shall be based on the assessment on the highway safety, examination and verification of the capacity, and reliability of these highway works.

4.4.1 to 4.4.4 This clause gives the principles of environmental protection that shall be carried out in a highway overall design, emphasizes the measures for environmental protection to be designed, implemented and put into operation at the same time as the main works of a project, and indicates the major points in terms of the selection of transportation corridor, alternative assessment, the arrangement of borrow pits and disposal sites, and the environmental restoration of the land temporarily used for construction purpose.

4.4.5 and 4.4.6 give key requirements for resource saving and material reutilization aiming to recycling and reclamation of water, steel, asphalt, and cement concrete pavement.

4.5.1 Experience in practice shows that the harmonization of the operating speeds, and the consistence of operating speed and design speed between adjacent segments are main factors influencing traffic safety. Design verification focus on these two aspects forth purposes of design adjustment and optimization hence may be conducted in multiple cycles if necessary.

4.5.2 In guidance of the requirements for road safety audit specified in JTG B02-2014, this clause stresses that the design shall be optimized and the facilities shall be improved in accordance with the conclusion of traffic safety assessment, including the proposed traffic management and speed control measures during highway operation stage. According to the relevant investigations and research, this clause pays special attention to the risky segments such as those on continuous and long steep grade and those at waterside or on a cliff or high embankment and gives corresponding guidelines for safety assessment and safety securing actions.

‘Continuous and long steep grade’ mentioned in this clause does not mean a specific grade, a certain length, or the combination of both. Instead, it is defined as a continuous segment with comparatively long lengths of comparatively steep grades, which may significantly reduce the passing opportunities and through capacity and affect the traffic safety according to detailed analysis and assessment on such a segment. The analysis and assessment on capacity and the impacts on traffic safety are related not only to geometric parameters such as grades and length of a segment but also to traffic volume, composition of vehicle types, performance of major vehicles and roadside interferences. Therefore, whether or not a specific road segment is a continuous and long grade depends on traffic safety assessment including geometric design optimization, adjustment to safety facility arrangement and proposed traffic management and control measures.

A segment ‘at waterside or on a cliff or high embankment’ mentioned in this clause refers to the situation in which the width of safety clearance at a road edge is narrower than that specified in JTG D81 Specifications for Design of Highway Traffic Safety Facilities.

5Highway Route Location

5.0.1 This Clause gives the whole process and the scope of works that shall be covered by highway route location.

5.0.2 A highway route is determined by a number of control points, such as the origin and destination of a highway route, the cities and towns that must to be interlinked with each other, the important sites, industry zones or mining quarries, and transport transfer centers, and localities of bridges, tunnels, interchanges, and railway crossings. Among these control points, some of them are identified by the project feasibility study as the places with high importance, which must be interlinked or passed by the proposed highway. They are the control points of primary orientation of a highway route, including the origin, and destination of a highway, the cities and towns that must be interlinked, important zones, mining sites and factories, transfer centers, and the particular extra-large bridges, particular extra-long tunnels. The macro-route proposal based on these major control points is defined as primary orientation of a highway route.

In between any two control points of the primary orientation of a highway route, there are some other points or localities in contribution to controlling roles, including ordinary extra-large bridges, ordinary extra-long tunnels, interchanges, railway crossings, pipeline crossings, a particular riverbank, a particular city corner, a particular hill saddleback or hillside and so forth. Such control points usually only affect the orientation of a certain part of a highway route. Therefore, the route proposal that is detailed by these control points is defined as the orientation of a highway route.

The location of medium bridges, small bridges, culverts, medium tunnels, short tunnels, and normal structural works do not play controlling roles in a highway route proposal. They shall follow the orientation of a highway route.

5.0.3 At different design stages, the task of route location is different from each other. Highway route location is a process of continuous selection and optimization as the design progresses. In practice, designers shall pay attention to these works from feasibility study to the design of construction drawings.

5.0.4 Many factors shall be taken into designers' account during highway route location and these factors may change significantly. Facing the same conditions, different designers may have different perceptions and give different solutions based on their own understanding and experience. Therefore, only general guidelines are presented based on practical experience in highway route location, which shall be used by designers as basic rules for the time being and shall be further improved in future. This Clause gives key points.

1This sub-Clause emphasizes the concept of highway function.

2 Comparison and assessment shall be done in a stepwise and cycling way from general outlines to specific details, that is from the national or regional network to a transportation corridor, and then further to a highway route.

3 A highway route location shall take into account the coordination with irrigation development, urbanization planning and mineral resource exploitation.

4 According the regulations of the national Land Administration Law, Article 4, the State applies a system of control over the purposes of use of land, and classifies land into land for agriculture, land for construction and unused land. It shall rigidly control conversion of land for agriculture to land for construction, keep the total area of the land for construction under control and give special protection to cultivated land. Land for construction means land for construction of buildings and other structures, including land for housing in urban and rural areas, for public utilities, for industries and mining, for communications and water conservancy, for tourism and for military installations.

Sub-Clauses 5 and 6：According to the Law on Protection of Cultural Relics, Article 3, 'Immovable cultural relics, such as sites of ancient culture, ancient tombs, ancient architectural structures, cave temples, stone carvings and murals as well as important modern and contemporary historic sites and typical buildings, may depending on their historical, artistic and scientific value, be designated respectively as major sites to be protected for their historical and cultural value at the national level, sites to be protected for their historical and cultural value at the provincial level, and sites to be protected for their historical and cultural value at the city or county level.' Because of the difficulties in determining the exact location and scope of an ancient cultural site or an ancient tomb, investigations shall be planned and executed according to the protection level of the site in order to avoid the possibility of passing through such sites, protect water sources and keep away from hazards.

7 The benefits of taking the existing road resources for further use in upgrading or reconstruction are obvious in terms of land use, time efficiency and environmental protection. The construction costs are considerably lower. It is encouraged to use the existing road resources in an upgrading project as far as possible and to combine the reconstruction with utilization of existing road works effectively.

5.0.5 Highway route location may be affected by many factors. Some of the important substantial requirements are summarized in this Clause.

1 The geological investigations and surveys are very important to identify the influencing level of the geological conditions on a highway route. Special attention shall be paid to the areas with adverse geology such as fault zones, soft ground, wetland, land above underground mines and where vulnerable to landslide, falling rock, collapse, debris flow, sinkholes, etc. The route of a motorway, a class-1 highway or a class-2 arterial highway usually shall divert from or bypass these areas. However, if it is unavoidable, a suitable location shall be selected to minimize the cross over segment and effective engineering countermeasures shall be arranged. For other classified highways and in the case of tight construction budget, bypassing should be considered as a priority.

2 Sensitive places such as schools, hospitals, recovery centers, and residential areas shall be investigated. The impact of a highway route on such places shall be reduced as far as possible. Natural resources are material bases for human survival and social development. Mineral resources are non-renewable and therefore a highway route shall avoid mineral resources wherever possible.

3 and 4 The function, location and service of a highway shall be coordinated with the connections to the control points of the highway route. The existing city ring-roads should be utilized or a new link road should be constructed as the connections of a highway to the traffic sources, such as seaports, airports, transit stations, cities and transfer centers, which shall also be coordinated with the relevant urban development plans.

5 As highway infrastructure rapidly develops, more highways are built in mountainous areas. In a highway route location, the positions and elevations of highway facilities, such as bridges, tunnels, interchanges and service areas, shall be arranged to ensure a coordinated interrelationship.

6 Designers shall handle the relationship of the highway with land occupation and other transportation modes, such as railways, electricity lines, and pipelines. Minimization of resource consumption is one of the important tasks in highway route location.

7 In plain terrain, higher technical indicators should be used, but a long tangent and a small deflection angle in a curve shall be avoided wherever possible.

8 The mountain passes in terms of location and elevation are key control points for route location in mountainous terrain. Designers shall assess comprehensively the natural environment in terms of terrain, geology, hydrology, weather and climate so as to determine the proper location of a mountain pass.

9 During the highway route location for a river (stream) bank route, assessment of the alternative of bridges parallel to the river flow direction and the alternative of road segments along the hill side shall be conducted depending on actual situation.

5.0.6 There are two methods of highway route location, one is a desk study and the other is field location. In order to ensure accuracy and adequacy this Clause emphasizes that the field verification must be conducted if a desk study location method is used for a motorway or class-1 highway.

Nowadays, CAD has been popularly adopted in highway survey and design practice, by which geometric design and its optimization have been significantly improved in contrast to traditional methods. However, as far as highway route location is concerned, CAD technology is regarded in concept as an extension to the traditional desk study method of highway route location. In this sense, field verification must be conducted where computer-aided highway route location is used.

5.0.7 New technologies such as remote sensing, aero-mapping, satellite positioning, and digitalized processing shall be used to improve the adequacy, accuracy and quality of investigations and surveys as well as to prevent feasible alternatives from being overlooked.

6 HIGHWAY CROSS-SECTIONS

6.1.1 Referring to Clauses 4.0.2 to 4.0.14 of *JTG B01-2014*, this Clause gives the provisions for main elements of a roadway cross-section stated in sub-clauses 1 to 3 hereof.

6.1.2 Highway functions, technical classification, traffic volumes and terrain conditions are major factors for determining roadway cross-sections of a highway.

1 Integral type and separated type are typical roadway cross-sections commonly used for motorways or class-1 highways. Designers shall select the type depending on local conditions in accordance with the project environment and land utilization. It would not be a good practice to take an integral type for granted just because otherwise the design process could be more complicated

2 According to the investigations and research on multilane motorways, especially the Research on Types of Roadway cross-sections for Multilane Motorways Under the Technical Action Program (Phase-1) of the National Road Safety, this edition of the specifications gives recommendations on the roadway cross-sections for dual 10 lane and more than 10 lane motorways, that is, the roadway of a dual 10 lane or more than 10 lane motorway may be separated into inner-roadway and outer-roadway. Referring to the practical experience in traffic operation on combined cross-sections of multilane motorways, it is recommended that the inner roadway should mainly accommodate the trough traffic or passenger vehicles, while the outer-roadways should mainly accommodate the local traffic and heavy vehicles.

3 Class-2, class-3 and class-4 highways are dual two-lane highways, of which some segments allow vehicles to use the opposing traffic lane occasionally for overtaking. Therefore, an integral roadway cross-section shall be adopted. In some of the segments where a separated roadway cross-section is used, traffic control shall be enhanced and special traffic signboards shall be placed to prevent vehicles from entering the wrong-way.

6.1.3 Highway technical classification, traffic volumes, traffic composition, and element functions are the major factors for determining the roadway cross-section of a highway.

1 Following the guiding policy in JTG B01-2014, this edition of the specifications made several changes to the last edition: detailed criteria on roadway widths of a classified highway were deleted, and the ‘double control’ on both overall width of roadway and the individual width of each component element, is not required. Instead, this edition only specifies the width of each element in a roadway and clarifies the considerations for selecting the width of each component element and their applications.

2 Following JTG B01-2014 and its supporting research, this edition permits that outer separations, non-motor vehicle lanes and sidewalks may be placed as needed on the segments with high density of non-motor traffic and pedestrians on a classe-1 or class-2 collector-distributor highway. The widths of these elements shall be included in the overall roadway width. The specific width of a

non-motor vehicle lane or a sidewalk may be determined in accordance with relevant industry specifications.

3 and 4 In the segments of a class-1 or class-2 highway where the proportion of slow-moving vehicles is high, the right hard shoulders may be used for the placement of slow lanes. According to past experience, this edition requires that physical separation facilities shall be installed in between a slow lane and its adjacent lane on a class-1 highway to mitigate the interference of slow-moving traffic to the traffic flow on normal lanes. For a class-2 highway, it requires a lane line to separate the slow lane from normal lanes and that the speed limit in such segments shall not be higher than 60km/h for the sake of traffic safety.

6.2.1 Lanes, or traffic lanes, are defined as belt elements arranged longitudinally for safe and comfortable travel on a highway. For traffic safety and comfortable driving, designers shall determine the widths to accommodate various vehicles traveling at different speeds in accordance with traffic composition and vehicle speeds. This edition gives specified lane widths corresponding to design speeds: 3.75 m for design speeds of 120km/h, 100km/h and 80km/h; 3.50 m for design speed of 60km/h and 40km/h; 3.25m or 3.00m respectively for design speed of 30km/h or 20km/h for dual two-lane highways; and 3.50m for design speed either 30km/h or 20km/h for dual single lane highways.

1 JTG B01-2014 specifies that for a highway with eight or more lanes, the inner lanes (the 1st and 2nd lanes adjacent to the median) accommodate passenger cars only and the lane widths may be 3.5m. This is related to the traffic control mode. A 3.5m lane width can only be used where vehicle control on lanes is practiced.

2 Where the traffic is dominated by medium or small passenger vehicles and the design speed is over 80km/h, 3.5m can be adopted as the lane width subject to the approval after specific assessment. These highways refer to tourist highways and airport highways.

3 The width of a slow lane shall be 3.5m wide, in which the width of right marginal strip is included.

4 The single-lane section of a dual Class-4 highway shall adopt the lane width of 3.5 m.

5 The width of a non-motor vehicle lane or a sidewalk shall be determined for actual situations and by referring to the relevant specifications for the design of urban roads for details.

6.2.2 The number of lanes in the segments of a motorway or class-1 highway shall be determined in accordance with predicted traffic volumes, design speeds, level of service and so forth, which shall not be less than four lanes and shall be increased in pairs and symmetrically on each side.

Both class-2 and class-3 highways are two-way, two-lane highways. Class-4 highways are either two-way two-lane or two-way single lane highway. A class-4 highway usually has two lanes and may have single lane where traffic volumes are small and physical conditions are extremely difficult.

The dynamic performance of a truck is comparatively lower than medium or passenger vehicles. Its operating speed is sensitive to upgrades of the highway. According to the results of Technical Studies for Highway Operating Speed Design, which was one of the projects under the Technical Research Programs for West China Transportation, the speed of a truck would be reduced significantly on an upgrade steeper than 2%. In contrast, the speed of a medium vehicle or passenger car would reduce on an upgrade more than 3%. In the case of a large proportion of trucks in mixed traffic, the highway capacity on upgrades is significantly affected and a climbing lane should be placed. Slow moving vehicles vulnerable to upgrade are accommodated on slow lanes so that the capacity of the highway segment can be improved and wrong-way overtaking can be reduced or avoid thus traffic safety is improved.

According to the conclusions of The Study on Key Technical Indicators and Parameters for Highway Engineering Projects (Phase 1 and Phase 2), the vehicle types and composition of highway transportation has changed significantly in the last decade. The dominant truck type on the highway has progressively changed from two axle trucks to 5 or even 6 axle articulated semi-trailers. This type of vehicles covers about 40% of the total truck population on motorways， and is responsible for 80% of the overall cargo turnover on motorways. However, the dynamic performance of this type of vehicles is very low and a power-to-mass ratio is about 5.1kw/t, reflecting that the climbing performance of the dominant cargo transport is much lower than before. In other words, given the same entry speed and segment upgrade, the climbing upgrade length, over which the dominant truck vehicles can keep moving at a speed not lower than the lowest speed limit, is much shorter than before; given the same segment upgrade, the stable running speed (or travel speed) which the dominant vehicles may maintain, is much lower than before as well. These facts increase the necessity of placing climbing lanes on continuous long and steep upgrades of a four-lane motorway or class-1 highway. The placement of climbing lanes is an effective engineering solution to solve the problems such as slow traffic and lower climbing performance caused by low-performance trucks， and thus improves the highway capacity on upgrades.

The Clause 4.0.8 of JTG B01-2014 stipulates that ‘for motorways, class-1 highways or class-2 highways, climbing lanes shall be placed on a long and continuous ascending grade if the highway capacity and operational safety would be affected.’ In practice, the designers shall take the factors such as real traffic volumes, vehicle type composition, dominant type of truck vehicle and its dynamic performance into account, analyze the impact on highway capacity and level of service, assess the necessity of placing a climbing lane, and then determine the position if such a climbing lane is needed.

As far as the placement of climbing lanes on class-2 highways, the investigations show that in mountainous terrain where the roadway of a class-2 or class-3 highway segment is 7.00 meters wide, the speeds of loaded trucks, especially the semi-trailers, reduce significantly and cause serious traffic queuing. On other hand, a typical case study shows that the traffic and safety conditions in a 4% segment of Guangzhou-Zhencheng class-2 highway have been significantly improved after a climbing lane is placed. According to published research, some countries also specify the placing of climbing lanes in segments where the upgrade is greater than 5%, reflecting the consideration that a design allowing significant speed reduction of the trucks, especially the semi-trailers, is inappropriate and such a problem can be effectively solved by placing climbing lanes for the sake of highway capacity and traffic safety.

1 Generally, climbing lanes may not be placed on six or more multilane highways. This is considered that the outer lane may accommodate the slow moving loaded trucks while inner lanes accommodate passenger cars traveling at normal speeds.

2 This edition clearly specifies that a right hard shoulder shall be placed abutting to the outer edge of a climbing lane on the ascending segment of a motorway or class-1 highway to provide a sufficient lateral clearance required for traffic safety. However, taking into account the facts that the terrain where a climbing lane is required is usually complicated and the operating speeds on a climbing lane are comparatively lower, this clause requires that the width of a right hard shoulder shall not be less than 0.75m. However, in such a case, a hard shoulder will not provide the function of temporary stopping for vehicles in difficulty.

6.2.4 An acceleration lane is a speed-change lane providing a distance required for vehicles to join into the main route without impeding through traffic. A deceleration lane is a speed-change lane providing a distance for vehicles to turn away from the main route without impeding through traffic.

Note that speed-change lanes at interchanges are quite different from those at service or rest areas, bus bays, administrative and maintenance facilities, etc. in terms of service functions and the requirements for placement. Some countries stipulate that width of a speed-change lane is 3.50m, which could be narrowed to 3.00m in difficult conditions. This clause gives general requirements of 3.50m in width. However, designer may make a decision on their own discretion based on local conditions and specific requirements.

Following the provisions as stated in Clause 4.0.7 of JTG B01-2014, this clause requires that transit segments shall be placed at various accesses to or from a class-2 highway.

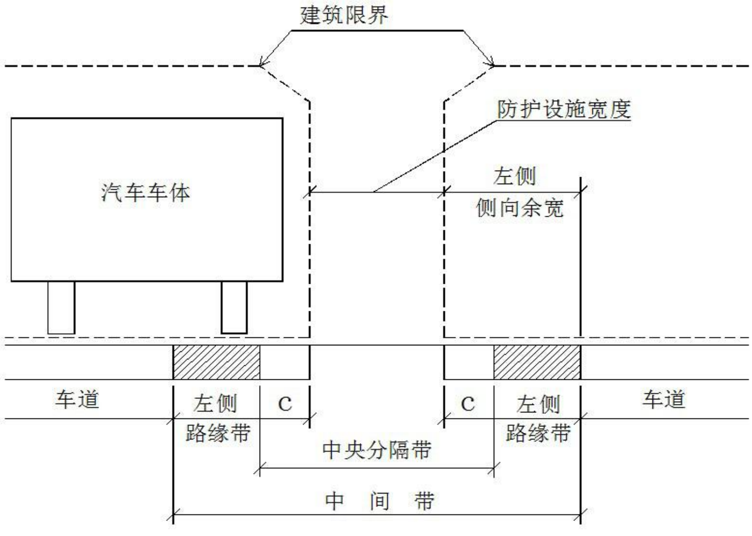
6.2.5 Passing bays on a two-way, single lane class-4 highway are placed for the passing of vehicles travelling in different directions, or the overtaking of vehicle travelling in the same direction.

6.2.6 The placement of emergency escape ramps shall be verified in conjunction with road safety audit. An emergency escape ramp may be placed beside a tangent segment or before the curve where a disabled vehicle could not safely follow the curve, and shall be kept away from residential areas in order to ensure the safety of other vehicles traveling on the main route and the people dwelling nearby.

JTG B01-2014 defines the purposes and functions of an emergency escape ramp as a special facility of self-preservation for the vehicles, whose braking system is out of control, to move out of the main traffic stream, and slow down to stop. In other words, the purpose of placing an emergency escape ramp is to allow disabled vehicles to move out from travelled-way as soon as possible to minimize resultant danger to other vehicles, people and facilities on the highway. Moreover, escape ramps also help the disabled vehicle to reduce speed and minimized damages from the incident.

Attention shall be paid to the use of emergency escape ramps. The placement of emergency escape ramps is a measure of fault-tolerance, which cannot reduce the probability of accident occurring due to failure of a vehicle breaking system although it effectively reduces the damages and losses possibly caused by such accidents. According to the supporting survey and investigation for this edition and the other research on the subject, the placement of emergency escape ramps shall not be regarded as a remedial methodology to solve the safety problems on continuous long and steep upgrades. Instead, the problems shall be solved by effective traffic management, segmental speed control and so forth.

The median and central dividing strip on a highway separates opposing traffic flows, and plays a critical role for driving safety and functional performance of the highway project. A median must be placed on motorways and class-1 highways with an integral roadway. A median consists of one central dividing strip and two abutting left marginal strips on each side. A central dividing strip consists of the space for barriers and two lateral clearance allowances C on each side, in which a left marginal strip and a clearance allowance C jointly serve as a lateral clearance necessary for driving safety while providing vehicle drivers with sight guidance. The geometric relationship of the above-mentioned elements is shown in Figure 6.1.



			Clearance profile			
Outline of Design vehicle			Space for barriers		Left-side lateral clearance	
Traffic lane	Left marginal strip	C	Central dividing strip	C	Left marginal strip	Traffic lane
			median			

Figure 6.1 Cross-section of a median

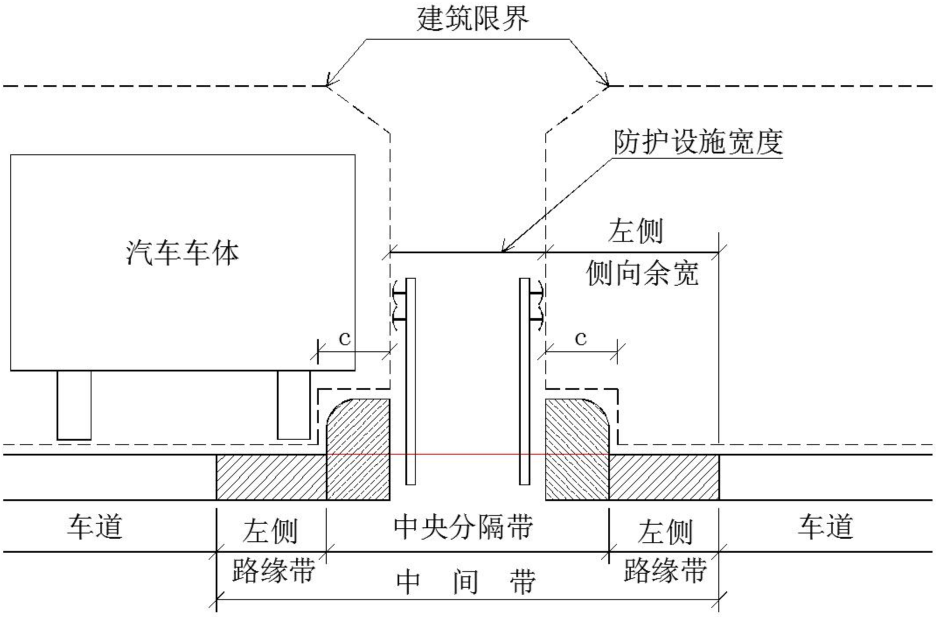
Lateral clearance is the space reserved on both edges of a traveled way for safety of the vehicles traveling at speeds on highway. It is the distance from the edge line of the travelled-way to any fixed obstruction such as roadside barriers, side slopes and so forth. According to the relevant empirical research, when vehicles move on a motorway at a certain speed, the minimum lateral clearance on the left and right edges of a lane shall follow the requirement as shown in Table 6.1. Where the left and right lateral clearances are less than the minimal values, a driver would be affected psychologically as well as by the tracking capacity of vehicles at high speed (the drifting amount). In such a case, a driver would involuntarily reduce the operating speed and thus affect the lane capacity. Adjacent lanes shall not be provided with lateral clearance because the lane width is wider than vehicle width and the time of travelling abreast is very short. Therefore, lateral clearances only relate to left lane and right lane at a specific cross-section of the same travelled way. In the layout of a roadway cross-section, the left-side lateral clearance is provided by the left hard shoulder (for separated roadways) or left marginal strip (for integral roadway) and the lateral clearance allowance, C. The right-side lateral clearance is usually provided by the right hard shoulder (including the width of right marginal strip).

Table 6.1 Lateral Clearance on a Motorway

Operating Speed （km/h）	Lane lateral clearance	
	Left (m)	Right (m)
120	1.25	1.75
100	1.00	1.50
80	0.75	0.75

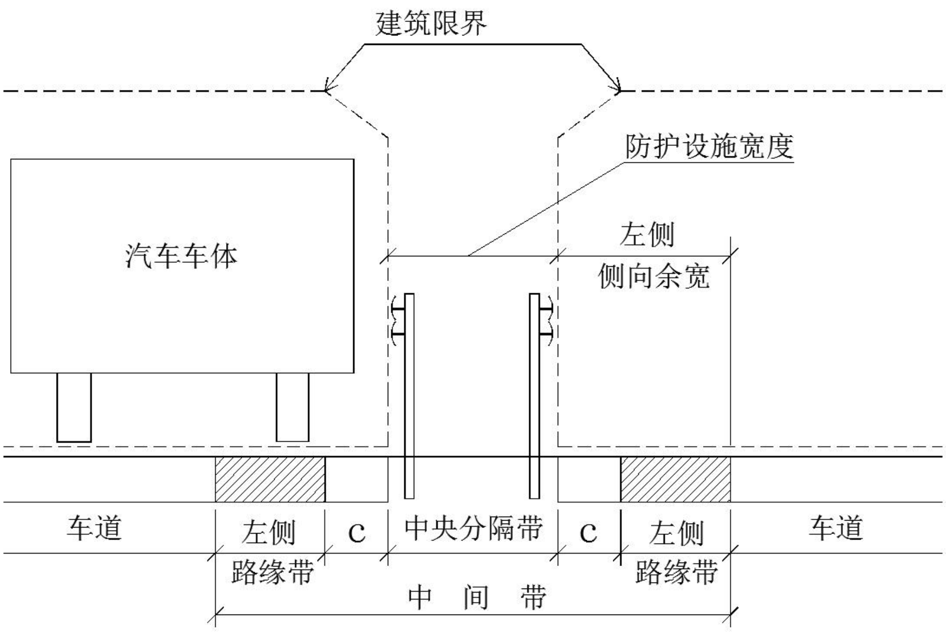
Earlier editions of highway standards and specifications did not give detailed criteria and relevant applications for lateral clearance allowance, C. Recent nationwide investigations indicate that the left marginal strip and left-side lateral clearance allowance C were adopted quite differently for median placement .It was found during the survey and investigations conducted for this edition that some of the previous projects took the width of C as an integral part of the median, while others did not. This edition clarifies that the width of C shall not be added if the width of left marginal strip adopted is greater than the left-side lateral clearance as specified in Table 6.1; if the normal value or minimal value listed in Table 6.3.1 is taken as the left-side lateral clearance, the width of C shall remain. The lateral allowance C is 0.50m where design speed is greater than 100km/h, or 0.25m where design speed is equal to or lower than 100km/h.

The value of lateral clearance allowance C may be taken by referring to Figure 6.2 to Figure 6.4.



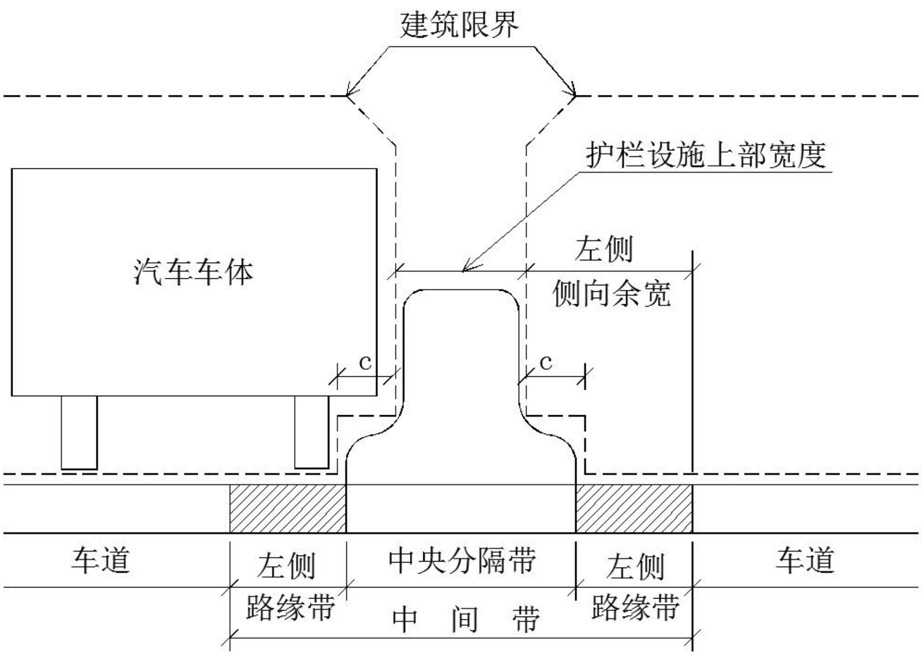
	建筑限界 Clearance profile			
汽车车体 Vehicle body		防护设施宽度 Spacing for barriers	左侧侧向余宽 Left-side lateral clearance	
车道 Traffic lane	左侧路缘带 Left marginal strip	中央分隔带 Central dividing strip	左侧路缘带 Left marginal strip	车道 Traffic lane
	中间带 Median			

Figure 6.2 Median with guardrails and curbs



	建筑限界 Clearance profile			
汽车车体 Design vehicle profile		防护设施宽度 Spacing for barriers	左侧侧向余宽 Left-side lateral clearance	
车道 Traffic lane	左侧路缘带 Left marginal strip	中央分隔带 Central dividing strip	左侧路缘带 Left marginal strip	车道 Traffic lane
	中间带 Median			

Figure 6.3 Median with guardrails but no curbs



	建筑限界 Clearance profile			
汽车车体 Design vehicle profile		护栏设施上部宽度	左侧侧向余宽 Left-side lateral	

		Top width of parapet	clearance	
车道 Traffic lane	左侧路缘带 Left marginal strip	中央分隔带 Central dividing strip	左侧路缘带 Left marginal strip	车道 Traffic lane
	中间带 Median			

Figure 6.4 Median with concrete parapet (Type F barriers)

This clause details the provisions of medians given in clause 4.0.4 of *JTG B01-2014*. The specified values for central dividing strips in the previous edition have been deleted for the reasons *as given in the backgrounds of JTG B01-2014*.

1 On a motorway or class-1 arterial highway, the width of central dividing strip shall be determined by the functional requirements such as for dividing opposite traffic flows, installing barriers, and so forth.

Subject to the requirements of the functions, the width of a central dividing strip shall not cause frequent changes in highway alignment and vehicles' wheel tracks due to its difference in bridge segments and road segments. On a highway with few bridges, different width of central dividing strip may be adopted for bridge segments. In such a case, transition segments shall be placed before and after the bridge segment. However, in the areas where the density of bridges is high, a constant width of central dividing strip shall be adopted for both bridges and road segments.

2 According to JTG B01-2014, the width of a class-1 collector-distributor highway shall be determined in accordance with the width of the median barriers. The functions of the median barriers mentioned here is mainly to separate opposite traffic flows. The protecting functions such as that against collision may not be required. The 'spacing for barriers', as shown in Figure 6-1, is the total width within which various median facilities are installed a class-1 collector-distributor highway. However, the lateral clearance allowance at the outer edge (on left) of travelled way shall be maintained.

3 Normal values shall be taken as the width of a left marginal strip under normal circumstances. Where design speed is 120km/ or 100km/h, the normal value, 0.75m, shall usually be taken. Where constrained by complicated terrain or important ground objects, or for inner lanes assigned only to accommodate small vehicles in a multilane highway, the minimal value, 0.50m, may be adopted subject to the approval of specific assessment.

6.3.2 The spacing of separated roadways refers to the distance between each roadway of a multilane highway where opposite traffic flows are divided by individually separated roadways. A left shoulder (including a hard shoulder and an earth shoulder) shall be placed at the left edge of each travelled way after the transition from integral type to separate type.

A certain space shall be kept between two roadways to install all necessary drainage and safety facilities as required. For a motorway or class-1 highway in less populated and desert areas, a broad median wider than 4.5m should be adopted which. The width of such a broad median is usually 6 to 15m wide between the adjacent edges of two roadways, and may vary depending on terrain and not necessarily be equal or fixed. The center area of a broad median in flat terrain should be covered with turf. The two roadways beside may be at different elevations so as to fit the terrain and landscape around. Side slopes within the median should be between 4:1 and 6:1declined towards middle for drainage.

6.3.3 Median openings are placed for vehicles to cross over the median, enter into and drive on the opposite roadway to implement repairs, maintenance, and emergency rescue. Spacing of median openings shall be decided based on actual needs, and this edition of the specifications just specifies that the minimum spacing shall be 2 km.

Removable barriers shall be placed at median openings to prevent unauthorized vehicles from turning around (U-turn movement). The anti-collision performance of movable barriers shall be the same as that of regular barriers for generic roadways.

6.3.4 Separated roadways shall be provided with cross-over links at a certain spacing to accommodate the needs of maintenance, repairs, and emergency rescue. The cross-over links are usually placed ahead of or after a tunnel portal, at both ends of a bridge, and relatively flat terrain areas.

6.4.1 According to JTG B01-2014，the ‘nominal value’ of a right hard shoulder on a motorway or class-1arterial highway is 3.00m, and the ‘minimum value’ is 1.5m, while that on a class-1 collector-distributor highway or a class-2 highway is 1.50m and 0.75m respectively, and the ‘minimum value’ is 0.75m and 0.25m respectively.

Under normal circumstances, the width of a hard shoulder shall take the ‘normal value’ specified in this clause. For segments with climbing lanes, speed-change lanes, or passing lanes, the ‘minimum value’ is used subject to the approval after specific assessment of restrained terrain conditions or multilane bridges. On a motorway or Class-1 highway where the adopted width of right hard shoulder is narrower than 2.5 m, which is inadequate for disabled vehicles to stop, the shoulder shall be supplemented by placing intermittent turnouts (widened sections of shoulder). Relevant details are given in Clause 6.4.3.

For motorways and class-1 arterial highways, where the dominant traffic is passenger cars (such as tourist highways and airport highways), the width of a right hard shoulder may be taken as 2.50m.

1 It is commonly recognized that the outer edge lines have a guiding function and partially provide lateral clearance to accommodate vehicle off-tracking, and thus increase traffic safety. Therefore, these specifications require that a 0.50m wide marginal strip shall be placed within the width of right hard shoulder.

2 In segments of a class-2 highway where non-motor traffic volume is large, the earth shoulder may be improved to accommodate the non-motor traffic by using a hard shoulder so as to safeguard the motor traffic on the travelled-way.

3 On-road facilities on a class-2, class-3 or class-4 highway must not intrude into the highway clearance profile. Otherwise, the subgrade shall be widened wherever necessary to increase the spacing for installing the facilities such as barriers, retaining walls and other vertically erected elements.

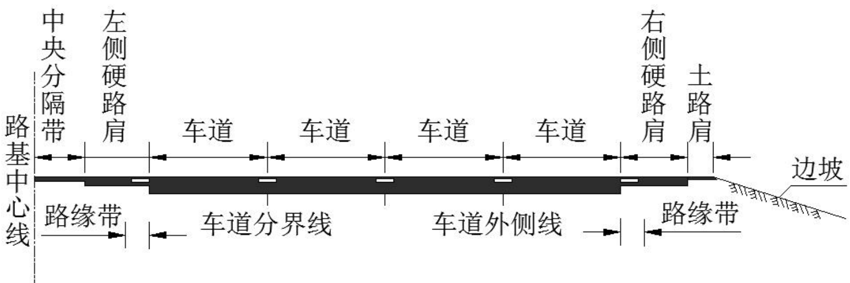
6.4.2 Left shoulder is one of the component elements of a roadway. Its width is closely related with highway classifications.

1Left shoulders shall be placed in separated roadways of a motorway or class-1highway to provide adequate lateral clearances required by moving vehicles. It is specified that a 1.25 m wide left hard shoulder shall be taken where the design speed is 120km/h; 1.00m shall be taken where the design speed is 100km/h and 0.75m shall be taken where the design speed is 80 km/h or lower.

The earth shoulder in separated roadways shall be 0.75 m where design speed is 80 km/h or higher and 0.50 m where the design speed is lower than 80km/h.

A marginal strip is a part of the shoulder and abuts to the travelled way, which guides drivers' sight, supports the pavement structure, and acts as a part of lateral clearance to ensure that the travelled way functions correctly. A marginal strip shall keep a certain width without much fluctuation. In the case of separated roadways, a 0.50 m wide left marginal strip shall be placed within the left hard shoulder and abut to the travelled way.

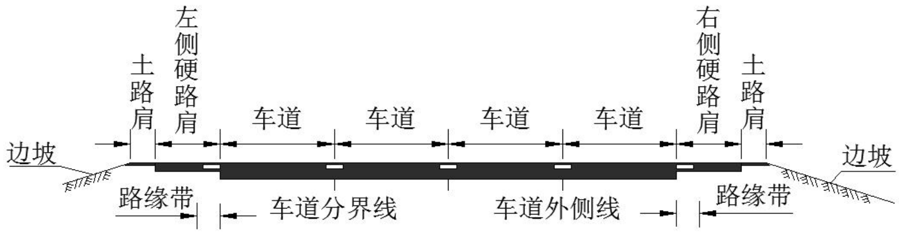
2& 3 On a dual 4 lane or 6 lane motorway (or one way 2 lane or 3 lane in the same traveling direction), if a mechanical trouble randomly happens to a vehicle, the vehicle needs to be maneuvered once or twice to change lanes in order to reduce its speed and stop on the right hard shoulder (which is one of the functions to be served by a right hard shoulder). Where there are 4 or more lanes in the same direction, the troubled vehicle needs to cross over three or more lanes before it stops on the right hard shoulder. The large number of lane-change maneuvers will not only increase the difficulties and running distance, but also cause adverse impacts on the other vehicles moving on the travelled way. According to the experience in other countries, this edition gives recommendations that a 2.5 m wide left hard shoulder should be placed on a motorway with 4 or more lanes in the same direction regardless of integral or separated roadways in order to provide troubled vehicles moving on inner lanes with a refuge for temporary stopping (see Figure 6-5 and Figure 6-6).



Centerline of roadway	Central dividing strip	Left hard shoulder	lane	lane	lane	Lane	Right hard shoulder	Earth shoulder	Side slope

	Marginal strip	Lane lines	Outer edge line	Marginal strip	

Figure 6.5 Left hard shoulder of a motorway (integral roadway)



	earth shoulder	Left hard shoulder	lane	lane	lane	Lane	Right hard shoulder	Earth shoulder	
Side slope	Marginal strip		Lane lines		Outer edge line		Marginal strip		Side slope

Figure 6-6 Left hard shoulder on a motorway (separated roadway on right)

6.4.3 Turnout is one of the main facilities provided for troubled vehicles to stop on, which plays a vital role in an emergency.

1 On motorways and class-1 arterial highways where the right hard shoulder is narrower than 2.50m, turnouts shall be placed for troubled vehicles to leave the travelled way as quickly as possible. On class-2 highways, turnouts may be placed in the segments with such needs.

The spacing between adjacent turnouts should not be longer than 500m. Designers must consider the distance over which a troubled vehicle may possibly move and the distance over which the troubled vehicle can be pushed by hand in the determination of the length of turnout spacing. According to experience, the most common problem that a vehicle encounters is a punctured tire, and the second most common defect is engine failure. The distance for a disabled vehicle to stop is directly proportional to the square of its traveling speed. The higher is the traveling speed, the longer is the stopping distance. The distance that a disabled vehicle may be pushed by hand is about 200 meters long or 500 meters at most. A large disabled vehicle may need 3 or 4 peoples to push over a distance much less than that of a passenger car, depending on the gradient of the road.

Transition sections shall be placed before and after a turnout for vehicles to move in and out. Usually the construction conditions are quite complicated in segments where turnouts are needed and there is a process of speed reduction before the troubled vehicle stops in a turnout. Taking cost efficiency and safety requirements into account, these specifications recommend that the lengths of a transition section before or after a turnout may be determined as the lengths of tapered sections of speed-change lanes for a design speed of 60km/h.

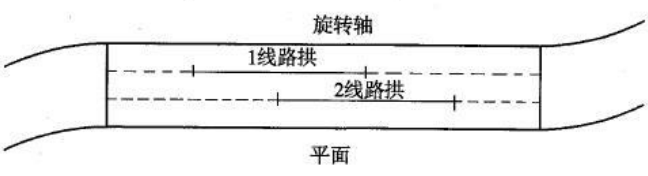
The widths of turnouts are quite different in application. The width of 5 meters and even wider have been adopted in some highways, which is good for traffic safety and convenient for vehicle stopping but might not be good for economic efficiency. Taking the costs and the practice in various districts onto account, the relevant requirement has been slightly relaxed to ‘the width of a turnout shall not be less than 3.5m’ in this edition in contrast to the previous edition ‘the width of a turnout shall be 3.5m’.

2 As far as the turnouts placed on super-large bridges or in extra-long tunnels are concerned, this sub-clause gives the requirements for motorways and class-1 highways only; for other situations, reference shall be made to Chapter 8 of JTG B01-2014.

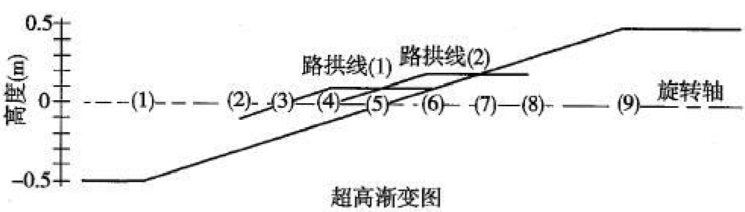
6.5.1 A normal crown, of which the highest point is in the middle and two downward slopes on both sides toward the road edges, is normally used for highways with no central dividing strip. For highways with a central dividing strip, the cross-slopes, of which the highest point at both edges of the median and downward to the edges of each roadway, are normally used.

6.5.2 On separated roadways, a crown may be used for each roadway to facilitate quick drainage of road surface water, while a single cross-slope may be used where the roadway is not wide. On the roadway with a central dividing strip, the cross-slope downward toward the roadway edges is normally used, on which drivers may feel more comfortable because the cross-slope is unchanged during a lane-changing maneuver. However, a road crown can be placed in each of the travelled ways in regions with seasonal snow and freezing.

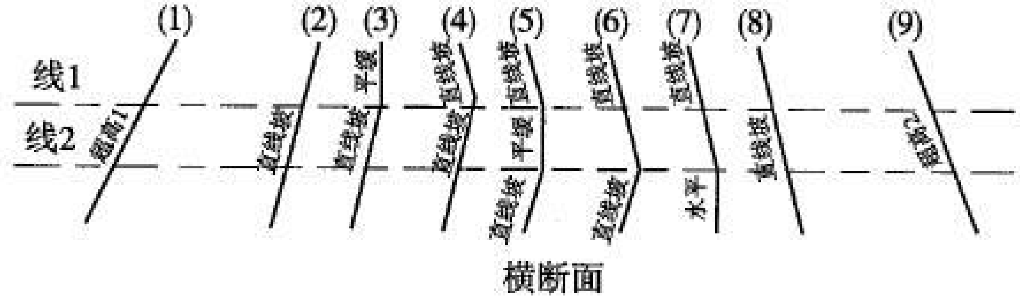
6.5.3 For six or more multilane highways, two road crowns, one on each travelled way, may be placed in the segments where the pavement is wide and the surface is flat，as shown in Fig. 6.7.



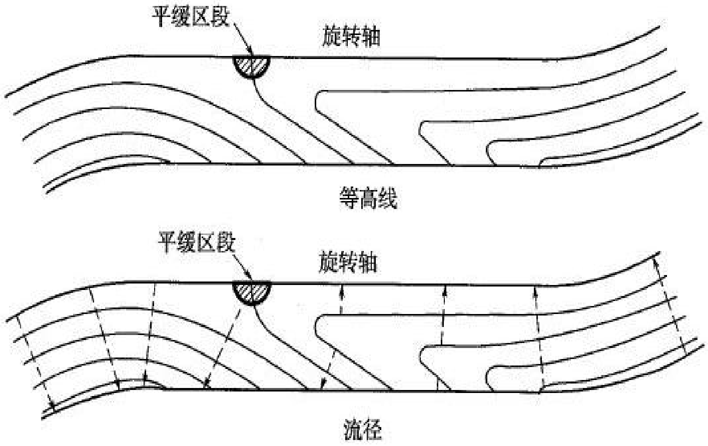
revolving axis
Crown on travelled way 1
Crown on travelled way 2
in plan



Height	Cross-slope transition (1)
	Cross-slope transition (2)
	revolving axis
Superelevation transition	



Crown (1)	Superelevation 1	Tangent	flat	tangent	tangent	tangent	tangent	tangent	Superelevation 2
Crown (2)	Superelevation 1	Tangent	Tangent	Tangent	flat / tangent	tangent	Flat	tangent	Superelevation 2
Cross-section									



Flat area	Revolving axis
Contour	
Flat area	Revolving axis
Water flows	

Figure 6.7 Diagram of two road crowns

During the investigations for this edition of the specifications, the phenomenon of standing water on the road surface were observed in some of the multilane motorways in wet areas, which has significant and adverse impact on traffic safety. Therefore, it is recommended that for the segments where the resultant road slope is flat, a drainage analysis should be conducted to identify and solve the problem of standing water on the road surface. A drainage analysis is usually performed either by plotting a contour map of the road surface and plotting the drainage flow diagram or by means of CAD software. According to the conclusions of *Prevention Technologies and Model Projects for the Highway Safety under Rainstorm Conditions in Hainan Province of China*, for areas subject to rainstorms, there is a high potential of water standing in the segments where the road cross-slope and superelevation transition become comparatively flat (especially where the cross-slope transitions from -2% to +2% and the rate of transition is less than 1/200). This kind of problems may be mitigated by adjusting the position of superelevation transition, increasing the rate of transition and adopting two road crowns.

6.5.4 A road crown with two downward cross-slopes shall be adopted for class-2, class-3 and class-4 highways. The cross-slopes may be determined in accordance with the type of pavement and local environment. Under normal circumstances, a lower value may be adopted for dry areas and higher values for rainy areas. For the areas subject to strong rainstorms, the cross-slope may be increased appropriately or the other type of road crown with a better drainage performance may be adopted.

6.5.5

2Thisedition made revisions on the cross-slopes of hard shoulders in terms of direction and magnitude. The same value as the adjacent pavement shall be adopted where the superelevation on a curve is equal to or less than 5%. This is for the convenience of construction. In such circumstances, the shoulder transitsions along with the pavement and the width of revolving extends to full width of the shoulder. Where the superelevation for a curve is great than 5%, the cross-slope of a hard shoulder shall not be greater than 5% otherwise a fully loaded truck may not be stable to stop on it. In the highway segments with gentle grades and water curbs for channelized drainage, the cross-slope of hard shoulders should be 3% to 4%. The transition rate in terms of cross-slopes on a flat segment or on a tangent-curve transition section shall be controlled within a range greater than 1/330 but less than 1/150, or from 0.3% to 0.7% for a transition section in order to meet the requirements for drainage.

4 For an earth shoulder on a tangent segment or on the lower edge of a curve segment, the cross-slope shall be the same as that of travelled way or hard shoulder if it is equal to or greater than 3%， or shall be 1% or 2% greater than the cross-slope of the travelled way or the hard shoulder if it is less than 3%. For the earth shoulder on a curved segment or on the higher edge of a transition section, a reverse cross-slope of 3% or 4% shall be adopted.

The revisions in this Clause are made in accordance with Section 3.6 ‘Clearance profile’ of JTG B01-2014.

The revisions in this Clause are made in accordance with Clause1.0.5 ‘Clearance profile’ of JTG B01-2014.

7 HIGHWAY HORIZONTAL ALIGNMENT

7.1.1 In JTG B01-2014, Clause 4.0.19 specifies ‘a transition section shall be placed where a tangent section links to a circular curve section which has a radius smaller than the minimum radius of circular curves without superelevation as listed in Table 4.0.17. Such a transition section shall be a spiral curve and in compliance with the criteria below…..’ Using spirals as transition curves in highway alignment is because the wheel tracks of vehicles moving in and out of a circular curve segment are close to spiral curves. Therefore, it may express that highway horizontal alignment consists of three elements, namely tangent, circular curve and spiral curve. However, because of low design speeds, spirals may not be placed on class-4 highways.

Basic equation of a spiral is as follows

$$r \times l = A^2 \qquad (7.1)$$

Where r ——radius at a point on the spiral curve;

l——length of curve from the point on spiral to the origin (m);

A2——parameter of spiral.

In practice, placing and computation (such as computing the coordinates and mileage of a highway route stake) of highway horizontal alignment, a spiral curve is calculated by a series expansion as expressed in Equation (7.2), of which the number of series items may directly affect the accuracy of the calculation. Taking the spiral parameter A as determined, the longer the spiral the more items are required to meet the accuracy. Therefore, the calculation for placing a horizontal alignment, no matter whether by manual or CAD software, shall be conducted by taking necessary number of series items that are required for the desired accuracy.

In some textbooks, a spiral is usually simplified to a cubic or higher order curve for an approximate calculation. It is for the convenience of learning calculation principles and methods, but may not meet the accuracy requirements of modern technology and CAD design and mapping, especially when the calculation and mapping error of center and edge stakes in a CAD context shall be as high as 1mm, or even higher. In principle, the accuracy for a spiral and horizontal alignment, as shown by Equation (7.2), shall conform to the details specified in prevailing Specifications for Highway Survey and Investigation (JTGC10).

$$\begin{cases} x = L_S - \frac{{L_s}^3}{40R^2} + \frac{{L_s}^5}{3\,456R^4} - \cdots \\ y = \frac{{L_s}^2}{6R} + \frac{{L_s}^4}{336R^3} + \frac{{L_s}^6}{42\,240R^5} \cdots \end{cases} \quad (7.2)$$

x—x axis of a point on spiral;

y— y axis of a point on a spiral;

Ls—the length of a spiral (m)

R— curvature radius of a point on spiral.

This Clause only discusses the types, characteristics, the ‘normal values’, and ‘minimum values’ of indicators. The application and combination of these indicators are discussed in Chapter 9 of ‘Geometric Design’.

7.1.2 The design parameters and criteria for horizontal alignment shall be selected in accordance with highway classification, design speeds, local social and natural environment, exploiting the advantages of tangents, curves, effective combination of vertical and horizontal parameters, and its harmonization with site terrain, landscape and environment.

7.2.1 Tangent, or straight line, is one of the basic elements of a horizontal alignment. A tangent characterizes as the shortest link between any two control points and a convenient application for alignment selection. However, there is limited scope for change and has low adaptability to the terrain environment. In mountainous terrain it is very difficult or even impossible to use or could be very costly to use a tangent alignment. On motorways and class-1 highways where vehicles travel at high speeds, drivers on a long tangent alignment may easily become bored, tired, or find it difficult to judge the spacing between vehicles. In addition, tangent alignments increase glare from the opposite direction at night and induce speeding during the daytime. For these reasons, designers shall be prudent and careful to select a long tangent alignment.

In some countries conditional constraints are practiced. For example, curve alignments dominate in motorways in mountainous countries like Italy and Japan. Japan and Germany require that the length of a tangent segment should not be longer than 20 times the design speed, travelled during 75s. Spain suggests that a tangent segment should not be longer than the distance travelled during 90s at 80% of the design speed. In France, it is considered that a long tangent should be better replaced by a circular curve with a radius larger than 5000m. United States suggests that an alignment should be as straight as possible as long as it matches the terrain. Although there are no requirements for tangent alignment and no access control on some express arterial roads in Russia, measures such as adopting wide medians, lower embankment, and gentle side slope are provided to improve traffic safety.

Research suggests that practitioners in various provinces have different opinions on application of tangents and there are cases of tangent segments constructed much longer than 20 v (times design speed). It does not matter that tangent alignment is good or bad, the importance depends on how to apply the design guidelines to match the local terrain. Therefore, these specifications do not give limitations on the maximum length of a tangent segment, but only states that 'the length of a tangent should not be very long' and leaves space for designers to analyze and judge at their own discretion.

In the cases where a long tangent segment has to be adopted due to restrictions of the environment, the designer shall make reference to the operating speed analysis and safety assessment, and arrange additional traffic control measures or warning signs to prevent drivers from becoming fatigued.

7.2.2 The requirement that the length of a tangent between circular curves should not be too short is based on the need for alignment continuity. The modal verb 'should' expresses option for this priority. It is a good guideline for alignment design for a multilane highway under high design speeds. For highways where design speeds are lower, the requirement 'may be applied' reflects a lower degree of flexibility in the sense of wording.

The judgment and assessment of the length of a tangent between two circular curves are closely related to the selected technical criteria, design speed and the geometric indicator values used for the adjacent road sections. In the context of new technology, designers may be able to diagnose potential problems in the alignment design by establishing a 3-D model for the highway and its surrounding environment, using driving simulation and BIM methodology to verify and assess the sight distances and other controlling parameters, and to carry out intuitive analysis and assessment on the continuity of alignment. In addition, the operating speed coordination assessment is another intuitive and effective method commonly used in alignment continuity assessment because the changes of operating speed between adjacent segments is the reflection of a driver from identifying and responding to the geometric alignment, and thus reflect the description of the alignment continuity and consistency.

Minimum radius is based on the condition that a vehicle can travel in a safe and comfortable manner on a curved highway segment. Minimum radius defines that the centrifugal force experienced by a vehicle moving on a curve does not exceed the limit friction force between vehicle tires and road surface. The 'limiting values' and 'normal values' given here define different levels of driving comfort. Where design speed v is determined, the minimum radius Rmin of a circular curve depends on the desired values of the side force factor f and superelevation i. Considering psychological capacity and comfort levels, where the desired $f < 0.1$, road users may not feel the existence of a curve; where $f = 0.15$, road users may feel the existence of curve but travel is still stable and smooth; where $f = 0.20$, road users feel the existence of curve and feel unstable; where $f = 0.35$, road users feel the curve and experience instability; and where $f>0.40$, road users feel the instability with even the danger of overturning. The limit minimum radius can be derived in accordance with the maximum side force factor fmax and the maximum superelevationimax.JTG B01-2014specifies that the minimum radii are defined as the ‘limiting values’ derived where the maximum superelevation is 8%.

‘Normal value’ of minimum radius of a circular curve is the value suggested for the radius on which a vehicle can travel comfortably and safely at the design speed. According to empirical data, the side force factors taken for determining the ‘normal values’ of minimum radius of a circular curve is about 0.05 to 0.06, with which normal value of minimum radius is derived by calculation and rounding off.

Under the same design speeds, if the value of maximum superelevation is taken differently, the minimum radius (limiting value) of a circular curve will be different. This edition, as required in JTG B01-2014, added (actually put back) limiting values of minimum radii corresponding to maximum values of superelevation.

7.3.3 Driving on a circular curve with large radius, the driver may not need to adjust the steering wheel and it feels as if driving on a tangent. Where the radius exceeds 9,000m, the visual effect within a distance of 300-600m on which the driver’s sight focus is not different from that on a tangent. Therefore, the radius of a circular curve shall not be very large.

7.4.1 The minimum radii for non-superelevated curves are the results of the calculation by taking side force factor (f = 0.035), and rate of superelevation (I = -0.0015).

Considering the situation that the cross slopes may be 2% or steeper, this edition adds the criterion on the minimum radii for non-superelevated curves where the crossfall is over 2%. In practice where the cross slope of 2% is adopted, a larger value should be taken for non-superelevated curves wherever possible.

7.4.2 The critical radius of smaller circle in a compound circular curve is determined as follows.

(1) The minimum length of a spiral is the distance travelled in 3s;

(2) The inner shift of the spiral for smaller circular curve is less than 10cm as required by driving dynamics.

In these specifications, a spiral can be eliminated from a compound curve if the difference in inner shifts of two circular curves is less than 0.10m. This is because it is more difficult for a driver to operate the steering wheel to transit from one circular curve to another than that from a tangent to a circular curve. This edition still specifies that a spiral can be eliminated if the ratio of radii of the two circular curves is less than 1.5 where the design speed is 80km/h or higher. This is slightly higher than that recommended in Australia. It is argued that the difference of inner shifts will be no more than 0.10m as long as the ratio of radii is smaller than 1.5. However, a higher ratio gives a wider choice for the combination of radii in a compound curve.

7.4.3 The minimum length of a spiral is usually adequate for the length of transition section superelevated by revolving a two-lane traveled way about the centerline of. However, in the case of revolving about the edge of traveled way, wide roadway, either multilane or wide shoulders, the transition section required for superelevation may be slightly longer. Therefore, the longer length derived from the calculation results shall be used.

7.5.1 The purpose of placing superelevation on curves of which radii are smaller than the specified values for non-superelevation is to generate centripetal force to offset the centrifugal force of the vehicles traveling on a curve at high speeds. Curve superelevation is related to vehicle traveling speeds and side friction force. Side friction force has a negative impact on the stability of moving vehicles and motorist comfort. The design of superelevation and calculation of superelevation rates shall attempt to minimize the side friction force. For a given design speed, the value of maximum superelevation mainly depends on the radius of curve, texture of road surface, and local weather conditions. In the United States, the maximum superelevation in ice-free areas is usually taken as 10%, or 12% at most; and 8% at most in wet and seasonal freezing areas taking into account that large superelevations may cause vehicles to slide inward on icy pavement. Australians consider that on segments with large superelevations, the vehicle travelling at a speed lower than the design speed will be subject to the effect of centripetal acceleration; if the superelevation is as high as 10%, the action of centripetal force may cause a vehicle to move sideways or even cause overturning.

According to the specific research on 'Side Forces on Highway' for JTG B01-1997 and referring to the experience in other countries, this edition of the specifications specifies that the maximum superelevation for motorways and Class-1highways are 8% and 10% respectively, and 8% for normal circumstances. Furthermore, the maximum superelevation for motorways and Class-1 highways that are mainly for medium and small passenger vehicles shall be 10% while that for Class-2, -3 and -4 highways should be 8%. However, considering the high proportion of truck traffic in China, it is recommended to take 6% as the maximum superelevation for safety in seasonal freezing areas. In this edition, the requirements for urban areas have been included and proposed as 4%, the same as specified in JTG B01-2014, referring to factors including non-motorized traffic, pedestrian and urban drainage.

7.5.2 The segments of a class-2, class-3 or class-4 highway near cities or towns, where mixed traffic volumes are large, the traveling speed would be somehow reduced and large superelevation is not allowed for urban road drainage. Therefore, the maximum superelevation shall be reduced appropriately.

7.5.3 In a design project, designers shall determine the maximum superelevation to be adopted for the project first and then calculate and determine the full superelevation in accordance with design speeds and radii of circular curves. Where the design is to be checked by operating speeds, the values of superelevation to be adopted shall be calculated and determined in accordance with operating speeds and radii of circular curves.

Table 7.1 shows the full superelevation, which is derived by calculation where maximum superelevation is taken as 10%, 8%, 6% respectively and the cross slope of normal crown taken as 2% for seasonal ice and snow conditions, as designers' reference.

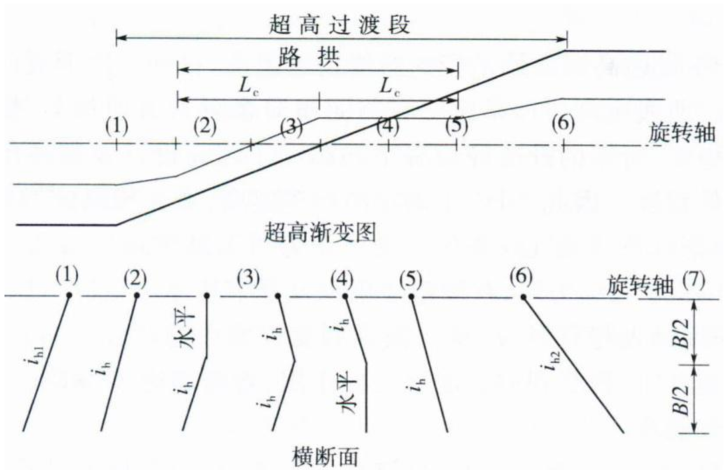
Table 7.1 Radii of Circular Curves and Full Superelevation

Design speed (km/h) / Superelevation(%)		120				100				80				60				
		Normal circumstances			Snow &Ice	Normal circumstances			Snow & Ice	Normal circumstances			Snow & Ice	Normal circumstances				Snow &Ice
		10%	8%	6%		10%	8%	6%		10%	8%	6%		10%	8%	6%	4%	
Superelevation(%)	2	5500 (7550) ~ 2950	5500 (7550) ~ 2860	5500 (7550) ~ 2730	5500 (7550) ~ 2780	4000 (5250) ~ 2180	4000 (5250) ~ 2150	4000 (5250) ~ 2000	4000 (5250) ~ 2090	2500 (3350) ~ 1460	2500 (3350) ~ 1410	2500 (3350) ~ 1360	2500 (3350) ~ 1390	1500 (1900) ~ 900	1500 (1900) ~ 870	1500 (1900) ~ 800	1500 (1900) ~ 610	1500 (1900) ~ 860
	3	2950~ 2080	2860~ 1990	2730~ 1840	2780~ 1910	2180~ 1520	2150~ 1480	2000~ 1320	2090~ 1410	1460~ 1020	1410~ 960	1360~ 890	1390~ 940	900~ 620	870~ 590	800~ 500	610~ 270	860~ 570
	4	2080~ 1590	1990~ 1500	1840~1340	1910~ 1410	1520~ 1160	1480~ 1100	1320~ 920	1410~ 1040	1020~ 770	960~ 710	890~ 600	940~ 680	620~ 470	590~ 430	500~ 320	270~ 150	570~ 410
	5	1590~ 1280	1500~ 1190	1340~ 970	1410~ 1070	1160~ 920	1100~ 860	920~ 630	1040~ 770	770~ 610	710~ 550	600~ 400	680~ 490	470~ 360	430~ 320	320~ 200	—	410~ 290
	6	1280~ 1070	1190~ 980	970~ 710	1070~ 810	920~ 760	860~ 690	630~ 440	770~ 565	610~ 500	550~ 420	400~ 270	490~ 360	360~ 290	320~ 240	200~ 135	—	290~ 205
	7	1070~ 910	980~ 790	—	—	760~ 640	690~ 530	—	—	500~ 410	420~ 320	—	—	290~ 240	240~ 170	—	—	—
	8	910~ 790	790~ 650	—	—	640~ 540	530~ 400	—	—	410~ 340	320~ 250	—	—	240~ 190	170~ 125	—	—	—
	9	790~ 680	—	—	—	540~ 450	—	—	—	340~ 280	—	—	—	190~ 150	—	—	—	—
	10	680 ~570	—	—	—	450~ 360	—	—	—	280~ 220	—	—	—	150~ 115	—	—	—	—

7.5.4 Transition rates of superelevation shall range from 0.4% to 2.0%. The length of a superelevation transition section can be calculated by using Equation (7-3) after the axis of rotation and the full superelevation are determined. However, for highways with hard shoulders, the value B for s hard shoulder revolving with the traveled way should be taken into account, and thus the length of the superelevation transition section will be extended accordingly.

7.5.6 The transition rate on an overlong spiral might be too small to drain surface water on a curved segment. Taking 0.3% as the minimum slope for drainage, the transition rate for superelevation must not be less than 0.3%, that is, 1/330.

On a motorway or class-1 highway where the traveled way revolves about the outer edge of the median, the surface drainage may not be sufficient due to a wide traveled way and gentle grade even if the transition rate is greater than 1/330. In order to avoid such unfavorable situations, relevant measures could be applied including reducing the length of the superelevation transition, increasing the transition rate of the superelevation, placing the superelevated section only on a part of the spiral, and placing an additional crown line in the middle of the traveled way to reduce water flow distance. One or two additional crown lines maybe placed for improving drainage. Therefore, these specifications require that 'more crown lines should be added on a six or more multilane highway' in order to improve surface drainage, as shown in Figure 7.1.



	Superelevation transition Cross slopes Axis of rotation Superelevation Transition Diagram Axis of rotation flat Cross Sections

Fig. 7.1 Superelevation with additional crown lines

7.5.7 Highway superelevation transition should be a linear relationship as shown in Equation (7.3):

$$L_c = \Delta_i \cdot B/P \quad (7.3)$$

Where Lc—the length of superelevation transition section;

$\triangle i$— the difference of the superelevated cross slopes to the normal crown

B— the width from the axis of rotation to the outer edge of traveled way (or right marginal strip if there is one).

P — transition rate of superelevation.

7.5.8 Refer to the provisions and background of Clause 6.5.3 and the background of Clause 7.5.6.

7.5.9 On segments on steep grade of a divided multilane highway, the operating speeds on upgrade and downgrade could be quite different from each other, and thus different superelevations may be used for traffic safety.

7.6.1 When a vehicle is making a turn on the circular curve with a small radius, its front wheels and rear wheels will not be on the same tracks. Because the outline of a vehicle is a rigid rectangular shape, part of the vehicle body would traverse out of the traffic lane and lean outwards due to centrifugal force. The widening on circular curves is to provide the turning vehicles with sufficient space. Table 7.2 gives the values of pavement widening for five design vehicles and Table 7.6.1 is a simplified format for practical convenience, in which no specific values are given for large and articulated buses because they are quite similar to the situation of articulated trailers.

Table 7.2 Values of Pavement Widening for Two-lane Highways

Design Vehicle	Axle spacing plus Front suspension (m)	Radius of Circular Curve								
		250~200	<200~150	<150~100	<100~70	<70~50	<50~30	<30~25	<25~20	<20~15
Passenger car	4.6	0.4	0.5	0.6	0.7	0.9	1.3	1.5	1.8	2.2
Trucks	8.0	0.6	0.7	0.9	1.2	1.5	2.0	—	—	—
Large bus	9.85	0.7	0.9	1.3	1.8	2.4	3.8	—	—	—
Articulated bus	7.5+6.7	0.8	1.0	1.4	1.8	2.5	—	—	—	—

Articulated trailer	5.38+9.05	0.8	1.0	1.5	2.0	2.7	—	—	—	—

(1) For 2, class-3 and class-4 highways, the widening values are closely related to design vehicle types and functional categories. Attention shall be paid to the corresponding design vehicle types when Table 7.6.1 of these specifications is used for selecting values of pavement widening of two-way two-lane highways.

(2) For class-2 and class-3 arterial or collector-distributor highways, articulated trailers shall be taken into account. Sometimes only trucks may be considered for road widening if the traffic of articulated trailers is low. For class-3 and class-4 local highways, truck traffic shall be considered for road widening.

(3) The widening values for articulated buses shall be adopted for highway segments with regular routes of articulated buses in urbanized areas.

(4) Widening values for articulated trailers shall be adopted for special highways which regularly accommodate large semi-trailers for container transport. Calculation and verifications on the widening for large and over-long cargo vehicles should be conducted for the linking highways such as those to ports and trans-shipment yards.

7.6.3 For a divided highway, the inner side and outer side of its traveled way shall be widened individually. The two lanes in the same direction shall be widened equally. However, the two lanes in different directions may be widened equally if the widening values are small, or shall be widened individually with the widening values determined by specific calculations where the widening value is large.

7.6.5 For traffic safety, widening transition shall be gentle, smooth, and free of kinks. The mode of widening transition may be either in a linear tangent or in a high order parabola. Usually, a biquadratic parabola is adopted as the widening transition shape for motorways, class-1 highways and other highways with a high standard for road appearance, as expressed by Equation (7.4). In some cases, a linear transition can be used as transition shape for class-2, class-3 and class-4 highways, as expressed by Equation (7.5).

$b_x = (4k^3 - 3k^4)b$ （7.4）

$b_x = k \cdot b$ （7.5）

Where $k = {}^{L_x}/_{L}$

Lx—Stake distance (at any given point) to the start point of a widening transition section (m).

L — length of the widening transition section (m);

b — full value of widening on circular curve (m);

bx—widening value at a stake (any given point), (m).

7.7.1 No spiral curve but a superelevation/widening transition section shall be placed as specified. Section 7.5 of these specifications shall be complied with where only superelevation and widening is required; and Section 7.6 of these specifications shall be followed where only widening but no superelevation is required.

The total length of a horizontal curve shall not only accommodate spirals or superelevation/widening, but also reserve a part of a circular curve to provide vehicles with a smooth driving transition from one curve (or tangent) to the next. The minimum length of a horizontal curve on a classified highway shall be controlled as twice the minimum spiral length, which is actually an extreme state of a ‘spiral-spiral curve’, and would make the drivers feel uncomfortable in terms of driving and visual conditions. Therefore, the minimum length of a horizontal curve shall theoretically be at least 3 times as long as the minimum length of a spiral.

Horizontal curves of a classified highway shall not be too short. Taking the requirements for alignment design into account, the appropriate length of a horizontal curve should be 5 to 8 times the minimum value in length, that is1000m to 1500m long. In these specifications, the listed 'normal values' are three times the 'minimum values' in length of horizontal curves.

7.8.2 Small deflection angle and large radius curves in the horizontal alignment design are a concession to the environmental constraints. Placing a large radius curve with a small deflection angle is caused by the specified length of curve, otherwise the route would appear like a kink and the curvature looks much larger than it actually is. Because of this shortcoming and taking diversified opinions in its application into account, these specifications extend the range of small deflection angles to the angles between 7° and10° , which are not used in design if possible.

Taking 7o as the critical angle that may induce visual illusion is based on empirical evidence. The visual problem can be solved by selecting a suitable curve radius or placing a long enough curve. Thus, the limitation for minimum length of the curve with a small deflection angle is given in these specifications.

7.9.1 Stopping sight distance comprises two components. One is the distance over which a vehicle moves during driver's response time; and the other is the braking distance over which the vehicle moves during the time from starting to brake till full stop.

$$s_{停} = \frac{v}{3.6} t + \frac{(v/3.6)^2}{2gf_1} \quad (7.6)$$

Where f1—— coefficient of longitudinal friction, depending on vehicle speed and condition of pavement surface;

t——Driver's responding time, taken 2.5s (1.5 seconds for judging and 1.0 seconds for reacting) .

The stopping sight distance of passenger cars under damp condition calculatedby using Equation (7.6), is shown in Table 7.3.

Table 7.3 Stopping Distance of Passenger Cars under Damp Conditions

Design speed (km/h)	Running speed (km/h)	f1	Computed Value (m)	Value specified (m)
120	102	0.29	212.0	210
100	85	0.30	153.7	160
80	68	0.31	105.9	110
60	54	0.33	73.2	75
40	36	0.38	38.3	40
30	30	0.44	28.9	30
20	20	0.44	17.3	20

Braking-stop distance may vary on grades. The computed values in Table 7.3 are derived on level pavements with a grade of 0%. These values underestimate stopping distance on down-grades and are conservative for up-grades. However, the specified values contain a certain allowance, and thus traffic safety is ensured.

On motorways and class-1 highways, only the braking stop sight distance needs to be considered for vehicles traveling in the same direction since there is no interference from opposite traffic because of the median.

7.9.2 For two-way class-2, class-3 and class-4 highways, it is considered that two vehicles moving towards each other in opposite directions will brake to stop simultaneously. Thus, the passing distance shall not be shorter than twice the stopping sight distance corresponding to the design speed. In cases where terrain is a constraint, and the passing sight distance cannot be fulfilled, stopping sight distance may be used but traffic dividing measures such as road markings shall be provided to prevent overtaking.

7.9.3 Overtaking sections shall be provided on two-way two-lane highways. Because the length of distance for overtaking is quite long, it could be difficult to apply on class-3 and class-4 highways to conform to the overtaking requirements over the highway length. Thus, such a highway may be divided into segments, some of the segments are allowed for vehicle overtaking and the others are not allowed.

A certain number of overtaking sections should be provided on the class-2 arterial highways where traffic volumes are large. The number of over-taking sections may be reduced if traffic volumes are not large. No-overtaking signboards may be placed in mountainous terrains. Usually, at least one over-taking section shall be provided within a length of road equivalent to the distance traveled in 3 minutes at the design speed. The total length of overtaking sections shall not be less than 10% to 30% of the total length of the highway route.

Specific and relevant road markings and signboards shall be placed on the overtaking sections and no-overtaking sections.

7.9.4 Trucks may have performance shortcomings such a spoor braking performance when unloaded, non-uniformity of load distribution among truck axles, out-of-balance caused by sliding of one axle, and brake failure of articulated trailers. Trucks usually need a longer stopping sight distance than passenger cars, although truck drivers have relatively higher sight position and longer sight distance.

The driver’s sight position is at 2.00 meters height, the height of an object is 0.10 meter, and sight verification shall be executed for the following highway segments.

(1) Deceleration lane and its exit end;

(2) Down-grade segments of a main route where the radii of vertical curves are smaller than normal values.

(3) The traffic merging or diverging segments, and the segments where the number of lanes is reduced and the radii of vertical curves are smaller than normal values.

(4) The segments where the radius of a circular curve is less than twice ‘normal value’, or the segments in cutting where the side slopes are steeper than 1:1.5， in order to ensure the sight distances on horizontal curves.

(5) Segments near a highway at-grade junction or a railway grade crossing.

7.9.6 A highway is a solid 3-dimensional structure. Besides the impact of geometric indicators, parameters and their combinations, highway sight distance may also be blocked by side slopes, barriers, and roadside works. According to recent research on highways in mountainous terrain, sight distance may be poor or insufficient even if the main technical parameters satisfy the criteria given in the relevant specifications. Therefore, these specifications stipulate that sight verifications shall be conducted on the highway segments or places with poor sight distance, for which technical measures shall be provided accordingly wherever necessary.

Sight distance verification and the improvement measures are specifically related to particular requirements for sight distance in specific segments of a highway. For instance, insufficient stopping sight distance due to the side slopes, barriers, dazzle screens and roadside structures may be improved by benching the side slopes, shifting barriers, removing sight obstructions and so on. Pavement widening at particular segments or road marking shifting may also be effective. The overtaking segments on a two-way highway shall be shifted to other locations if the overtaking sight distance is not satisfied. In such a case, signboards and road marking shall be re-arranged accordingly.

During checking highway sight distance, every ‘hundred-meter’ stake shall be checked along the most unfavorable lane such as the inner lane on horizontal curves, or at critical positions such as beginning and end points in terms of sight distance from the sight position, at the sight height and for the height of objects (or obstructions).Positions of sight spot shall be at 1/2 of the traffic lane (i.e. the middle of a traffic lane); height of sight spot shall be 1.2m above road surface for passenger cars and 2.0m above the road surface for trucks; position of an object (or obstruction) shall be at the edge line of the traffic lane; the height of an object shall be 0.1m above road surface for stopping sight distance, 0 (the height of road marking) for decision sight distance, the height of front lights (0.6m) of a vehicle (passenger car) in the opposite traffic direction is taken as the height of an object for overtaking sight distance.

7.10.1 Switchback layout is one of the solutions to locate a highway route in mountainous terrain. The route of a class-3 or class-4 highway may be located in a switchback layout by taking advantage of terrain where natural location is ineffective because of large height differences between control points or where natural location is not applicable due to the terrain and geological constraints. The shortcoming of a switchback curve is that the upgrade and downgrade are on the same hillside and susceptible to overlapping each other, especially the auxiliary curves before and after a switchback curve could be very close to each other, which could be difficult for construction, maintenance and vehicle travel.

8 HIGHWAY PROFILE

8.1.1 Using elevations at the roadway edge as the highway design elevations is for the convenience of controlling the lowest height of the highway. An existing highway to be upgraded or reconstructed should use the elevations at centerline of the roadway as the highway design elevations.

8.1.2 Table 8.1.2 of these specifications only lists design flood frequency for normal circumstances and gives a general description of the relationship between the level of roadway edge and specific ground water table in practice. Designers shall take the impacts of the hydrological environment on the road works into account. A specific hydrological analysis shall be conducted and corresponding design measures shall be taken in the areas with special geological, geographical and meteorological conditions,

4 In the determination of the roadway flood frequency in suburban areas, a detailed assessment shall be conducted in accordance with the criteria for city flood prevention, by taking the highway function of disaster rescue access into account, and based on the requirements for city drainage and flood discharge.

8.2.1Maximum grades for classified highways are mainly concerned with the climbing performance of trucks and highway capacity. The values of highway grades adopted in China are similar to those used in countries such as the United States, Japan, and Germany.

In recent years, large trucks became the representative vehicle type for road cargo transportation in China. According to *the Research of Key Indicators and Methodology for Grade Design of Motorways*, one of the supporting research projects for JTG B01-2014, the power/mass ratio of a 6-axle 49t articulated trailer (limited highway loading is 55 t) is only 5.2kw/t (equivalent to 4.55kw/t for 55t), which is significantly lower than the power/mass ratio (9.3kw/t) of the major representative vehicle type (12.6t/14.15t)reflected in research for updating *JTG B01*in 2003 and 2006. Therefore, caution must be taken in using the maximum grade for classified highways. Similarly, caution shall be used in applying the provision that '*subject to the specific techno-economic assessments, maximum grades may be increased by 1% in segments constrained by terrain or other conditions on the motorways where the design speed is 120km/h, 100km/h or 80km/h*'.

8.2.2 As altitude increases, air pressure and atmospheric temperature and density reduces. Air density has impacts on vehicle engine performance and thus the mobile dynamic performance. According to research and trial operations, the output power of a Jiefang truck (the most popular truck manufactured and used in China) drops by 11.3% at an altitude of 1000m above sea level, by 21.5% at 2000m; by 33.3% at 3000m; by 46.7% at 4000m and by 52% at 4500m. Furthermore, the lower the air density the lower will be the heat dispersion, thus a vehicle engine may have to run in low gears with high engine rotation speed, and the radiator may be susceptible to overheating and the cooling system may fail. According to the experimental analysis, the deduction shall be taken into consideration for grades at an altitude over 3000m.

8.2.4 The provisions for bridge grades mainly account for both mechanical and structural aspects of the bridges, while the provisions on the grades on bridge approaches mainly consider the requirements for traffic movement and the coordination to the bridge grades. In practice, the grades on a bridge shall be selected and determined in accordance with the type of the bridge, mechanical characteristics, structural requirements, and so forth.

On the highway segments near cities, the grades of a bridge and its approaches shall also account for the climbing capacity of non-motorized vehicles. Steep grades should be avoided for bridges and bridge approaches in areas susceptible to ice and snow cover.

Highway grades are related to automobile emissions. The gradient of 3% is the critical limit, above which automobile emissions will increase significantly. Therefore, the gradients in a mechanically ventilated tunnel should not be steeper than 3%. Where constrained by the physical environment and subject to a techno-economic assessment, the gradients inside tunnel of a motorway or Class-1 highway may be relaxed appropriately but should not be steeper than 4%.

8.3.1 Length of a grade mentioned in these specifications is defined as the horizontal distance between two vertical points of intersection. During investigations, some designers suggested that the length of grade should be reduced because a vertical curve is placed before and after a vertical point of intersection. The gradient of a point on a vertical curve is the tangent at the point rather than the tangent of the grade. Therefore, the reduction should be made to the length of a steep grade. Hoverer, others argued that the reduction for equivalent length of grade is not practical but just increases the workload to calculate grade length. However, in the traditional way of control the grade length between two vertical points of intersection is used. The vertical alignment after placing a vertical curve would usually be improved, which would in turn benefit the driving comfort and traffic safety. The conclusion is that the definition of ‘length of grade is the horizontal distance between vertical points of intersection’ remains.

8.3.2 In the Research on The Relation Between Vehicle Speed, Fuel Consumption and Longitudinal Gradient (1991) and the Research on the Highway Gradient and Grade Length Limit (2003), two types of Chinese trucks, Dongfeng and Jiefang (loading capacity 12.6t and 14.15t respectively, and power/mass ratio of 9.3kw/t for both) were tested on various grades. According to the test results, there is a stable speed at which vehicles run on a certain length of grade, and accordingly there is a stable length of grade. From a point of view of operating quality, the length of grade should not exceed the stable length of grade. Note that the stable length of grade depends on the engine performance of the vehicle, the speed at which a vehicle drives into the grade and the speed of the vehicle when it reaches the top of the grade. The higher the engine performance, the higher is the initial speed entering the grade and the lower is the speed at the top of the grade, and thus the longer will be the stable length of grade. In accordance with the operating speeds derived from site observation on classified highways and taking the trends of automobile development into account, 85% of the truck operating speed is taken as initial speed and 15% of the truck operating speed as the speed at the top of the grade. From this information the critical lengths of various grades were identified, and references and considerations were also made to the relationship of length of grade to the changes in vehicle operating speed. It was found that the actual vehicle upgrade speeds were slower than that in tests that also defined the needs for automobile industry development.

Figure 8.1 shows the curves of upgrade acceleration and deceleration speeds and the speed loss curves of the vehicle types, *which were derived from* the Research on *the Highway Gradient and Grade Length Limit (2003).*

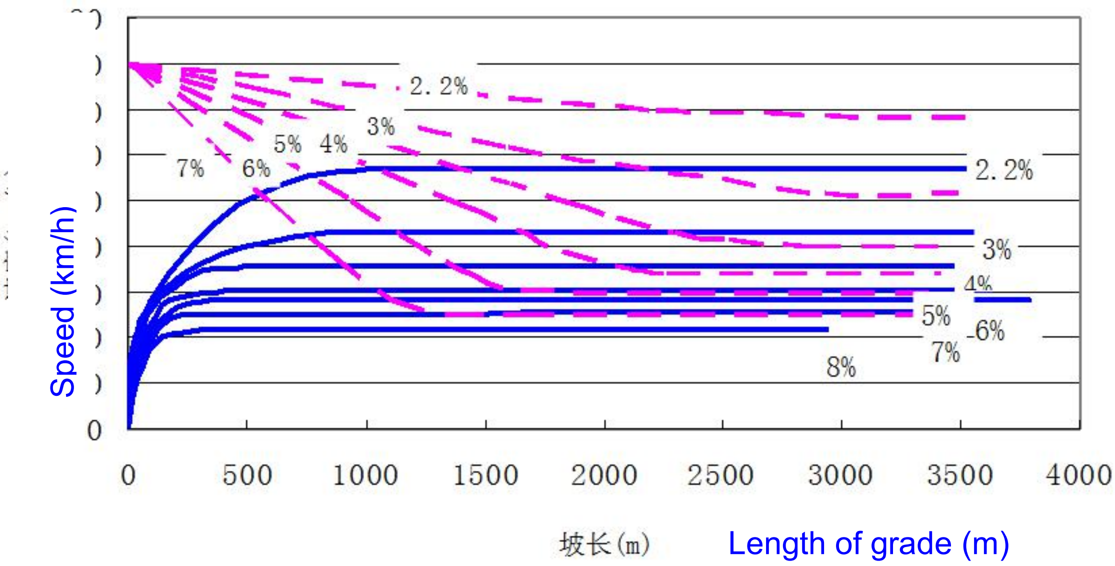


Figure 8.1 Upgrade Acceleration and Deceleration Curves of Two-Axle Loaded Trucks (12.6t and 14.15t, power/mass ratioof9.3kw/t)

According to the research on Key Indicators and Design Methodology for Highway Grade Design (2011), there is a significant change in composition of the vehicle types used for cargo transportation on motorways. Currently typical truck types are 5-axle or 6-axle articulated semi-trailers. Their overall performance is comparatively low (ratio of engine power to mass is 5.1kw/t only); the climbing capability is much lower than that of the previous typical trucks (the power/mass ratio was between 8.3 and 9.3kw/t). For the same gradient and length of grade, the grade length over which trucks keep to a speed not slower than the minimum speed limit is much shorter than before and the stable speed at which vehicles may be capable to keep is much lower than before. For instance, on an average gradient of 3%, the maximum stable speed that a fully loaded typical truck is able to reach is only 40km/h, which is lower than the minimum speed (50km/h) allowable on motorways and lower than the speed limit (60km/h) on normal segments of motorways. This is a problem of 'vehicles unfit to roads' and means that the prevailing typical trucks and their performance capacity were not adapted to the design capacity of and traffic requirements for the continuous upgrade sections in mountainous terrain on some of the existing motorways.

On an upgrade section, the operating speeds of the current typical trucks, due to their low engine performance and climbing capacity, are reduced and this will definitely affect the capacity and level of service on continuous upgrade sections of motorways and class-1 highways, and hence will cause traffic congestion in the upgrade sections. On the other hand, the reduction in upgrade speeds of trucks will amplify speed difference between passenger cars and heavy trucks, which may result in accidents such as rear-end collisions and side scraping, and thus undermine traffic safety.

Relevant information and research show that in the United States and some other countries the power/mass ratio of 8.3kw/t is taken as the minimum requirement for measuring truck overall performance. Worldwide, performance of heavy trucks is enhanced progressively and the power/mass ratio in some countries is even higher than 10.0kw/t. Therefore, the problem of 'vehicles unfit for highway' as mentioned above should be solved by increasing truck overall performance (including using more powerful engine, fitting more stable and efficient braking system and so forth). However, this needs a long time to implement. For the time being, it is suggested that for continuous grade sections on motorways or class-1 highways, where the truck population is comparatively high, designers shall take the performance of current typical trucks into account during highway grade design.

For motorways and class-1 highways, the above-mentioned changes and corresponding effects shall be taken into account in the design of continuous upgrades where truck traffic is 20% or more of the total volume. In a specific project, alternatives of either a continuous single grade or a combination of multi-grades shall be proposed in accordance with traffic volumes, composition of vehicle types, and actual performance of major vehicle types, by referring to the upgrade acceleration (deceleration) diagram and the table of grade lengths, and based on premise that the upgrade speed of the major vehicle type will not be reduced to a speed slower than the allowable minimum speed. It is important to ensure that the upgrade speed of a typical truck will not be reduced to such a level that is below the allowable minimum speed, otherwise a certain length of reduced grade shall be provided for the speed lost trucks to accelerate for further upgrade climbing.

Figures 8.2, 8.3, 8.4 and Tables 8.1 and 8.2 were derived from the results of the *Research on Key Indicators and Design Methodology for Grade Design of Motorways (2011)*, indicating the accelerating and decelerating curves on upgrades, the list of grade lengths of acceleration and deceleration on upgrades and the upgrade speed loss curves of fully loaded (49t) typical trucks (6 axle articulated trailers) on motorways.

Designers may subtract speed loss of vehicles on upgrades from these figures and tables. For instance, Figure 8.2 and Table 8.3 depict the speed loss as a vehicle traverses on upgrade after entering into the grade at a rather high initial speed while Figure 8.3 and Table 8.2 depict speed increase of the vehicle traveling on grade after entering it at a comparatively low initial speed. Figure 8.4 gives the values of speed loss on upgrades (in km/h) by referring to a grade length (horizontal ordinate), a gradient (vertical ordinate) and their combination (intersection of ordinates). By trial and error, the speed loss under several and different grades may be obtained.

Based on the actual climbing capacity of a 6-axle articulated trailer, specific research and verification give recommendations on the critical lengths of different uphill gradients on motorways, as shown in Table 8.3. The criteria on the critical lengths are derived after necessary adjustment and based on the allowable speeds on upgrades of motorways as stipulated in the previous edition of these specifications, as shown in Table 8.4, in which the speed loss value of trucks on an upgrade is 20km/h, as shown in Table 8.5.

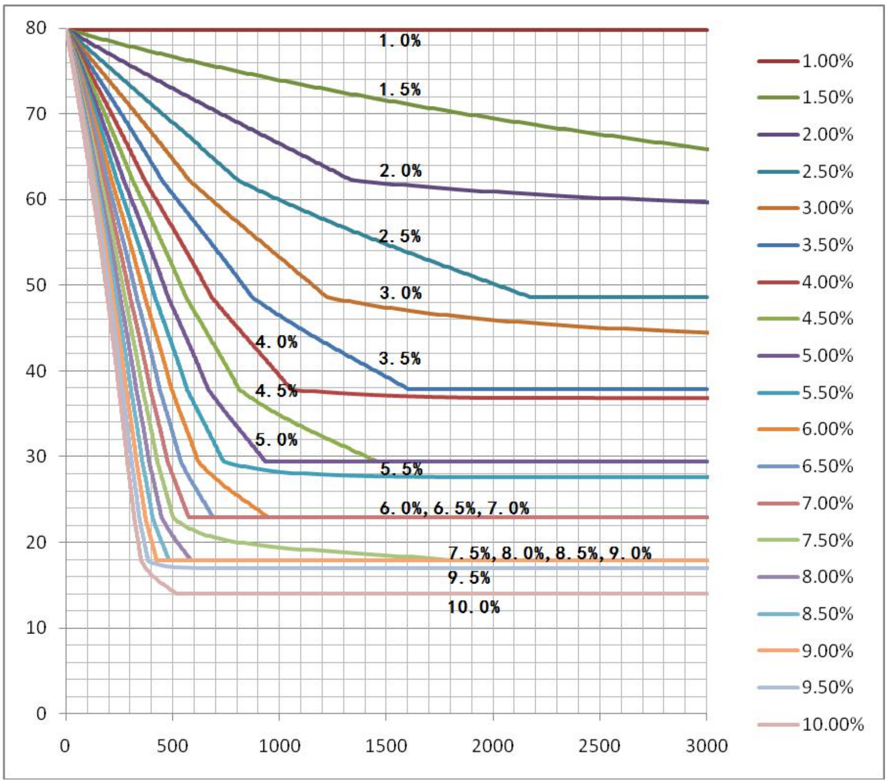


Fig. 8.2 Speed Loss of 6-Axle Articulated Trailers on Upgrades (Fully Loaded 49t, Power/mass Ratio 5.1kw/t)

Table 8.1 Grade Lengths of Speed Loss of Fully Loaded 6-Axle Articulated Trailers (49t) on Upgrades

Gradient / speed	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10
75	46	798	349	224	165	130	108	92	80	71	64	58	53	49	45	42	40	37	35
70	—	1871	727	454	330	259	214	182	158	140	125	114	104	96	89	83	77	73	69
65	—	3288	1121	682	491	384	315	267	232	205	184	166	152	140	130	121	113	106	100
60	—	4220	2691	996	680	520	422	355	307	270	241	218	199	183	169	157	147	138	130
55	—	—	—	1479	917	677	540	449	385	337	300	270	246	225	208	193	181	169	160
50	—	—	—	2021	1156	830	652	538	459	400	355	319	289	265	244	227	212	198	187
45	—	—	—	2173	2542	1095	806	647	543	469	413	370	334	305	281	260	242	227	213
40	—	—	—	—	—	1451	981	764	631	539	471	419	378	344	316	292	271	253	238
35	—	—	—	—	—	1606	4713	990	753	625	538	474	424	384	351	323	300	280	262
30	—	—	—	—	—	—	—	1407	915	726	611	531	471	424	386	354	328	305	285
25	—	—	—	—	—	—	—	1455	933	3380	829	639	544	479	430	391	359	332	310
20	—	—	—	—	—	—	—	—	—	—	947	688	574	809	522	449	402	367	339
15	—	—	—	—	—	—	—	—	—	—	—	—	—	1809	586	482	425	838	461
10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	519

Stable speed	79.8	62.3	58.2	48.6	43.2	37.8	36.8	29.4	29.4	27.6	22.9	22.9	22.9	17.9	17.9	17.9	17.9	17.0	14.0

Note: Units in the table above: speed in km/h, length in m. The figures in last line are stable speeds, not designated speeds.

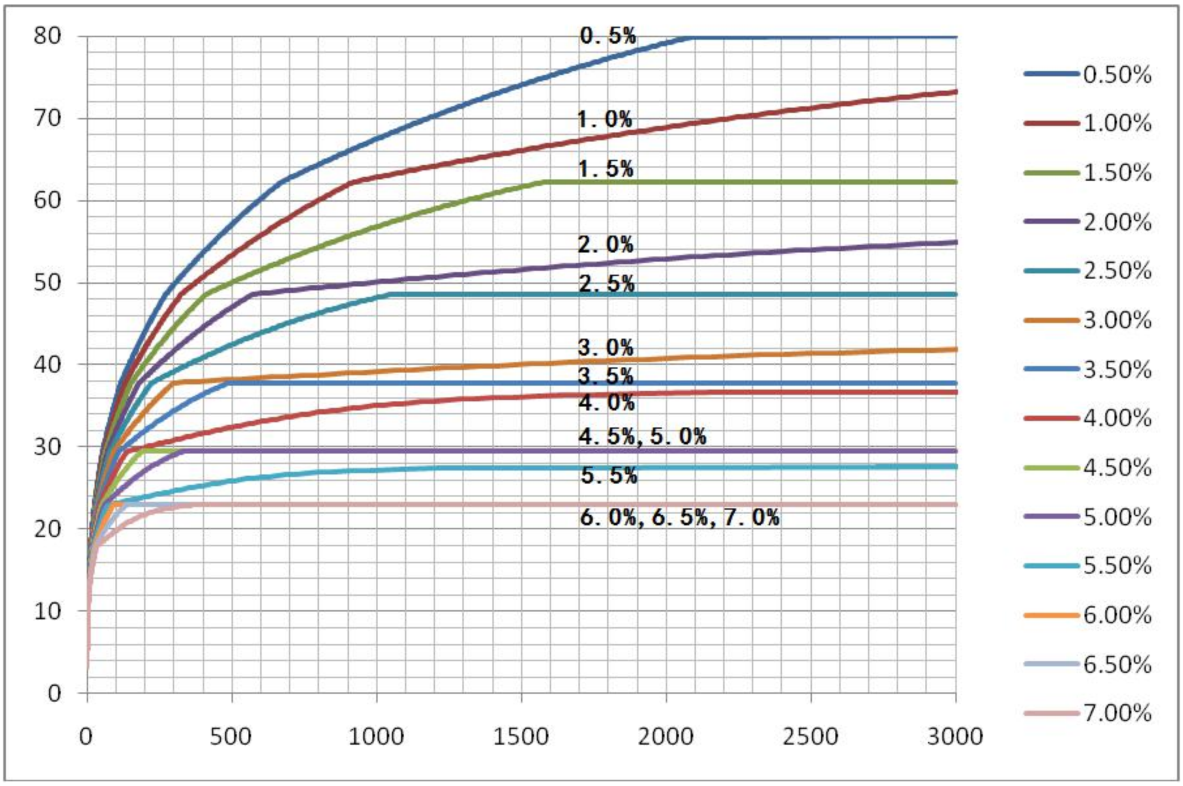


Fig. 8.3 Accelerationg Curve of Fully Loaded 6-Axle Articulated Trailers (49t) on Upgrade

Table 8.2 Grade Lengths of Speed Increase of Fully Loaded 6-Axle Articulated Trailers (49t)

Gradient / speed	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10
10	2	2	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	5	5
15	7	8	8	8	9	9	10	10	11	11	12	13	14	16	18	20	24	33	66	20
20	17	18	19	20	21	23	25	27	30	34	40	48	63	105	38	47	64	112	749	
25	33	35	38	41	46	51	58	69	86	122	350	90	134	363	—	—	—	—	—	
30	56	62	68	76	87	103	128	200	187	329	3248	—	—	—	—	—	—	—	—	
35	93	104	118	138	167	216	326	992	—	—	—	—	—	—	—	—	—	—	—	
40	144	165	196	245	346	1470	492	5208	—	—	—	—	—	—	—	—	—	—	—	
45	213	252	311	417	687	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

50	305	374	498	981	1058	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
55	438	567	851	3066	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
60	592	798	1308	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
65	838	1325	1583	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
70	1177	2223	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
75	1583	3557	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
80	2176	6422	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
	>80	79.8	62.3	58.2	48.6	43.2	37.8	36.8	29.4	29.4	27.6	22.9	22.9	22.9	17.9	17.9	17.9	17.9	17.0	14.0

Note: Units in the table above: speed in km/h and length in m. The figures in last line are stable speeds not designated speeds.

Relationship of Speed Loss and Length of Grade

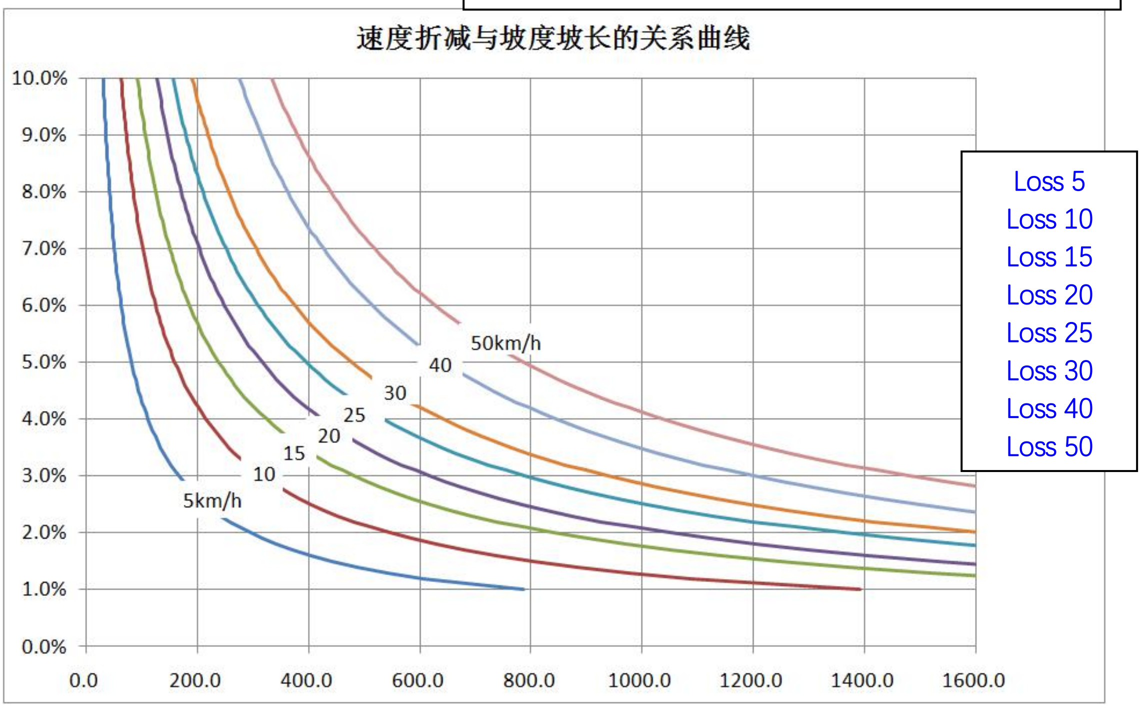


Fig. 8.4 Speed Loss of Fully Loaded (49t) 6-Axle Articulated Trailers

Table 8.3 Critical lengths of Grades (Articulated Trailer, in m)

Design speed (km/h)		120	100	80	60
Gradient (%)	2.0	N/A	N/A	N/A	N/A
	2.5	1000	N/A	N/A	N/A
	3.0	680	910	N/A	N/A
	3.5	520	570	930	不限 N/A
	4.0	420	440	560	N/A
	4.5	-	360	410	540
	5.0	-	300	320	370

	5.5	-	-	-	290
	6.0	-	-	-	240

Table 8.4 Allowable Minimum Speed on Upgrade

Design speed (km/h)	120	100	80	60
Allowable Minimum Speed (km/h)	60	50	40	35

Table 8.5 Speed loss of Trucks on Upgrade

Design speed (km/h)	120	100	80	60
Truck operating speed (km/h)	80	70	60	55
Allowable minimum speed (km/h)	60	50	40	35
Speed loss of Truck (km/h)	20	20	20	20

For the motorways and class-1highways with low truck population, it is recommended to use the specified values in Table 8.3.2 of these specifications, which is limiting indicators on critical length of grade for performance conditions of two axle trucks, as basic data for grade design.

For class-2, class-3 and class-4 highways, where the traffic conditions and vehicle compositions are quite different from those of motorways and class-1 highways, the values specified in Table 8.3.2 shall also be used for design and control of upstream and downstream of a continuous grade section.

8.3.3 When a truck is climbing on a steep grade, its speed will be reduced progressively. The longer the length of grade, the more speed will be lost. The limiting indicators on critical lengths of grades in Table 8.3.2 (of the main part) and Table 8.3 (of the background) of these specifications are based on the speed loss of trucks on upgrades. The placing of reduced grade sections is to provide trucks with conditions to accelerate in order to recover speed and to and maintain speed at a level above the allowable minimum speed for the following grade. Therefore, in the design of road sections with continuous grades, the gradients and lengths of the steep grade sections and the reduced grade sections shall be properly selected and placed in accordance with these requirements. Designers shall keep in mind that the design is not a game of technical indicators. Combination of marginal indicators, such as ‘maximum length for a steep grade plus minimum length of flatter grade”, shall be avoided.

8.3.4 This Clause is based on the research on Limiting of Grades and Lengths of Highway Grades (2003).

8.3.5 According to the Research on Key Indicators and Design Methodology of Highway Grade Design (2011), it was found that the performance of a6-axle articulated trailer, which is the typical truck type of the current truck composition on a motorway for truck transportation, is comparatively low in terms of engine displacement, engine output and braking capacity on long and steep downgrades. On one hand, the trucks manufactured in China are equipped with engine gear braking and exhaust braking systems, of which the braking energy comes mainly from the power of the engine. Compared with the typical truck types selected in the previous editions of these specifications, i.e. two-axle 8-t trucks, two-axle 12.6-t trucks, and two-axle 14.15-t trucks, the overall mass of prevailing typical type of trucks has increased 2.88 to 5.12 times, but the engine power has only increased 1.1 to 2.3 times. This means the braking capacity of current 6-axle trucks is not as good as the previous typical trucks. On the other hand, the capacity of a heavy truck on continuous long downgrades depends on its auxiliary braking system. However, due to economic and other constraints, the heavy trucks manufactured in China are seldom fitted with Jacob or other engine retarders, which are more stable and efficient. This means that there is still a huge deficiency in trucks' braking system compared with developed countries. The problem is that frequent braking for speed control on a long and steep downgrade may cause the brake drums to overheat and lose braking effects, which thus cause accidents.

Poor performance of continuous braking on downgrade and poor technology in auxiliary braking system reflects the problem of 'vehicles unfit the roads' as discussed in previous paragraphs, which have a direct impact on traffic safety on motorways. However, such a problem cannot be solved overnight as the standards of automobile manufacture and market access must be significantly improved.

The current performance of 6-axile articulated trailers in China was investigated in a number of experiments and studies on 'indicators of verification for continuous and steep downgrade', which are presented in Table 8.3.5, were developed during the research. These indicators are the critical lengths over which 6-axle articulated trucks can maintain a fairly unfavorable speed (60km/h) by using engine brakes without significant loss in braking capacity (i.e. keeping the temperature of brake drum below 200 ^{o}C) to travel continuously on a downgrade road section. According to the tests, if the truck is running on a continuous downgrade at a constant speed over 60km/h or the truck is equipped with either an exhaust braking system or a retarder braking system, the indicators will much greater than the figures in Table 8.3.5, which are thus safe. Therefore, this Clause specifies that 'the average downhill gradient and the length of continuous grade on a motorway or class-1 highway shall not exceed the criteria in Table 8.3.5.'

The research concluded that when a truck is running on a continuous long and steep downgrade, the driver may have to use vehicle brakes continuously to reduce speed, which may cause the temperature of the brake drums to rise significantly until the brake system fails when the temperature reaches 200 ℃ or higher. In such a case, the truck may be in danger of being out of control. Therefore, where the gradient and length of a continuous downgrade on a motorway or class-1 highway is close to or exceeds the critical indicators, a stopping area shall be placed for large vehicles (mainly for trucks) to have a mandatory break. The purpose is to let the trucks stop to cool down the braking devices on one hand, and to let the truck drivers have rest to refresh from tension and fatigue on the other hand.

Where the length or average gradient of a downgrade section is close to the critical indicators, the level of traffic control and roadside safety shall be increased, especially the effective planning for speed control and traffic management. This is because according to the braking characteristics of vehicles on downgrade, the lower is speed that a vehicle can maintain on downgrade, the higher will be the sustainable capability of a truck traveling on downgrade.

It is worthwhile to point out that all the conclusions above are based on the assumption of legal and regular driving and free from illegal vehicle remounting. Under no circumstances are violations of laws or regulations allowed. Based on this principle, the technical criteria and indicators are determined. In addition, the verification criteria above are set up based on the performance of the composition of truck types and the typical truck type for transportation on motorways in China, which should be applied in practice in accordance with the local environment.

In summary, these specifications clarify that for the upgrade direction of continuously long and steep sections of a motorway or class-1 highway, the grade design shall be executed in accordance with Clause 8.3.2 and Clause 8.3.3 in the case of low truck population; or the grade design shall be done in accordance with the performance of typical trucks and corresponding critical lengths of grades given in the Background to Clause 8.3.2 together with verification of traffic capacity and level of service in the case of a large truck population. For the downgrade direction of continuously long and steep sections of a motorway or class-1 highway, the average gradient should be effectively controlled in compliance with Clause 8.3.5, or a traffic safety assessment should be conducted. This applies to an integral roadway or separated roadways, and the examination, analysis, and assessment shall focus on the through traffic capacity and level of service on upgrade sections and on the traffic safety on downgrade sections.

Inspection, analysis and assessment shall concentrate on traffic capacity and level of service on the upgrade direction, and on traffic safety on downgrade direction for the highway segments of either integral roadway or separated roadways.

8.4.1 Refer to the Background to Clause 6.2.6 about climbing lane and the Background to Clause 8.3.2 about the critical length of grade.

The freedom of vehicles traveling on highway not only depends on traffic volume but the obstruction caused by slow moving trucks as well, especially on two-lane highways, and the four-lane motorways and class-1 highways with a large truck population. Traveling on an upgrade section does not affect the speed of passenger cars but causes speed loss of heavy trucks, which enlarges the speed differential between vehicle types, increases the demands for overtaking, encourages dangerous lane changes, and thus undermines traffic safety. Therefore it is a common practice worldwide to provide slow moving vehicles with climbing lanes on upgrade sections. Climbing lane is a remedial facility to improve reduced traffic capacity on continuous long and steep upgrades. The placement of a climbing lane shall be considered wherever the operating speed of trucks on an upgrade drops below the allowable limit, or the length of a continuous upgrade exceeds the limit, or the capacity of a highway segment falls significantly.

According to the research *On the Key Indicators and Design Methodology for Motorway Grade Design*, the overall performance of current typical trucks on a motorway is quite low in terms of climbing ability and travelling speed. Therefore, for the upgrade sections of motorways and class-1 highways, climbing lanes shall be placed in accordance with traffic volume, composition and the performance of typical truck to mitigate the problem of ‘vehicles unfit the roads’.

8.4.2 The superelevation on a climbing lane is determined in accordance with design speed of the climbing lane. Usually the superelevation on a climbing lane is flatter than that on traveled way because the running speed on a climbing lane is comparatively slower.

8.4.3 The layout of a climbing lane is shown in Figure 8.5.

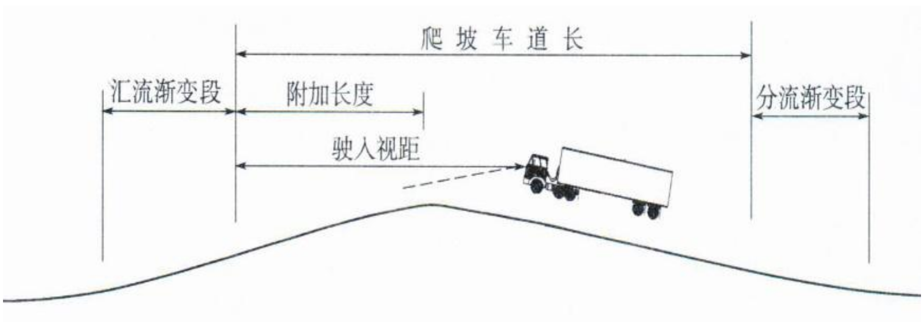


图 8.5 典型爬坡车道

	Climbing lane		
Merge section	Additional length	Climbing section	Diverge section
	Sight distance on crest vertical curve		

Fig. 8.5 Typical section of a climbing lane

8.5.1 Resultant speeds shall be controlled within such a range to avoid the adverse results in the combination of steep grade and sharp turning. However, so far there is no theoretical computation for determining the maximum values of resultant gradients. In practice, the maximum allowable values are roughly estimated based on analytical calculations on longitudinal and side forces and in accordance with the highway classification and type of terrain.

8.5.2 Resultant gradients usually incline towards the edge of roadway, which sometimes may cause danger to traveling vehicles. In areas with snow and ice in winter, the danger of sliding movement to the edge of the road would increase, which may cause serious traffic accidents. It is therefore recommended to use a resultant gradient equal to or less than 8% on the road sections that are vulnerable to vehicles side sliding.

8.5.3 Resultant gradients relate to pavement surface drainage. A resultant gradient which is too small may cause poor pavement surface drainage, rainwater standing on the road surface and the danger of a vehicle aquaplaning. The spray behind the front vehicle may reduce the drivers' visibility, which may thus cause an accident. Therefore, a 0.3 to 0.5% resultant gradient shall be ensured on the road surface. Special precautions shall be taken in drainage design where a flatter resultant gradient is to be used.

8.6.1 A vertical curve must be placed at the intersecting point of two grades to eliminate the impacts due to the changing of energy of vehicle's motion and maintain driver's sight distance. A vertical curve is usually a circular curve or a second-degree parabola. However, because the gradient difference at the point of intersection is small, a parabolic curve is almost the same as a circular curve. In practice, for the convenience of calculation, a circular curve is popularly used.

The 'limiting values' of minimum radii of vertical curves of classified highways, as listed in Table 8.6.1, shall be only used under very special circumstance, such as difficult terrain conditions. In order to ensure traffic safety and comfort,1.5 to 2.0 times the 'normal values' as listed in the Table 8.6.1 or even larger values are used in practice.

9 GEOMETRIC DESIGN

9.1.3 A highway may be segmented to select different technical classifications and design speeds. For example, had higher design speeds been selected for difficult terrain segments on one highway route, investment would have been unreasonably high and the environment might have been damaged seriously. However, a design using one design speed should be sufficiently long; otherwise the operating speeds would have to be changed frequently. The lack of a uniform operating speed may intensify drivers' tension and thus reduce the driving safety.

9.1.5 The concept of operating speed was introduced in *JTG B01-2003*. According to research, operating speed is a random variable. Different vehicles travel at different speeds, which is usually a normal distribution. Normally the 85th percentile of running speeds on the speed distribution curve of representative vehicle types is taken as the operating speed (or v_{85}). Using operating speed to verify geometric design not only reflects the expectation for higher running speeds, but also accounts for the impact of roadside environment and driving behavior on running speeds. Operating speed may change significantly in the segments where different technical indicators are adopted. According to research, the probability of traffic accidents will increase significantly on the segments where the operating speed (v_{85}) is different from its design speed by more than 20%. Therefore, checking by operating speed shall be conducted on the highway segments where maximum (or minimum) values of horizontal or vertical alignment parameters are used due to difficult environmental conditions, or where the horizontal and vertical alignment combinations are complicated, or where actual running speeds may be significantly higher (or lower) than the design speed.

After a period of trial application, the checking by operating speed has been approved in theory and methodology and a large amount of practical experience has been accumulated. Therefore, this edition of the specifications stipulates that highway geometric design shall be verified for operating speed, and gives relevant quantified criteria in detail.

9.2.1 The 'technical measures' mentioned in Item 2 of this Clause refer to visual cue, speed limit, alerting, and other devices or installations for eliminating or mitigating visual boredom and driving fatigue and so on.

9.2.2 A driver would like to accelerate the vehicle on a long tangent. Exceeding the speed limit is likely to occur on a downgrade steeper than 3%. It is common knowledge that the end of a long downgrade is the place with a high accident rate, which is attributed to speeding. Therefore, a long tangent shall be used only after prudent assessment and conservative consideration.

9.2.3 The selection of the radius of a circular curve relates to many factors such as design speed, terrain, the equilibrium of successive curves, the lengths of curves, the length of the tangent between curves, the matching of vertical alignment, and highway cross-sections. The value of the radius of a circular curve shall not be determined and evaluated for only one factor.

An overlarge radius may usually bring about an overlong curve, which may cause fatigue and delays in response of the motorists. According to relevant research, drivers do not like to drive on overlong and very gentle curves. Therefore, designers shall be careful and prudent to use a large radius for a circular curve.

'Normal values' of circular curves may be adopted only in the areas constrained by environment; 'limiting values' shall be adopted only in extremely difficult areas where no other options are available. Designers shall be careful and prudent to use a small radius for circular curves, pay special attention to the consistency and equilibrium of successive curves and make sure the fluctuation in operating speed is less than 10km/h.

9.2.4 According to the experience in countries such as Germany, the relationship of spiral parameter A and circular parameter R should be: $R/3 \leqslant A \leqslant R$.

1 Investigations show that the alignment with long spiral curves looks smooth, natural, and thus provides highway users with more safety and comfort. The flexible and skillful application of the spiral parameter A increases freedom in geometric design and provides the highway alignment with a better adaptation to the terrain.

2 In an oval-curve, using two spirals of different curvature between the two circular curves is because the spirals in a range of $R=\infty$ to $R=R2$ are unavailable. However, the criterion of $R_2 / 2 \leqslant A \leqslant R_2$ is to avoid sharp changes in curvature.

3 In aspiral-spiral curve, where the radius of curvature at the connecting point is quite small, and thus needs to be superelevated, the same cross slope on pavement shall be maintained over a distance equivalent to 0.3v on each side from the connecting point. This is to improve the continuity of the highway alignment and avoid an abrupt change in alignment at the connecting point of an oval-curve.

4 In general, the cross-slope on a tangent ($R=\infty$) always falls outwards. In a C-curve, the cross-slope of outer lanes may change over a short distance, which may cause spatial alignment twists and thus endanger

traveling vehicles. Therefore, it is necessary to keep cross-slope in a constant direction for a certain distances before and after the common tangent point.

9.3.1 While driving visual judgment, flatness and uniformity of the vertical alignment of a highway segment are the major factors in contrast to its horizontal alignment. . Sometimes drivers may have a negative feeling about a highway alignment because small radii of vertical curves look like sharp bends and a large number of vertical curves appear like road oscillation. Any humps, unseen sags, bumps, broken-backs and oscillations may cause visual interruption to drivers, thus shall be avoided.

4 For continuously long and steep road sections, besides considerations of traffic capacity on upgrades, attention shall also be paid to the verification of traffic safety on both upgrades and downgrades.

9.3.2 It is better to choose a flat or gentle vertical alignment. Maximum gradients and the maximum lengths of grades should not be adopted for classified highways. According to research, the rate of traffic accidents on grades steeper than 3% is about 2 to 3 times, or even higher, than that on gentle grades. In addition, on steeper grades energy consumption and air pollution may increase, truck speeds may significantly reduce thus capacity and level of service will reduce. In the case where a steep grade has to be adopted, checking by operating speeds shall be executed in order to ensure the highway capacity and level of service in compliance with relevant criteria.

9.3.3 Abrupt gradient changes should be avoided on a highway profile of either a segment crossing a plain or a mountain to ensure alignment evenness in visual perception.

9.3.4 The quality of a vertical alignment depends on the magnitude of radii of vertical curves. The radius selected larger than those listed in Table 9.3.4 of these specifications shall be preferred to achieve an alignment with good visibility. The minimum radii specified in*JTG B01-2014*are the minimum radii required for stopping sight distances. Large radii of vertical curves shall be used for the segments with overtaking demands on a two-lane highway.

An excessively short vertical curve may cause an uncomfortable feeling and visual difficultiesduring driving. A grade between two sag vertical curves with small radii may give a visual impression of a broken-back. In the case of vertical curves in opposite directions, where the centrifugal acceleration is $0.5m/s^2$ as a vehicle moves from a crest curve to a sag curve (or vice versa), a grade section shall be placed between these two vertical curves.

9.4.1 Highway cross-section, alignment and profile are three dimensions of highway geometry that require interactive consideration. The design of the cross-section is to reduce the height of highway embankment as far as possible, encompass slope protection, drainage, borrow pits and disposal yards, minimize the impacts on eco-environment, prevent soil erosion, and position a highway in harmony with nature. The highway side slopes shall be neither too high nor too steep. A proposal for high fill or deep cut shall be fully assessed and compared with alternative options of viaducts, tunnels and separated roadways.

9.4.2 Investigations show that some engineering failures were induced by deep cuts and high fills on integral roadway cross-section. Integral roadway is normally adopted in plain terrain. However, in rolling and mountainous terrains, the option of separated roadways should also be taken into consideration. For instance, motorway segments in mountainous areas with separated roadways and independent cross-sections at different elevations may be selected, which may reduce the impacts on environment and avoid geological distresses.

9.4.3 The position of traffic lanes will have to be moved where the median width changes. The alignment shall be designed individually for each roadway in order to ensure traffic safety. In segments that are constrained by the environment, the design speed is lower than 80km/h and the change of median width is less than 3.0 m, transition sections may be adopted with a rate of transition not greater than 1/100.

Appropriate rates of roadside slopes shall be selected in accordance with natural ecologic and geologic conditions, which shall not be fixed as one single rate but change in accordance with landforms. The side slopes of a low embankment shall be as gentle as possible; the slope top and toe shall be in rounded transitions; and the outlines of side slopes shall be in harmony with surroundings. Road drainage works shall be designed as a self-contained and fully functioning system. The side drains placed in the road reserve should be shallow ditches or in unconstrained free flow, otherwise cover slabs shall be placed. The cross-section of the drainage works outside road reserve may be determined depending on local environment and in harmony with surrounding landscapes.

9.5.1 It is a common practice in geometric design that horizontal alignment is designed before vertical alignment. However, it is important to consider vertical alignment during horizontal alignment design. Otherwise, vertical alignment may have to be compromised for the horizontal alignment or marginal matching would have to be managed. This Clause is to emphasize the interactive considerations for both horizontal and vertical alignments.

9.5.2 The guiding policy for the combination design of horizontal and vertical alignments is ‘mutually corresponding’, while the horizontal curve should be slightly longer than the corresponding vertical curve, or so-called ‘horizontal envelopes vertical curve’. According to the research in China and other countries, mutual correspondence is important where the radius of a horizontal curve is smaller than 2,000 meters and the radius of a vertical curve is smaller than 15,000 meters.

However, the significance of mutual correspondence reduces progressively as both radii increase where the radius of the horizontal curve is larger than 6,000 meters and the radius of the vertical curve is 25,000 meters. For these conditions mutual correspondence is no longer sensitive. This means that the design policies of 'mutual correspondence' and 'horizontal envelopes vertical curve' shall be applied by evaluating the level of mutual correspondence and matching the radii of vertical and horizontal curves actually adopted in design.

9.5.5 The placement of traffic control devices with visual cue on the road sections with high fill embankment is to prevent the drivers from misjudging the alignment curvature.

9.6.1 The travelling speeds of vehicles on motorways, class-1highway and class-2 arterial highways are high. Thus, the connections of a bridge and its approaches to a road section must be smooth to comply with the travel speed and traffic safety. Therefore, on motorways, class-1 highways and class-2 arterial highways, the alignment of bridges, except that of extra-large bridges, shall follow the general layout of the highway route to ensure continuous and smooth connections to the highway route alignment. However, a special- purpose large bridge shall be straight to facilitate structural design of the bridge.

Highway barriers may appear like folded at the interface between a bridge section and road sections, which will affect not only the appearance of the barrier but also the traffic safety. Therefore, it is required that the width of the traveled way on a bridge, culvert and bridge approaches (including acceleration (deceleration) lanes, climbing lanes, slow moving lanes, passing lanes, etc.) shall be maintained constant so as to align the road barriers on a continuous and smooth baseline and avoid bumps and dents. This means keeping the outer edge of traveled way (and the barriers), rather than the outer edge of roadway, in alignment.

9.6.2 The connecting of tunnels, tunnel approaches and road sections shall conform to the requirements of overall layout of the highway route. Investigations show that the sections before and after tunnel portals are susceptible to traffic accidents. This Clause gives the requirement for the consistency of off-portal and in-portal alignments, details the conditions that permit relaxation while it defines the conditions for applying the requirements for 'alignment coordination', and requires transition section in the case of different in-portal and off-portal roadways.

9.7.1 The road alignment before and after main route toll plazas, service areas and rest areas shall be continuous and smooth with no alignment combinations obstructing sight distance because the vehicle streams on these road sections are comparatively complicated and thus more information is required by road users. Smooth alignment and good sight distance are the basis for traffic safety.

9.7.2 The requirements that toll stations should be located on either tangents or non-superelevated curves but within a range of sag vertical curves are mainly based on the consideration of road surface drainage; while the requirement that no toll stations shall be placed at the bottom of a long downgrade is based on consideration of traffic safety.

9.8.1 The same alignment in different environments gives different sensation to people. Investigations found that poor environmental fitness of a highway alignment may produce psychological pressures and illusions, and thus cause traffic accidents. Traffic safety is the primary consideration of alignment-environmental fitness.

10 AT-GRADE JUNCTIONS

10.1.1 The positioning of an at-grade junction shall be limited where the function or classification or both are different for each of the intersecting highways. To ensure traffic safety and capacity of arterial highways, either class-1 or class-2, the direct linking of other highways shall be strictly limited and the number and spacing of at-grade junctions shall be controlled. However, froma safety point of view, the class-1 and class-2 collector-distributor highways shall be also limited in frequent linking of other roads, especially the random linking of farm roads. The wording 'restrict' and 'strictly restrict'shows the instructive opinions given by the editing team of these specifications. This means that the positioning is allowed but the number of at-grade junctions is restricted. Furthermore, the spacing of at-grade junctions shall be increased and appropriate traffic management and channelization shall be considered. The word 'strictly limited' is a stricter and stronger level than 'limited'.

The number and spacing of at-grade junctions directly affect the traffic flow efficiency of a highway. More junctions at a smaller spacing obviously provide more connections in the road network and accessibility to local communities, but will also significantly impede traffic flow efficiency, safety and traffic management. Therefore, designers shall identify the highway functions and the difference in technical classes and balance the traffic efficiency and accessibility to local people.

During the updating of these specifications, there was a debate on whether at-grade junctions should be allowed on motorwaysin western China where traffic volumes are low. The consensus was that at-grade junctions should be forbidden, which was based on the concept of full control of access, fully grade separated junctions and fully controlled accesses and the characteristic of traffic management mode of motorways to provide safe, rapid and straight through traffic services. This is also in line with the understanding on the function of motorways in China.

10.1.2 The guiding policies for at-grade junction design emphasize the provisions that traffic conflict spots and conflict zones shall be minimized and the effective measures such as conflict distribution, isolation and channelization shall be considered and implemented.

Previously the highway at-grade junctions in China were not well designed and the sizes were small, which made it difficult to accommodate traffic needs. Most of the junctions were not channelized. Drivers were unsure as to the path to follow and could not properly judge the other drivers' intention, which caused conflict and wrong entry or confusion and hesitation. The space of junctions could not be fully utilized and traffic accidents happened frequently. As the growth of traffic volume, the deficiency of non-channelized junctions became clear and reached such a level that change was required. Therefore, in this edition, channelization is taken as one of the policies to be followed in at-grade junction design to attract designers' attention on the subject. Detailed criteria are given in the following provisions of these specifications.

4 An at-grade design shall satisfy the requirements for inter-visibility and sight distances in the functional area of an at-grade junction. Where these requirements cannot be accommodated due to the terrain, ground features, ground objects or other factors, the at-grade junction shall be re-designed or relocated.

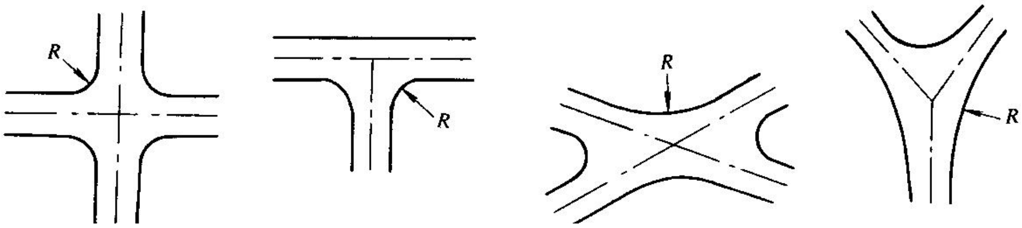
10 This Clause specifies that highway at-grade junction design shall accommodate the actual design vehicles in order to reflect the changes made to highway design vehicles. Wherever necessary, verification of the capacity of at-grade junctions and the turning lanes shall be executed in accordance with the characteristics of the turning tracks of the actual vehicle types (including special vehicles) travellingon the highways.

10.1.3 Traffic management mode determines the geometry of an junction. In junction design, designers shall firstly determine traffic management mode in accordance with the functions, roles, and traffic features, then determine the type of junction and geometric details. Of course, in some circumstances where constrained by local conditions, the traffic management mode may be determined in a reversed sequence. Therefore, traffic management mode is the base of junction design, which designers must be very familiar with and skillfully apply in practice. As the traffic volumes increase and facilities diversify, the role of traffic management facilities the pedestrian's dependency on them become significant. Therefore, this Clause gives more detailed definitions and criteria on traffic management modes. Furthermore, in some of the suburban areas, traffic signals have been used for traffic control and have achieved good results, reflecting the necessity for the use of traffic signals under certain conditions. Thus, this Clause also outlines the conditions for traffic signal applications.

10.1.5 Following the provision given in *JTG B01-2014* on the (acute) angle of an at-grade junction, this edition of the specifications made the updates accordingly.

10.1.6 Regardingthe seriousness of the traffic safety situations and the lack of channelization design of at-grade junctions, this Clause gives further details for the relevant provisions of *JTG B01-2014* and more clear requirements about the channelization design of at-grade junctions for classified highways.

Channelization may include widening of turning corners, widening at approaching legs, placing turning lanes and traffic islands, as shown in Figures 10.1 to 10.4 below.



a) b) c) d)

Fig.10.1 Channelization (widening turning corners)

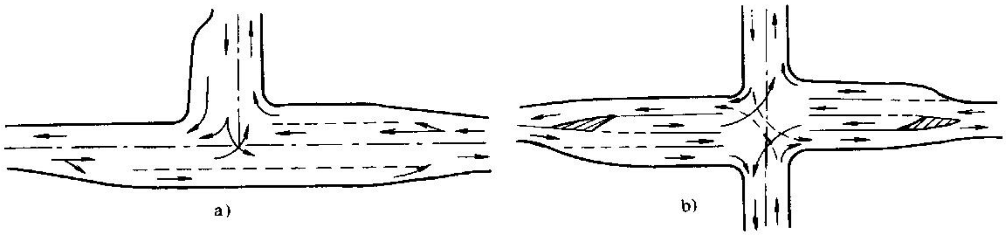


Fig. 10.2 Channelization (widening of approaching legs and placing turning lanes)

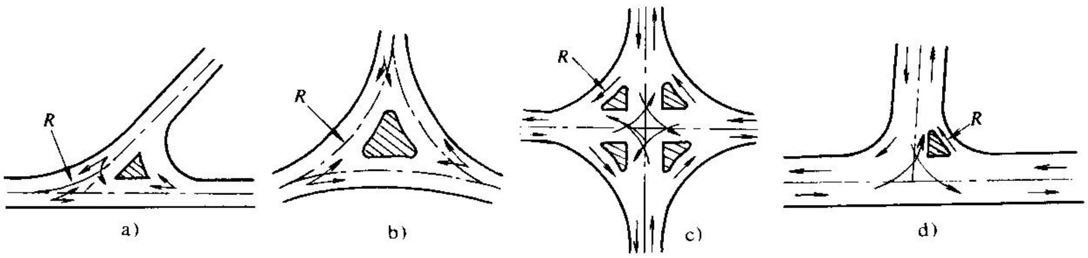


Fig. 10.3 Channelization (placing turning lanes)

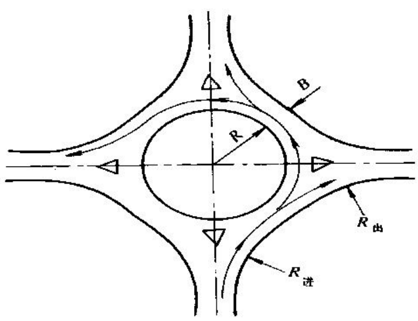


Fig. 10.1.4 Channelization (placing traffic islands)

10.1.7 Requirements for the spacing of at-grade junctions emphasize controlling the number of at-grade junctions and avoiding excessive numbers to and from the highway. For highway segments in highly urbanized areas, the streets and access roads shall only be positioned along the local highways, or along a paralleledminor roadwith limited entrances and exits. Highway authorities shall pay attention to the requirements above and take necessary administrative measures to ensure their implementation.

10.1.8 Following JTG B01-2014, this Clause gives the criteria for level of service on at-grade junctions and requires verification of the capacity and level of service on at-grade junctions on a class-3 or higher highway.

10.2.1 Apart from the requirements for intersection angle and alignment of the intersecting highways in the area of influence of at-grade junctions, this Clause gives the requirement that where a new highway intersects with an existing highway with lowerclassification(minor road) at a small skewed angle, the minor road shall be partially relocated to accommodate the intersection angle.

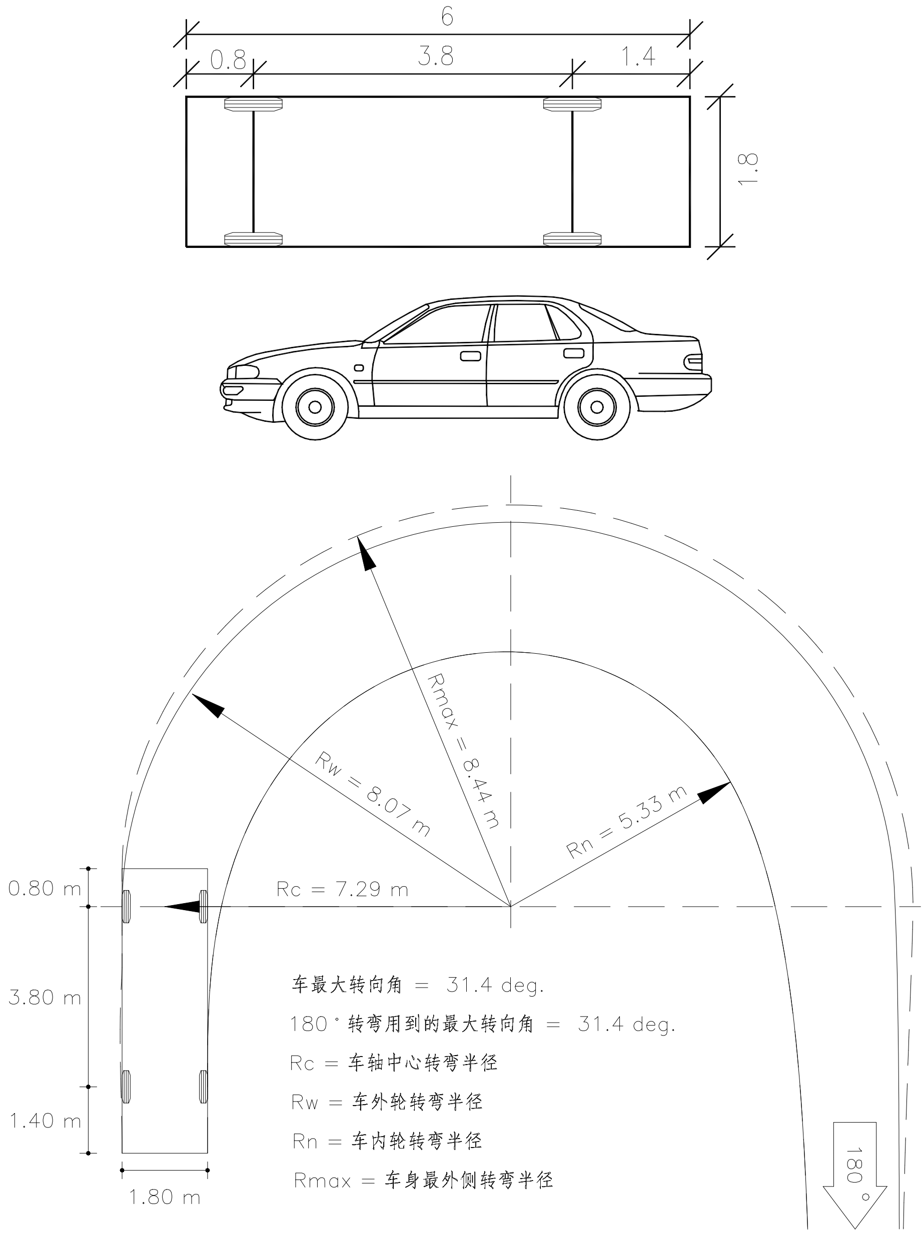
10.2.2 In the area of influence of an at-grade junction, driving operation may be complicated, which may cause traffic accidents. Although the running speeds may be slower than that on normal road sections, the vertical alignments are expected to be better than normal road sectionsso that drivers can observe vehicle movement in the functional area of an at-grade junction as early as possible to change vehicle speed or to stop.

10.3.1 Approach sight distance is referred to as the distance from the spot where a driver identifies a stop line on pavement to the spot where his vehicle stops. Therefore, the length of an approach sight distance is the same as that of the stopping sight distance, whichis defined as the distance for stopping the vehicle after seeing an obstacle in front. However, because that the height of object for approach sight distance is 0m, the radius of crest vertical curve for approach sight distance shall be slightly longer than that for stopping sight distance.

10.3.2 In the case where restricted by environment, the sight triangle defined by stopping distances cannot be satisfied, the requirement may be reduced as to ensure the sight triangle of stopping sight for safe crossing. However, the entrance on the minor highway shall be changed from ‘reduce speed to give way’ to ‘stop to give way’. This design criterion is in compliance with the traffic management modes stated in Section 10.2 of these specifications.

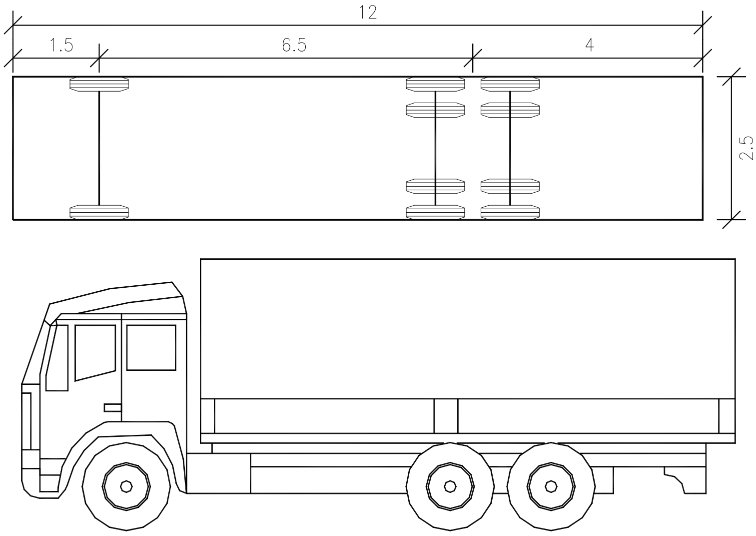
10.4.1 Most turning movements, especially left turns, at at-grade junctions are sharp turns, in which the wheel path and the occupied width of a vehicle are changing constantly. Therefore, the zone enveloped by actual inner edge and outer edge of wheel tracks shall be taken as the controlling element for design of turning curve and roadway.

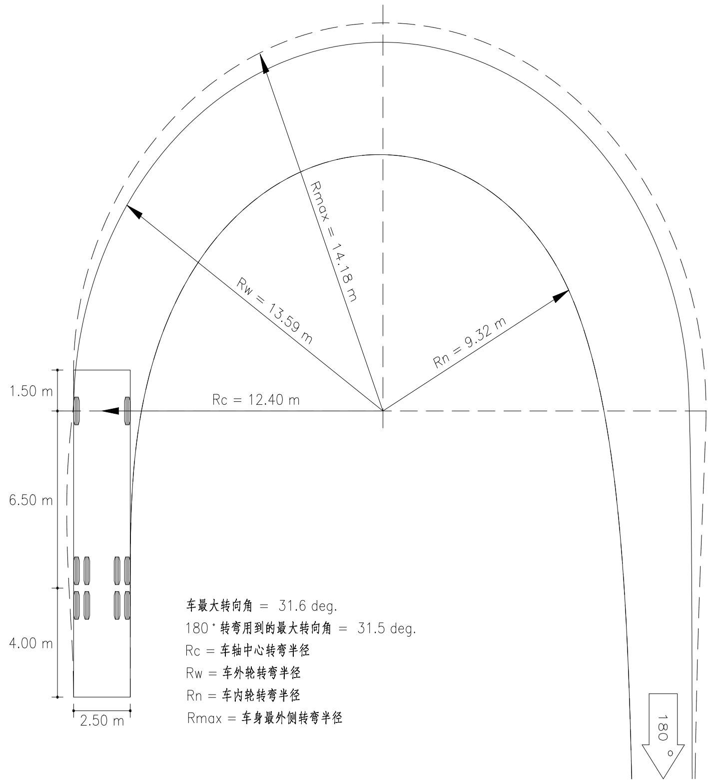
According to the outline dimensions of five design vehicles specified in JTG B01-2014, the minimum turning tracks and the clear outlines required for turning of these five design vehicles have been compared and analyzed during the updating of these specifications. The wheel trackof the five design vehicles turning at minimum running speeds (5～15km/h)are illustratedin Figure 10-5 to Figure 10-9. In addition, Figure 10-5 also shows minimum radii of the design vehicles for designers' reference.



Maximum turning angle of vehicle = 31.4 deg.
Maximum turning angle for 180° turning =31.4 deg.
R_c = turning radius of center of axle
R_w = turning radius of outer wheel
R_n = turning radius of inner wheel
R_{max} = turning radius of outline of the vehicle body

Fig. 10-5 Minimum Turning Radius of Passenger Car (m)





Maximum turning angle of vehicle = 31.6 deg.

Maximum turning angle for 180° turning =31.6 deg.

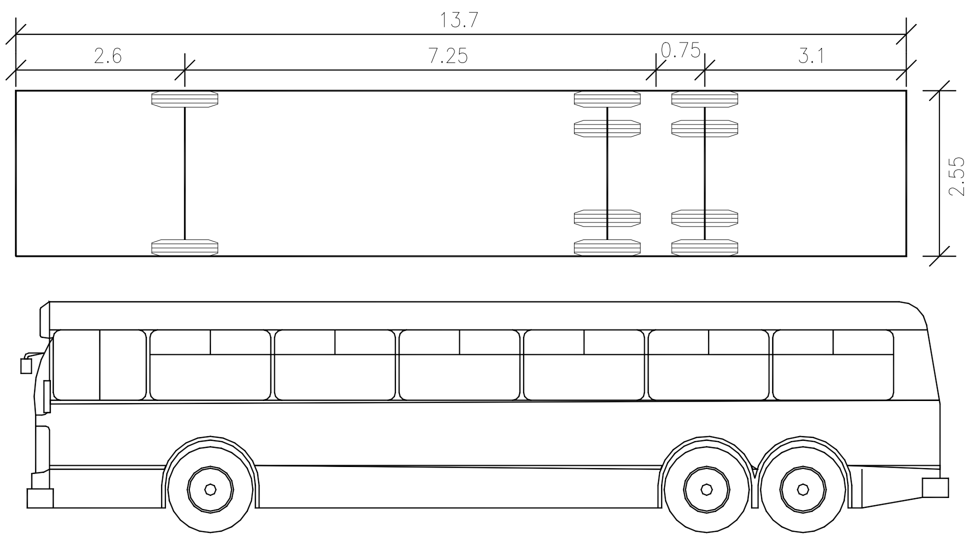
R_c = turning radius of center of axle

R_w = turning radius of outer wheel

R_n = turning radius of inner wheel

R_{max} = turning radius of outline of the vehicle body

Fig.10-6 Minimum Turning Radius of Truck (m)



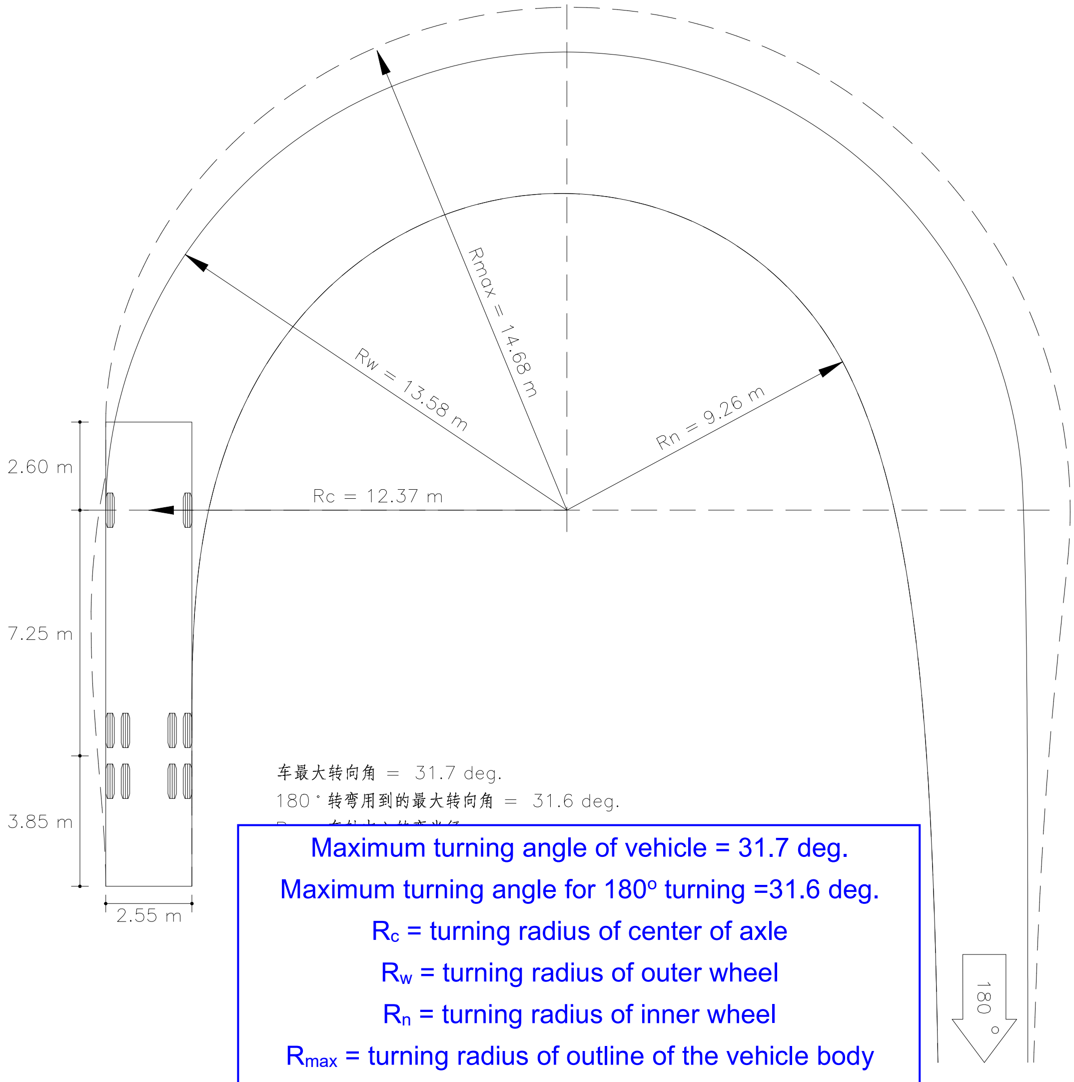
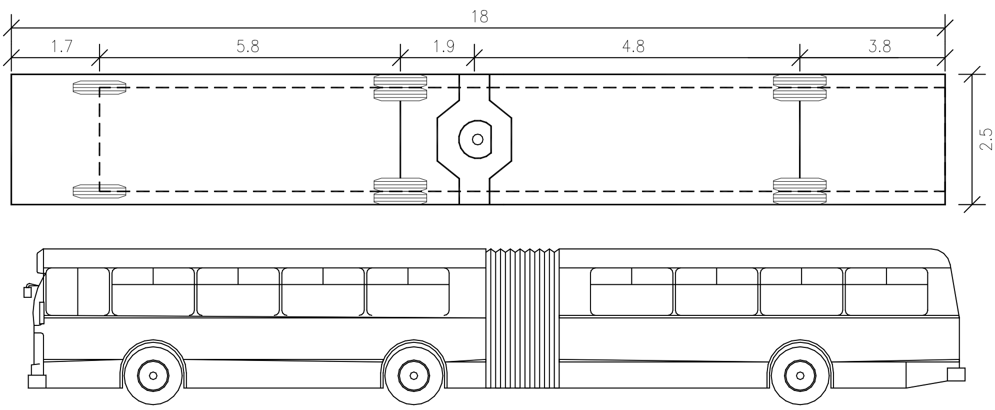
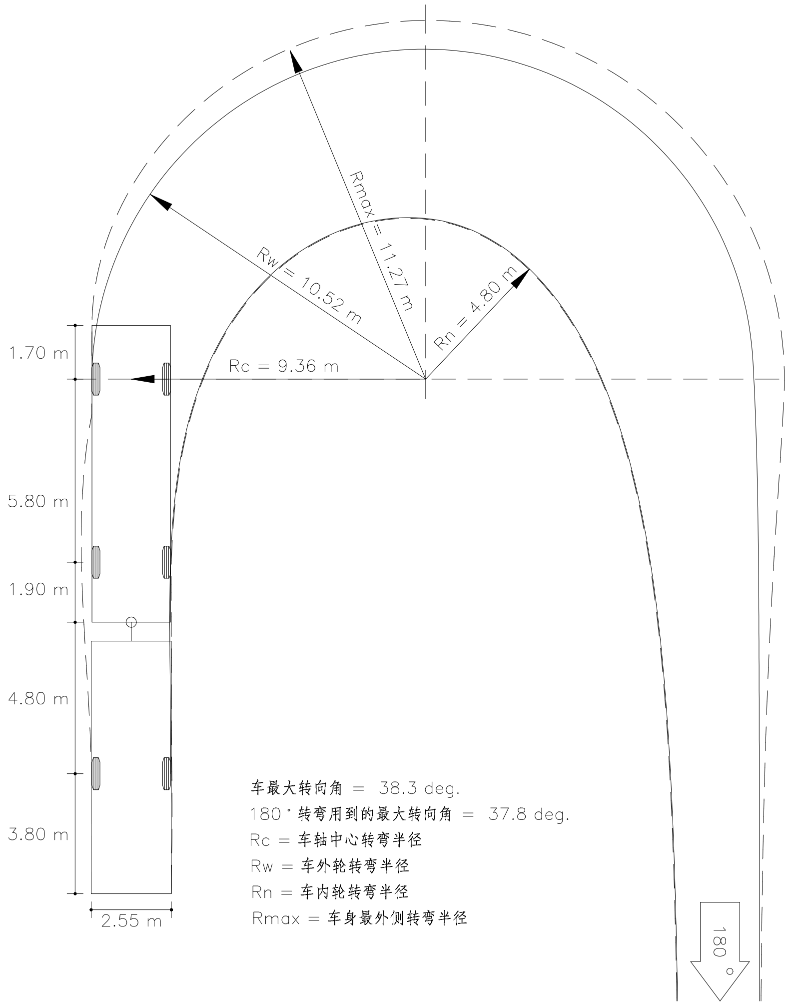


Fig. 10-7 Minimum Turning Radius of Large Bus (m)





Maximum turning angle of vehicle = 31.7 deg.

Maximum turning angle for 180° turning =31.6 deg.

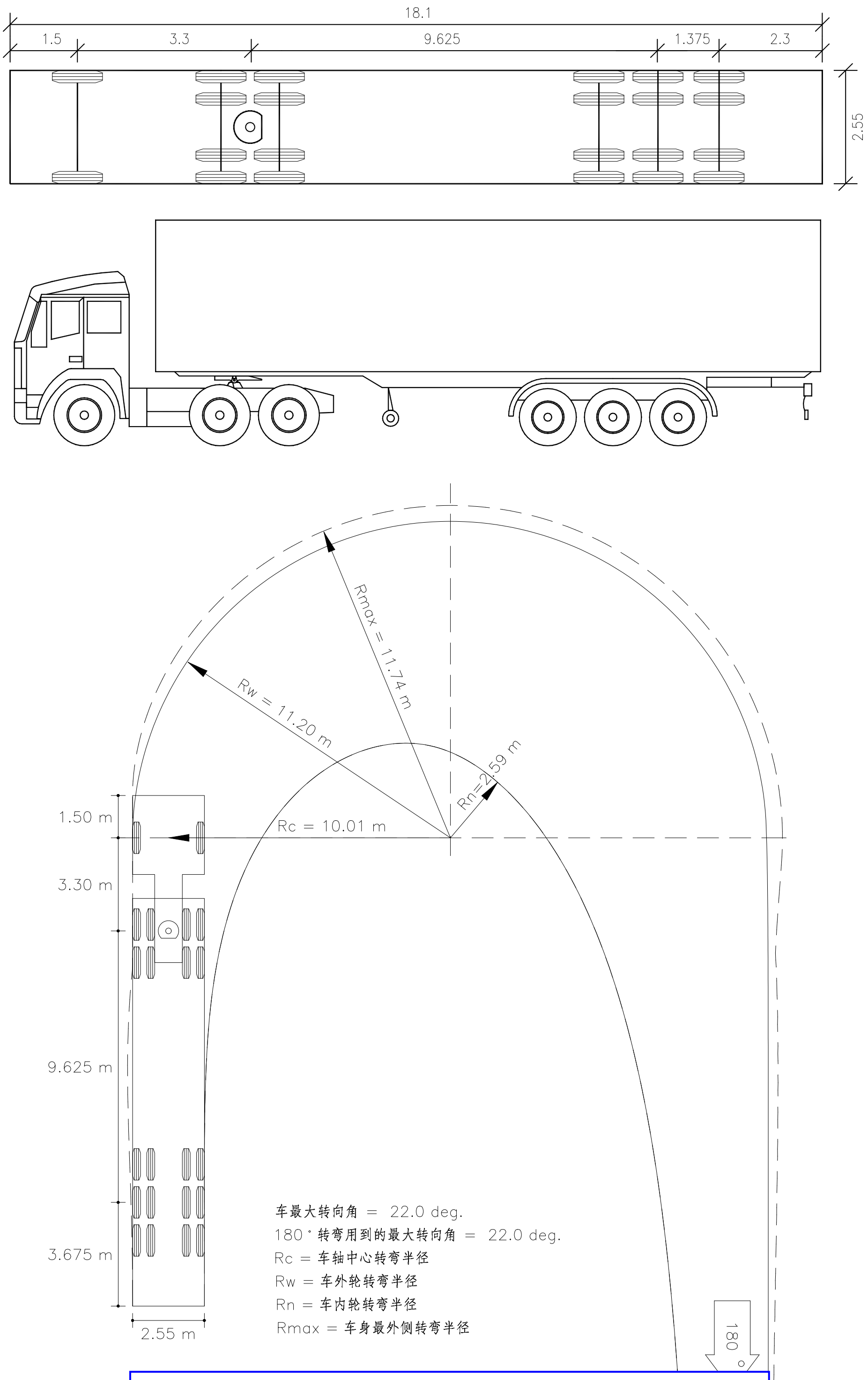
R_c = turning radius of center of axle

R_w = turning radius of outer wheel

R_n = turning radius of inner wheel

R_{max} = turning radius of outline of the vehicle body

Fig.10-8 Minimum Turning Radius of Articulated Bus (m)



Maximum turning angle of vehicle = 31.7 deg.

Maximum turning angle for 180° turning =31.6 deg.

R_c = turning radius of center of axle

R_w = turning radius of outer wheel

R_n = turning radius of inner wheel

R_{max} = turning radius of outline of the vehicle body

Fig. 10-9 Minimum Turning Radius of Articulated Trailer (m)

10.4.2 Each design vehicle has its own wheel tracks, which is unique and different from others. The same design vehicle hasdifferent wheel tracks asrunning at different speeds. Therefore, design of turning curve shall first select the design vehicles and design speeds for design control. It was found during the updating of these specifications that, although the overalllength of an articulated trailer is the longest among the five design vehicles, the minimum radius of turning tracking of trucks is larger than articulated trailers and the others; however, the clear space for turning of the outline of vehicle body of an articulated trailer is greater than truck and any other design vehicles. After extensive analysis, it states in these specifications that the turning design for at-grade junctions shall use the wheel track of trucks as controlindicator, butuse that of articulated trailers to verify pavement widening and widths for turning roadways wherever necessary.

Design speeds for turning curves shall be selected as follows..

(1) Sometimes vehicles are waiting for opportunities to make left turning, therefore design speeds for left-turn may not necessarilybe high, usuallytaken 5 to 15km/h in normal circumstance. In design, minimum radius of the inner edge curve of a left-turnis 15m. For the highways with low proportion of large vehicles (such as tourist highways) or the highway sections where vehicles may borrow a part of opposite lanes for turning, the design speeds may be as low as 5km/h and the corresponding minimum radius of inner edge curve of a left-turn may be 12.5m accordingly.

(2) For un-channelized junctions or the simply channelized junctions without separated right-turn lanes, the design speeds for right turning may be the same as or slightly higher than that for left turning. The minimum radius of inner edge curve may be 15m.

(3) At a channelized at-grade junction with separated right-turn lanes, the turning speeds shall be 20～30km/h and the width of turning roadway shall be ensured.

10.4.3 This Clause specifies the minimum radii and suitable alignments forinner edge of a right-turning roadway. Wheel track curves are complicated, and thus difficult to be depicted by the means of mathematic models. There are two simplified types of curves widely-usedfor inner edges of a turning roadway, of which one is the three-centered compound (a compound curve of three circular curves),and the other is the alignment with a circular curve inserted between two spirals. According to relevant research, the three centered compound curve has a better fitness, and thus is recommended in this Clause.

Un-channelized at-grade junctions are adopted to accommodate small or very small traffic volumes and allow wheel tracks partly ‘intrude’ into the space assigned to other vehicles. Therefore, there is no need to give strict, or even any requirements for the fitness of inner roadway edges. However, as long dimension vehicles such as articulated trailers is concerned, this ‘intrusion’ mentioned above should not be neglected, instead a two centered compound curve, which fits the wheel tracks, shall be used.

10.5.1 at the un-channelized at-grade junctions or simply channelized at-grade junctions without separated right-turn lanes, where the design speeds of main highway is quite high (e.g. 80km/h) and traffic volume is large, speed reduction for right turning may negatively affect the running speeds of through traffic or even cause vehicle crashes, though the right turning traffic is not large. In such a case, adding a deceleration lane may solve the problem of traffic turbulence.

A channelized right-turn auxiliary lane comprises a separated right turn lane and two speed-changing lanes at both ends of it.

10.5.2 Left-turn lanes are placed on the left side of through lanes, specific for left turning vehicles to diverge, reduce speed and wait for an opportunity to turn, which comprise transition section, deceleration section and awaiting section.

10.5.3 The lengths of speed-change lanes in at-grade junctions, as listed in Table 10.5.3-1, are applicable to the design of speed-change lanes with equal width and exclude the lengths of transition sections, The speed-change lane with unequal widths may be designed as a lane with tapered width controlled by lateral movement at a speed of 0.6m/s for merge (acceleration) and 1.0m/s for diverge (deceleration).

Where the capacity of through lanes is surplus or a full length of acceleration lane is impossible due to environment constraints, the length of an acceleration lane may be reduced but shall not be shorter than 50m. In such a circumstance, the traffic management of ‘yield’ should usually be applied.

10.5.4 Traffic islands at at-grade junctions may be divided into splitter islands (to separate vehicle streams in the same direction) and divisional islands (to separate vehicle streams in opposite directions).

In this edition traffic islands are divided into three structural types, namely physical islands, painted islands and plate islands. Their applications are as follows.

The usage of physical and shadow islands are quite different in other countries. However, it has been found that physical islands are usually used on 4-lane highways and shadow islands on two-lane highways. Physical islands provide traffic with mandatory and effective separation, but may cause traffic congestions especially in the case of traffic accidents. In addition, physical islands used as channelization are susceptible to vehicle scratching, and thus result in accidents. Therefore shadow islands should be a good choice for two-lane highways.

10.6.1 Improving shall be considered if the existing at-grade junction is susceptible to frequent traffic delay and traffic accidents due to its limited size and insufficient facilities. If such problems cannot be effectively solved by improvement in the context of high design speed and large traffic volume, the alternative of an interchange to replace the existing at-grade junction shall be taken into account.

11GRADE-SEPARATEDJUNCTIONS

11.1.1 Following the relevant provisions in *JTG 01-2014*, the conditions of placing highway-highway grade-separated junctions, including interchanges, have been updated in this edition of the specifications. For instance, the word ‘should’ has been changed to ‘shall’ in the provision class-1 highway intersects with another high-volume classified highway.

11.1.4 In this Clause, highway interchanges are categorized as hub interchanges and general interchanges in terms of two groups of highways, of which one is motorways and class-1 arterial highways, and the other is class-1 collector-distributor highways and other classified highways. A hub interchange is the one between motorways and class-1 arterial highways, which is similar to the ‘system interchange’ named in the United States for an interchange between freeways. In a general type of interchange, at least one of the intersecting highways shall be neither a motorway nor a Class-1 highway. The latter may also be termed a ‘service interchange’ as used in the United States. Where a class-1 highway serves as one of the national or regional arterial highways, and the spacing of at-grade junctions on it is large enough (⩾2 000m), the interchange between such a class-1 highway and a motorway shall be regarded as a hub interchange in design.

11.1.5 The minimum spacing of interchanges remains 4km as specified previously. The provision of a minimum spacing under restricted conditions is kept the same as in *JTG B01-2014*, that is, 1,000m as the minimum spacing for the net length of a weaving section. Such relaxation requires a detailed traffic engineering design. More specifically, access ramps of two adjacent interchanges may be joined by one collector-distributor highway. When this provision is applied in practice, attention should be given to the fact that the use of a 1,000m weaving-section will cause significant impacts on traffic streams on the main route, especially where traffic on the main route is large. For compound interchanges, weaving is allowed on collector-distributor highways. If there are either one or two interchanges in a compound interchange and it is a motorway-motorway interchange, weaving shall affect all turning streams in the compound interchange. Furthermore, placing signs in a compound interchange could be difficult. Therefore, 'compound' is only an expedient that should not be adopted until full assessments of the options for readjustment of the network nodes are conducted. This is the meaning of 'subject to the approval of specific assessment' in this Clause. Nevertheless, a compound interchange may be only a matter of cost if two interchanges in a compound interchange are both general interchanges with limited turning traffic flows.

11.1.6 For the distance from the exit of a tunnel to the next interchange, the provision that 'the distance from the exit of a tunnel to the start point of a deceleration lane of an interchange shall not less than 1,000m' remains as stated in the previous edition of these specifications; where constrained by terrain or other conditions, the relevant provisions in JTG/T D21-2014, Guidelines on Design of Highway Grade-separated Junctions.

11.1.9 Most of the criteria for the alignment of the main route at an interchange remain as specified in JTG B01-2014 and only a few are updated. Criteria for the main route alignment are a set of macro control of horizontal and vertical alignment elements, such as sight distance, visibility and predictability of road alignment, the connection between speed-change lanes and the main route, and the alignment of critical ramp sections. The purpose is to ensure smooth traffic flow, easy speed change, and effective performance in all parts of an interchange.

The maximum grade of the main route at an interchange is mainly to control the values of downgrade exit and upgrade entrance of a speed-change lane. Table 11.1.9 gives normal values and limiting values of maximum grades, to which a 1% increase is allowed for difficult terrain or other limiting factors. This is in contrast to the provisions in Japan where for the design speed of 120km/h the maximum grade is controlled as 2% without tolerance. The previous editions (1994 and 2006) of these specifications specified that both normal value and limiting value of the maximum grade should be 2% for a design speed of 100km/h, which may be too strict. The limiting value of maximum grade for a design speed of 100km/h has been increased from 2% to 3% in this edition.

Considering that the exit on a long and steep downgrade is susceptible to traffic accidents, the values in brackets listed in Table 11.1.9 should be adopted as the upper limits of maximum grades for the main route segment before an exit to the deceleration lanes and ramps with low geometrics in difficult environmental conditions.

There were opinions that some of the criteria in Table 11.1.9 are too high to be achievable. However, as indicators for macro control, these criteria shall not be reduced, especially the minimum radii of crest vertical curves that affect sight distances at exits and entrances of main route. The radius should be greater than the limiting values wherever possible. Within a certain range before an approach nose, the normal value for the minimum radius of the crest vertical curve, which satisfies decision sight distance, shall be used wherever possible. The 'limiting values' may only be adopted for a few of the criteria for the difficult conditions during design subject to countermeasures for traffic safety is emphasized. Under special circumstances, some criteria may be lower than the values specified in Table 11.1.9, such as the criteria for crest vertical alignment with little interference on sight distance at exits and entrances of the main route, and the criteria for horizontal alignments except those for speed-change lanes.

11.1.10 These provisions about compound interchanges are a new addition. In recent years a number of compound interchanges were built or are under construction, among which some are compound with one general interchange and one hub interchange. Combining two interchanges with auxiliary lanes shall not be recommended by these specifications because such a combination would affect the stability of traffic flow in and out of the hub interchange, and thus negatively interfere with safety. Such compound interchanges shall be avoided even during road network planning.

This edition of the specifications gives three basic connections for compound interchanges.

(1) Auxiliary lanes are used to connect the entrance of one interchange to the exit of next interchange.

(2) A collector-distributor ramp, which is separate from the main route, is used to connect all exits and entrances on one side of the main route to create a single exit and a single entrance between the collector-distributor ramp and the main route.

(3) Weaving separation lanes are used for diverging main weaving streams from the collector-distributor lanes to form an operation mode without weaving between the two interchanges.

Rules for connection within a compound interchange are as follows.

(1) Two general interchanges shall be combined by using the connection (1).

(2) One general interchange and one hub interchange shall be combined by using the connection (2). Where there is a large traffic volume, a short weaving length and two-way two-lane ramps in the interchanges, the connection (3) shall be selected. However, in areas with low traffic volume, connection (1) may be adopted subject to the approval of a thorough assessment of the capacity.

(3) A compound interchange of two hub interchanges shall be avoided wherever possible during road network planning. Where such a case is unavoidable, connection (3) shall be selected.

Whichever connection is adopted, analyses shall be carried out to verify the length of weaving sections between the two interchanges. The length of a weaving section shall not be shorter than 600m.

11.2.2 Required decision sight distance shall be ensured on the main route ahead of the approach nose at the exit of an interchange, of which the value shall be taken from Appendix B of JTG B01-2014. The value equivalent to 1.25 times the stopping sight distance may be used only where constrained by difficult conditions.

Using decision sight distance at exits is based on the consideration that a driver (with height of sight at 1.2m) shall see the road marking of the approach nose, (height of object is 0 m). Attention shall be given to this when determining the radius of a crest vertical curve.

11.2.4 In the case of the main route on downgrade and the ramp on upgrade, the gradient of the ramp shall not be different from the grade of the main route within the range of sight triangle, especially where the main route is on a bridge section with physical barriers installed, because such a barrier may completely obstruct the sight from the adjacent ramp. For the desirable visibility, the pavement of ramps should be higher than the pavement of the main route in the range of the sight triangle.

11.2.5 This Clause specifies that the distance from the ramp exit to the overpass shall not be shorter than 150m where the ramp is behind the overpass. However, this provision may not be applicable to the circumstances where the main route, either over or under an overpass, is on a tangent, or on a large-radius curve, while the piers and abutments do not obstruct the driver's sight or affect his judgment on the exit.

11.3.1 The design speed of a ramp is the maximum speed at which safety can be ensured on the segments with constrained alignments. The other segments shall be controlled by the speeds corresponding to the change in speed on ramps. Higher design speeds shall be adopted for ramp exits or entrances where traffic is at approximately free flow; design speeds may be reduced ahead of toll stations or at the ends of at-grade junctions. Therefore, designers must be aware of these changes to the previous approach of taking one design speed for all parts and segments of a ramp.

11.3.2 The elements, widths, and types are the main factors to be determined in the design of ramp roadways, for which the following factors shall be checked.

(1) Width of a right hard shoulder: during the information inquiry for updating of these specifications, most of highway administration and maintenance agents suggested that the width of a single lane ramp, or the width of right hard shoulder, be increased for convenience of maintenance without interrupting traffic and for emergency rescue. Therefore, in this edition, the width of right hard shoulder has been increased to 3.00m and that of right hard shoulder for turnout has been increased from 2.5 m to 3.00m.

(2) Lane width: the provision that 'where the ramp design speed is higher than 60km/h, the lane width may be 3.75m' is added in this edition. However, the width of the right hard shoulder has been increased to 3.00m, which in turn increased the pavement width. Under such circumstances, the 3.50-m wide lane on a ramp is adequate for a design speed higher than 60km/h. This means that a further increase of lane width would not affect the traffic safety. However, it would bring about unreasonable consequences. For example, in the case where 3.75m is taken as lane width, the width of a one-way, two-lane ramp will be as wide as 12.75m, even broader than a 12.25-m wide separate roadway with a design speed 80km/h as previously specified. Of course, it is unfavorable to the current standardized bridge design drawings and thus the lane width of a ramp shall be selected in accordance with the roadway width of main route. The 3.75-m lane may be adopted for ramps where the width of the right hard shoulder is less than 3.00m and the ramp design speed is higher than 60km/h.

(3) Type of ramp roadway: According to the previous edition (2006) of these specifications, 'type-II cross-section should be adopted for the ramp which is longer than 300m, with overtaking demands but single lane at either exit or entrance', resulted in practice that after transition

sections placed at both ends, only a 100m long ramp section would be left for overtaking. Consequently, designers took 500m as the controlling criterion on the ramps with two-lanes only for overtaking in their previous designs. In this edition, the length has been increased to 500m for ramps that accommodate traffic volumes between 300 to 1,200pcu/h and the have a type-II cross-section only for overtaking requirements. For ramps with a traffic volume less than 100pcu/h, no matter how long the ramp, a type-I cross-section shall be used.

Borderline traffic volume for selecting ramp roadways is 1, 200pcu/h and 1,500pcu/h, which is the demarcation between with or without turnout and the corresponding speed is between 40 and50 km/h.

The lane capacity of a ramp may fluctuate as design speed varies. In practice, designers may make reference to the capacity manuals and design guidelines to adjust the relative criteria in accordance with design speed of the ramp.

(4) For a multilane ramp diverging from or merging into a main route, the widths of lanes and shoulders on the ramp shall be the same as those of the main route. At a T-junction, type-III roadway may be adopted for both legs in a continuous alignment (for through traffic), and then taking a certain length of the ramp as transition section over which the roadway of main route gradually changes from one end to the roadway of ramp on the other end.

(7) According to the experience of practice in other countries, two-lane loop ramps are susceptible to traffic accidents, especially for small radii. Consequently a rule of ‘only a single lane for the loop ramp’ is applied in some of the countries. In China, the land resource is scarce and the radii used for loop ramps are small (less than 75m), and thus such a rule is introduced in this edition. The capacity of a loop ramp, which is a range of values, from 800 to 1,000pcu/h, may be determined by designers at their discretion in accordance with the radius of the loop ramp.

11.3.3 and 11.3.4 Horizontal and vertical alignments of ramps are essential for an interchange design. Attention shall be given to the following:

(1) The minimum radii of non-superelevated circular curves in Table 11.3.3-1 are applicable to the circumstance where cross slopes are smaller than 2%; otherwise, a specific calculation shall be executed.

(2) From the approach nose on an exit ramp section to the beginning point of the curve for design speed control (such as the beginning point of a loop ramp in a type-B trumpet junction), the operating speed of a vehicle is changing from the passing speed at the approach nose to the design speed of the ramp. This is known as ‘alignment transition section’. On transition, drivers may make mistakes and thus cause safety problems. Designers shall provide space for adjustment. Therefore, this edition gives criteria on the curvature radii at approach nose and the parameters of the spiral and the transition.

Edition (1994) of these specifications gave criteria for minimum curvature radii and minimum spiral parameters. However, the specified length of deceleration lane was considered too short. Some designers placed part of the spiral in the deceleration lane at the approach nose and thus the curvature radius at approach nose is small, or even insufficient. In edition (2006), the length of the deceleration lane was increased; the minimum curvature radius at the approach nose was increased slightly. In the background to this Clause, it is suggested (not a recommendation) that a three- centered compound curve with gradually reduced parameters (also termed a ‘break curve’) may be placed between the exit of the deceleration lane and the loop ramp with reduced parameters.

Edition (2006) of these specifications has played an active guiding role in terms of alignment criteria on exit ramps of interchanges and traffic safety since it was put into effective. The ‘brake curve’ was adopted in practice and results in good driving comfort and safety at ramps and should continue to be used wherever applicable. However, the edition (2006) abolished the provisions on minimum parameters of spiral at approach noses. In some projects, extra-large radii were used on the ramp at the approach nose, which in turn increased land use and construction costs. In recent years, more attention has been drawn to land conservation and farmland protection. Based on the enveloped relationship between the distance from a point on alignment transition to approach nose, and the curvature radii, this edition gives provisions on the design (passing by) speed and minimum curvature radii of horizontal alignment, as summarized in Table 11.3.3-3. It also specifies that a spiral curve may be connected at the approach nose, and that the minimum radius at the approach nose of a general interchange may take the values 5km/h less than the design speed at diverging nose in the Table to save land cost. Designers may select parameters of horizontal alignment for the ramps at the approach nose from Table 11-1 in accordance with interchange type(either hub or general type) and design speeds (either of main route or at approach nose), or their combinations if necessary.

Table 11-1 Minimum Curvature Radius and Minimum Parameter of Spiral at Approach Nose

<table>
<tr><td colspan="3">Design Speed of Main Route（km/h）</td><td colspan="2">120</td><td>100</td><td>80</td><td colspan="2">60</td></tr>
<tr><td rowspan="5">Hub Interchange</td><td colspan="2">Design Speed at Approach Nose (km/h)</td><td>80</td><td>70</td><td>65</td><td>60</td><td colspan="2">55</td></tr>
<tr><td rowspan="2">Minimum Curvature Radius (m)</td><td>Normal value</td><td>450</td><td>350</td><td>300</td><td>250</td><td colspan="2">200</td></tr>
<tr><td>Limiting value</td><td>400</td><td>300</td><td>250</td><td>200</td><td colspan="2">150</td></tr>
<tr><td rowspan="2">Minimum Parameter of Spiral (m)</td><td>Normal value</td><td>160</td><td>100</td><td>90</td><td>80</td><td colspan="2">70</td></tr>
<tr><td>Limiting value</td><td>140</td><td>90</td><td>75</td><td>70</td><td colspan="2">60</td></tr>
<tr><td rowspan="5">General Interchange</td><td colspan="2">Design Speed at Approach Nose (km/h)</td><td colspan="2">65</td><td>60</td><td>55</td><td>50</td><td>45</td></tr>
<tr><td rowspan="2">Minimum Curvature Radius (m)</td><td>Normal value</td><td colspan="2">300</td><td>250</td><td>200</td><td>150</td><td>125</td></tr>
<tr><td>Limiting value</td><td colspan="2">250</td><td>200</td><td>150</td><td>125</td><td>100</td></tr>
<tr><td rowspan="2">Minimum Parameter of Spiral (m)</td><td>Normal value</td><td colspan="2">90</td><td>80</td><td>70</td><td>60</td><td>50</td></tr>
<tr><td>Limiting value</td><td colspan="2">75</td><td>70</td><td>60</td><td>50</td><td>40</td></tr>
</table>

Note: For loop exit ramps of a hub interchange, the value may be taken as one class lower than the design speed of the main route

Minimum radius and length of the vertical curve at the approach nose shall conform to the criteria in Table 11.3.4-2 in accordance with the design (passing) speed at the diverging nose.

Minimum curvature radius at the approach nose: the normal value is derived with the design (passing) speed at the approach nose where superelevation is 2% and side force coefficient is 0.10; the limiting value is calculated with the design speed reduced by 5km/h at the approach nose.

Spiral curve within and after the approach nose: the beginning point of the spiral should usually be placed at the approach nose on the ramp. Where the spiral curve is extended into the nose zone for design reasons, the curvature radius at the nose shall be validated with the criteria in Table 11-1. Special attention will be paid where parallel exits are adopted, unless the speed at the approach nose can be efficiently reduced by extending the length of the deceleration lanes.

11.3.5 The procedure for determining ramp superelevation values are the same as that for the main route, that is, ramp superelevation is placed in accordance with the requirements in Section 7.5. Two issues shall be considered in the ramp design.

(1) Ramp superelevation shall match the running speeds during the process of speed change on the ramp. For instance, the ramp superelevation values at atoll station or an at-grade junction shall be smaller than that for interchange facilities, but shall be slightly larger at approach noses.

(2) In non-freezing areas where maximum superelevation is 6%, designers may begin with 8% as the maximum and calculate or select superelevation values for different radius values. In the final determination of the superelevation, the superelevation of 6% is universally applied for all the radii for which superelevation is greater than or equal to 6%, while the actual values are taken for the others. In such a way, the driving comfort, on superelevated curves less than 6%, can be ensured.

11.3.6 In this edition, the pavement widening of a circular curve on ramps has been adjusted for two reasons: one is the increase in width of right hard shoulder on a ramp from 2.5m to 3.0m; the other is that according to JTG B01-2014, the type of design vehicles and outline dimensions have been updated as shown in Table 2.1.3 of these specifications.

After the adjustment, Table 11.3.6 for ramp pavement widening is in agreement with JTG/T D21 Guidelines on Highway Interchange Design. In the case of the widening value of type-III ramps, the designer shall note that if the calculated widening value of type-II minus the difference in width of hard shoulder between type-III and type-II is zero or a negative value, it means that there is no need to widen the ramp on the curve. Where the width of type-III hard shoulder is 3.0m and the radius of circular curve is above 31m, or the width of hard shoulder is 2.5m (not a standard width) and the radius of circular curve is above 39m, the ramp may not need to be widened.

11.3.7 The exit and entrance of ramp is one of the main topics in ramp design. Attention should be paid to the issues as follows:

1Offset widening at approach (diverging) noses on right side:

Exits and entrances of ramps shall usually be placed on the right side of the main route. However, the exits for traffic diverging or entrances for traffic merging between main routes shall depend on specific circumstances. Because ramp connections on the left side of a main route is problematic, directional ramps with left side access is seldom used in practice.

Offset widening is applied on both sides of the approach nose. Note that the C1 is on the main route, which refers to the width of widened pavement including the width of hard shoulder abutting to the outer edge line of the traveled way; C2 is on the ramp, and defined as the width of widened pavement excluding that of left hard shoulder of the ramp.

For other types of offset widening, rate of transition, detailed configuration, and placement of approach noses on roadway or bridge, reference may be made to relevant design manuals.

2 Types of exits and entrances

Exits and entrances (or speed-change lanes) may be categorized as directional type and parallel type. The advantages of directional type are smooth alignment, uniform and convenient operation. Parallel type is easy for drivers to identify the change in the number of lanes but the twisting of the alignment may cause discomfort. These two types have their own advantages and disadvantages. There are no uniform specifications but application depends on tradition and preference. In Germany and Japan, all single lane entrances are of the parallel type and the others of the directional type while Germany recently mandated that all entrances and exits shall adopt the parallel type. Meanwhile, in U.K and some other European countries, all exits and entrances are of a directional type; Australia prefers paralleled exits and directional entrance. In China, parallel type is used in most of the exits and entrances on urban expressways, and thus could be the trend in future.

Since the 1994 edition of these specifications, the types of exits and entrances have followed the Japanese specifications, that is, directional type for single-lane exits, parallel type for single-lane-entrance, and directional type for two-lane entrances and exits. This has been used successfully for more than 20 years and thus defines the popular practice in China. Therefore, the previous provisions have remained the same in this edition. However, designers shall keep in mind that parallel type is allowed, especially in restricted conditions or for special needs.

Where an exit connects to a small-radius (e.g. R<45m) loop ramp, and if a directional type is adopted, the change in curve radii could be too much and abrupt while a 'brake curve' may not viable due to the restriction of terrain or other factors. In such circumstances, parallel type should be adopted, that is, a gentle S-curve with quite small deflection angles is placed in before and after an approach nose. Thus the ramp could be separated from, but very close to, the main route to manage an 'alignment transition section' with sufficient length and good parameters. Furthermore, parallel type may also be adopted for auxiliary lanes in loop ramps of a clover shaped interchange.

For single-lane acceleration lanes, parallel type is recommended but directional type is not excluded, for controlling the entrance length by the entry angle (rate of transition).

11.3.8 For the design of speed-change lanes, designers shall pay attention to the following issues:

1 Length of speed-change lanes

Motorways built initially followed provisions in the 1994 edition of these specifications that may have the problem of insufficient length of the speed-change lane. The 2006 edition stated that besides the requirements for the angle at the exit and entrance and the nose offset widening, the speed-change lanes should also satisfy the requirements for lengths calculated based on vehicle dynamics in deceleration and acceleration. The specified lengths of speed-change lanes were appropriately increased and given in the table of 'Lengths and other parameters of speed-change lanes".

The table on the lengths and other parameters of speed-change lanes remains in this edition, because the results in practice were satisfactory. Only the column of 'radii of approach nose' is cancelled, and a regular r ⩾0.6m may be used in design.

Designers shall notice that although the speed-change lane is longer than previously specified, good alignment parameters shall still be required for the ramp section approaching the speed-change lanes. A low design speed shall never be used on a transition section with sufficient length but poor alignment parameters, because only increasing the section length would not help technically but would be a costly solution for effective speed change.

Under the prevailing provisions, the lengths of speed-change lanes at different design speeds seem not to match the speed differences. However, this is the reflection of real driving speeds. On normal segments of motorways, the lower design speed is more likely to be achieved or even exceeded. The alignment parameters of an interchange are usually higher than that on normal motorway segments, as speeding is more likely to occur. Where the design speed is lower, the speed-change lane seems longer, as it needs to cater for the speed at a merging point usually being higher than the design speed.

2 Alignment of speed-change lanes

This Clause emphasizes the policy that a directional speed-change lane shall have the same alignment as the main route and gives diagrams showing the geometric relationship. The purpose is to avoid the improper treatment in the design that the length of the transition section is different from the length of a speed-change lane caused by poor alignment of the speed-change lane.

This Clause specifies that in the case of the main route being on a small radius left-turn curve, or other special circumstances, the segment of the directional speed-change lanes close to the connecting ramp may have an alignment different from that of the main route. To avoid the shortening of the speed-change lane due to this, designers may increase the radius at the approach nose, increase the nose offset, or make a slight change to the rate of transition.

In parallel type speed-change lanes, the alignment of the segment near the ramp is more flexible, but the curvature and its transition shall be appropriate for the speed requirements. In the case of deceleration lanes, provisions have been given for the alignment at the approach nose. Designers shall ensure that the curvature radius and road crown or superelevation complies with the relevant criteria.

It should be noted that the cross-section at which the width of the transition section reaches the full width of a lane is referred to as diverging (merging) point; the point where the main route and speed-change lanes split from each other is referred to as the approach nose.

11.4.1 This Clause gives the requirement that the basic number of lanes shall be kept constant on a motorway. According to JTG B01-2014, the number of at-grade junctions and accesses on a class-1 arterial highway shall be strictly controlled, reflecting that the number of lanes on a Class-1 arterial highway shall not be frequently changed in short segments.

11.4.4 As far as two-lane exit and entrance ramps are concerned, the highway practitioners in central and eastern parts of China complained that the length of auxiliary lane on the exit ramp specified in the 2006 edition was too short. According to the design principles practiced in United

States and Japan, long auxiliary lanes are required for a traffic diverging zone for exit recognition, psychological awareness and for positioning for lane change. AASHTO specifies that the length of auxiliary lanes at a two-lane exit should be 2500ft to 3000feet, or 726m to 1066.8m long from the start point of the transition section to the end of the exit; the minimum length of an auxiliary lane at a merging section is 2500ft, or 726m. Japanese specifications require that the ideal standard length of auxiliary lanes is 1000m for diverging and a minimum 600m for either diverging or merging. The length of auxiliary lanes for diverging shall not be less than the length for merging. This edition, maintaining continuity with the previous edition, gives a range of the lengths of the auxiliary lane at an exit ramp. The limiting value remains as previous, and the normal value is the sum of the lengths of speed-change lane and the auxiliary lane and should not be less than the required sum of these two kinds of lanes. The lengths shall not be less than the normal values for interchanges with large traffic volumes. Limiting values may be used only in the case of low traffic volumes or where constrained by terrain conditions or structural works (extra-large or special bridges and tunnels).

11.5.1 This Clause defines the major forks and branch connections of main routes and gives diagrams for designers to avoid confusion.

11.5.3 In most of cases, there might be a change in the number of lanes at a branch connection or a major fork, that is, a transition section exists. This Clause specifies the rate of transition, the roadway transition, and the alignment transition of two-way segments.

11.5.4 This Clause identifies two situations: one is the number of lanes in balance before and after diverging or merging, for which directional ramps may be adopted; the other is that the number of lanes is not in balance, and then a section of auxiliary lanes are required. The amendment made in this edition is adding an additional 10m to the minimum lengths of the transition sections for a design speed of 40km/h for diverging and merging, in comparison to the figures given in the 2006 edition.

11.5.5 The criterion for the minimum spacing of adjacent exits and entrances in the 2006 edition was developed by referring to the requirements on urban freeways in the United States and was based on various design speeds of the main route. In this Edition, the minimum spacing of adjacent exits and entrances on main route (L1) has been increased, and that on ramps (L2) has been adjusted, while the requirements for ‘local roads’ in the previous Edition were cancelled. Designers shall use ‘normal values’ wherever possible. The values that are smaller than ‘normal values’ or equal to ‘limiting values’ may only be used in restricted or difficult conditions.

Designers shall notice that it would be desirable to use a larger value for the distance from a two-lane exit on the main route to the diverging point on the ramp to avoid overlapping conflicts of overtaking and weaving, and the resulting traffic accidents.

11.6.1 The at-grade junction at an interchange refers to the one between an interchange ramp or link road and the intersected highway, and usually in a diamond, partial cloverleaf or single trumpet interchange configuration. Note that, in contrast to the other elements of interchange design, designers have not yet paid enough attention to the issues of at-grade junctions at interchanges, as reflected in design documents or even in completed works. This Clause emphasizes the importance of carrying out elaborate and detailed design of channelization for at-grade junctions at interchanges in accordance with the criteria and requirements given in Chapter 10 of these specifications and relevant design manuals.

12 RAILWAY, FARMROAD AND PIPELINE CROSSINGS

12.1.1 The provisions for highway-railway crossings are applicable to highways crossing over 1435mm standard gauge railways. For other gauge railways, of which are not many but still operating in areas such as seaports, the design of such crossings may be conducted by referring to the provisions below.

12.1.2 Reference has been made during the updating for this Edition by referring to the Code for the Design of High Speed Railways (TB10621-2014), Code for the Design of Railway Lines (GB 50090-2006), Structure Gauge for Standard Gauge Railways (GB 146.2), Procedures of Railway Technical Administration (for High Speed Railways), and Procedures of Technical Administration (for Ordinary Railways). In principle, grade separation shall be used for all highway-railway crossings.

12.1.4 Farm roads refer to the roads for farmers and their farming vehicles traveling in villages and to farmlands.

12.1.5 Referring to the relevant national standards, including GB50061-2010 Code for the Design of 660kV or Under Overhead Electrical Power Transmission Line, GB50454-2010 Code for 110-750kV Overhead Electrical Power Transmission Line, GB 50665-2011Code for the Design of 10000kV Overhead Transmission Line, GB 50790-2013 Code for Designing of about 800kV DC Overhead Transmission Line, 50423-2013Code for Design of Oil and Gas Transportation Pipeline Crossing Engineering, this Edition has rechecked the specified values for confirmation and gives additional information.

12.2.1 As background to the status quo of highway and railway development and for the sake of traffic safety, grade separation shall be considered as a priority wherever a highway crosses railways.

12.2.2 to 12.2.4 This Clause specifies the conditions for a grade separation to be adopted for highway-railway crossings to ensure the safety of both highway and railway vehicles.

12.2.5 From the perspective of the impacts on the highway, the highway alignment and the sight distances are of major concern in the design of highway-railway grade separation. Firstly, it is emphasized that the horizontal and vertical geometry of the highway section at a grade separation shall conform to basic requirements of the highway main route and no technical criteria shall be reduced at all. This means that the stopping distance must be ensured. Secondly, a small intersection angle will inevitably increase the bridge length and construction challenges and workload of the grade separation and related road sections. Following the requirements in JTG B01-2014, this Edition deleted detailed requirements on intersection angles, but emphasizes that the highway and railway at the crossing should be on tangent alignments and should intersect each other at right angle. Where a skew intersection is inevitable due to difficult terrain conditions, the intersection angle should be as large as possible. It is also noticed that GB50090-2006Code of Design for Railway Line gives the requirements on the conditions for crossing and structure gauges but no details about intersection angle.

12.2.6 Railways may require different structure gauges. To determine the structure gauge for the proposed highway overpass bridge, designers shall make reference toGB 146.2Structure Gauges for Standard Gauge Railways and consult railway administration departments about the planning of double level container transportation, and the requirements for operational safety of the electrified railway during construction.

This Edition emphasizes the operational safety and requires that collision barriers and netting to catch falling objects shall be installed on all the highway overpass bridges crossing over railways.

12.3.1 The intersection of a highway-railway at-grade crossing shall be at right angles wherever possible. This is to minimize the lengths of accesses and thus reduce the lengths and time for pedestrians and vehicles to pass over a railway at-grade crossing. Furthermore, a small intersection angle may cause vehicle tires to be trapped in rail gaps or present other hazards to traffic. This Clause specifies that the intersection angle of a highway-railway at-grade crossing should be greater than 45o, which is consistent with the requirements in the relevant railway specifications. Designers shall pay special attention to this, namely avoid small angles and arrange effective safety devices at railway at-grade crossings.

12.3.5 The roadway width of the intersecting highway shall not be reduced in the sections approaching to and at a railway grade crossing surface. This is based upon the consideration that any deduction in width of roadway cross section may negatively affect the safety for motor vehicles, non-motorized vehicles and pedestrians to cross over the railway at-grade crossing. It is required therefore to ensure traffic safety even when motor vehicles and low performing non-motorized vehicles are simultaneously traveling in both directions of the highway-railway at-grade crossing. Railway grade crossings with large traffic volumes shall be provided with flagmen and the width of railway grade crossing surface shall be properly increased.

12.4.1 There are several principles for determining the configurations of highway-farm road crossing. Underpass tunnels or overpass bridges must be adopted for farm roads crossing motorways. In general, either underpass tunnels or overpass bridges should be adopted for farm roads cross a class-1 arterial highway, or alternatively a number of farm roads may be combined into a frontage road to reduce the number of crossings, minimize transverse interference and ensure safety and capacity on the class-1 highway

Underpass tunnels or overpass bridges may be adopted where class-1 collector-distributor highways cross the farm roads. Effective and sufficient safety devices shall be installed at all at-grade crossings.

Where a class-2, class-3 or class-4 highway crosses a farm road, an at-grade crossing is usually adopted; an underpass tunnel or overpass bridge may be adopted where terrain is favorable. For a new class-2 arterial highway, grade separations are recommended wherever possible.

12.4.4 Attention shall be paid to the following issues.

1 The 400-m spacing is a general requirement for all types of structures for vehicles crossing roads, including underpass tunnels and overpass bridges.

2 Based on nationwide studies, the requirements for the intersection angle of an underpass has been reduced from the previous 70o to 60o in general, and reduced from the previous 60o to 45o for the locations constrained by terrain or other special conditions. The purpose is to reduce the difficulties and increase flexibility in implementation. However, a large intersection angle shall be adopted wherever physical conditions permit and as long as relocation would not cause a significant increase in construction size and cost.

5 The selection of roadway cross-section, especially the clearance of a highway-farm road crossing, is a sensitive issue in relation to people’s daily life and living needs. The clear widths given in these specifications are recommended values while the clear heights are lower limits. In practice, designers shall strive to use higher criteria for clear height in accordance with the terrain, profile, height of trucks and other factors, and avoid using the lower limiting values only for cost saving. Furthermore, attention shall also be paid to the density and spacing of farm road crossings along the main highway route.

The 4.00-m clear width specified in this Clause is a lower limit value. Considering that an underpass tunnel could be long under a multilane highway especially on a high fill segment, in practice wider clearance shall be used wherever possible for better illumination and ventilation inside a long tunnel, which may provide additional space for future demands and further development. The clear width of 4.0m maybe only be used for separated roadways or in sparsely populated areas.

The values of 3.20m and 2.70m given in Table 12.4.4 are lower limiting values in terms of actual clear heights for farmers' trucks, tractors, and animal drawn carts. Some of the local traffic administration authorities have increased the criteria for the clear heights, for instance, to 3.50m for farmer trucks and 3.0m for farm tractors and animal dawn carts. These values of clear heights may be determined in accordance with the characteristics of local traffic composition and the specific requirements of farming equipment and other vehicles.

Combine harvesters are popularly used in China. Investigations show that there are no unified standards available, and thus the outline dimensions of combines are different from one manufacturer to another. Designers shall determine the clear heights for underpass farmroads in accordance with local agricultural demands and the primary models of combines popularly used in the region.

If the underpass farm road is the only access to a village next to the highway, the requirements for firefighting and disaster relief shall be fully taken into account. The clear heights shall accommodate the height of fire trucks and emergency relief vehicles.

Where the underpass farm road is important for emergency rescue and disaster relief and is located on river bridge approaches, the designer shall consult the local waterway authorities for determining the clear heights and elevation of the underpass farm roads.

12.5.1 It is noticed that the current electricity technical specifications do not give specific requirements on minimum intersection angle of overhead electrical power transmission lines crossing over highways. This Clause follows the requirements specified in Clause 9.5.2 of JTG B01-2014 that the electric line crossing over a highway should be at right angles; or shall be at an angle greater than 45° if skew crossing is inevitable.

12.5.2 During the updating of this Edition of the Specifications, the criteria regarding the minimum vertical distance from overhead electrical lines to the highway surface beneath has been reconfirmed by referring to and cross-examining the relevant industrial standards, including GB50061-2010 Code for Design of 66kV and Under Overhead Electrical Power Transmission Line, GB50545-2010 Code for Design on 110～750kV Overhead Transmission Line, GB50665-2011 Code for Design of 1000KV Overhead Transmission line, GB50790-2013 Code for Designing of ±800kV DC Transmission line. The clear heights for 750kV,1000kV and ±800kV DC overhead electrical lines have been added in this Edition.

12.5.4 This clause adds the requirements for the distance from electrical posts to the highway side drains, either crossing over or parallel to each other.

12.5.5 Referring to GB 50423-2013, Code for Design of Oil and Gas Transportation Pipeline Crossing Engineering, the requirements for oil and gas pipelines crossing highways have been updated. The requirement specified in previous editions, namely that the minimum acute angle shall not be smaller than 70o in general and shall not be smaller than 60owhere constrained by terrain or other special conditions, has been updated to that it should not be smaller than 30o, which is consistent with the current national standards and maintains the status quo and anticipated future situations of highway and pipeline construction and technology development. However, large intersection angles shall always be preferred in order to mitigate construction challenges and quantities.

12.5.6 Considering the importance of motorways and class-1 highways for large and uninterrupted traffic flow, the needs of regular inspection, maintenance, and operations of a pipeline, the Edition 2006 of these specifications defined that an underground crossing should be adopted where a pipeline for oil or gas transmission, water supply, sewerage, chemical material crosses a motorway or class-1 highway. Specific underground passages shall be provided and manholes and identification marks shall be placed along and on both sides of the passage. Sleeve conduits shall be placed where an oil or gas transmission pipeline passes under a class-2 or class-3 highway. The sleeve conduits shall be placed and protection countermeasures against leaking and damage, and thermal isolation shall be provided where a cable for telecommunication, surveillance or electrical power transmission underpasses through a classified highway.

Following JTG B01-2014 and relevant research, this Clause clearly states that specific crossing-through passages such as tunnel, culvert, or sleeves are required for pipelines that underpass motorways and class-1 highways. This is based on the status quo of construction skills and technology (mainly pipe jacking construction) for pipeline construction operation, inspection and maintenance do not require a highway to be excavated that will interrupt highway traffic.

Safety prevention measures and protection treatment shall be designed and applied. Treatments include rust-proofing, leak-proofing for water pipes, fire and explosion prevention for oil and gas pipelines, barrier against vehicle collision and isolation from pedestrian access. Pipeline inspection and maintenance activities must not affect highway operation and traffic safety.

12.5.8 and 12.5.9 For the safety of highway transportation, it is strictly prohibited for the pipelines of high voltage electrical cables, or toxic, flammable, explosive substances to cross a river by means or highway bridges or to cross mountains by means of highway tunnels.

The river crossing of a pipeline transporting toxic, flammable or explosive substances shall be kept a distance of at least 100 m away from any extra-large, large or medium highway bridge; or at least 50 m away from any small highway bridge.

12.5.10As required in this Clause, it is essential for normal highway operation that all and any pipelines must not intrude into the highway clearance profile. Non-interference to highway traffic safety includes but shall not be limited to the following situations: for instance, although a high-voltage electrical line does not intrude into the highway clearance profile, if its suspension above the highway roadway is not high enough, it may endanger highway traffic; water canals and pipes do not intrude into the highway clearance profile, but leakage may undermine the stability of the highway slopes. Safety to highway and highway facilities shall include but not be limited to the following situations: for instance, pipeline facilities such as water tanks, pumping stations of oil or gas pipelines may be the type of hazards to highway safety, and thus must not be placed near the land reserved for the highway. Leakage of the pipelines of toxic, flammable or explosive chemicals may endanger the vehicles and personnel on the highway.

13HIGHWAY ROADSIDE FACILITIES

13.1.1～13.1.3 Roadside facilities refer to toll stations on the main route of a highway, toll stations on ramps (or link roads), service areas, rest areas, bus bays, U-turn facilities, and others. This Chapter of these specifications gives general criteria and requirements for the geometric design only. All the specific technical designs of particular facilities shall conform to the relevant design manuals. Service and other facilities shall be laid out holistically and by taking account of interchanges, tunnels and other large structures along the route. The spacing between the roadside facilities and special structural works shall conform to the criteria in Clause 11.1.6.

13.2.1 The maximum cross slope of 2% on a toll plaza shall be over a distance that is longer than 100 m on both sides from the centerline of the toll plaza on a motorway or class-1 highway with design speed greater than or equal to 100km/h. For highways with a design speed lower than or equal to 80km/h, the distance of a toll plaza on the main route may be reduced in accordance with the highway function, design speed, and traffic volume, but shall not be less than 50m on both sides from the centerline of the toll plaza. This is ‘the minimum length of concrete pavement before and after toll booths’ as specified in Table 13.2.2-1.

The cross slope on a toll plaza should be 1.5% in general or may be up to 2.0% for effective drainage considering high rainfall and multi-lane pavements. Where the toll plaza is on a horizontal curve with a superelevation transition, the resultant slope at any roadway crosssection shall not be less than 0.5%.

13.2.2 For the design of a toll plaza, designers shall pay attention to the issues as follows.

(1) A toll plaza shall not be placed at bottom of a sag vertical curve for considerations of visibility and drainage. Preferably, it should be placed near the top of a crest vertical alignment.

(2) L0 in Table 13.2.2-1 is the minimum length of concrete pavement at a toll plaza. In practice, L0 shall be determined as the maximum length from the centerline of the toll plaza to the end (either upstream or downstream) of the toll island plus a tangent of at least 10m long as a safety allowance. The length of L0 shall satisfy the needs for multi-tolling modes such as manual tolling and ETC, and accommodate the layout of one-lane with one-booth or one-lane with multiple booths.

L_0 is placed symmetrically before and after the centerline of the toll plaza. Asymmetrical placement may be adopted subject to special needs. Toll islands and the concrete pavement shall be arranged in line within the length L_0.

(3) Regarding the transition rate (L/S) of the roadway width in a toll plaza, the majority of the opinions from provincial administrators is that the previous criterion L/S⩾3is quite abrupt and should be more gentle; however the opinions from the south-west provinces suggested that the previous criteria should remain because of terrain constraints. This Edition gives a range of transition rates and a slightly increased lower limit. However, the previous criterion of 3 remains only for special circumstances.

(4) Where the distance from the centerline of the toll plaza to the at-grade junction point of intersected highway is shorter than 150 m, a waiting lane shall be placed on the intersected highway or on the ramp before toll plaza if necessary.

Where a toll plaza is close to the intersected highway, the layout of toll-by-weight stations and the lanes for turning back may be taken into account if necessary.

13.3.1 The standard spacing of service areas should be 50 km, usually within a range of 40 to 60 km, but shall not exceed 100 km. Where the spacing of two successive service areas is longer than 60 km, rest areas with refueling facilities shall be placed in between.

13.3.2 The geometric criteria of the main route at a service area are consistent with those at an interchange as shown in Table 11.1.9 to ensure sight distances and traffic safety at ramp exits and entrances.

The criteria listed in Table 13.3.2 for the main route vertical alignment near a rest area are the same as those in Table 11.1.9. Both tables insist that the requirements for sight distance at an exit from or an entrance to a ramp shall not be reduced. Reducing criteria for minimum radius of vertical curves and maximum grade (for a design speed within the range from 80 to 120km/h) is based on the scarce localities suitable for rest areas in mountainous terrain. Appropriate reduction of horizontal and vertical parameters helps to ensure highway functions are located on the one hand; and respond to the opinions and recommendations from highway administration practitioners on the other hand. However, a designer shall keep in mind that a steeper grade has a negative impact on traffic safety, and thus should be used with caution only in difficult conditions and subject to the approval of a thorough assessment.

Note that the ‘Limiting Values of minimum radius of circular curves’ under the column for ‘Design Speed of 60km/h’ has been increased from 350m (Table 11.1.9) to 400m (Table 13.3.2). This change took into account that a certain range of length and width is required to accommodate parking lots and other facilities in a service area or rest area and lower parameters of alignment may cause difficulties to the layout of the facilities. Also note that for the layout design that the horizontal criteria of a service area shall not be lower than the parameters of a rest area.

13.3.3 For the overall layout of a service area or rest area, the designer shall pay attention to the following issues.

(1) The design speeds of ramps in a service area or parking area should be 40km/h in general, but may be reduced in difficult terrain or for other constraints. Where the design speed of the main route is 100km/h or lower, the ramp design speed may be taken as 35km/h or even 30km/h.

(2) In Table 13.3.3, the limiting value of L1is the length calculated for the braking distance over which a vehicle decelerates at 2.0m/s2 from its design speed at the approach nose to a full stop plus a certain length for safety allowance. The limiting value of L2 is the minimum length of the sight triangle ahead of the merge point of the ramp and main route.

(3) The width of a ramp at a service or rest area is the same as that of a one-way, single-lane ramp at an interchange. The design of ramp alignments, speed-change lanes, and connecting roads shall conform to the relevant criteria in terms of interchanges in Chapter 11 of these specifications. The parameters of horizontal and vertical curves on an exit ramp at the approach nose shall also conform to the relevant requirements for interchanges.

(4) A passing through ramp usually connects with exit and entrance ramps and is partly connected to parking lots. Therefore, the pavement width of a passing through ramp should be 4.5min order to prevent vehicles from parking on it.

The profile design of a passing through ramp shall take into account the elevations of the parking lots, the cross-slopes and longitudinal slopes of parking lots, the connections to the access ramps, site drainage, and the scope of works.

13.3.4 Following the provisions of JTG B01-2014 on the placement of service areas and rest areas along class-2 arterial highways and the expert opinions during final review of these specifications, this Edition gives design rules for service areas and rest areas along class-2 highways. Designers shall pay attention to the issues as follows.

(1) The typical layout of a service area or rest area on a motorway or class-1 highway may be adopted for class-2 highways. In such a case, the lower limiting values of design speed for ramps may be selected and the width of right hard shoulder of the ramp may be taken as 1.50m.

(2) Where the traffic volumes on the main route and at roadside service facilities are small and where site conditions are constrained, a simplified layout may be adopted for the service areas and rest areas on class-2 highways. In such a case, the layout shall conform to the relevant provisions on bus bays on class-2 highways.

(3) The minimum length of a parking lot shall be able to accommodate the parked vehicles and relevant facilities.

13.4.1 The motivation that transit bus bays shall not be placed at the roadside of a motorway is based on the considerations for the safety of passengers and vehicles. It is also the consensus opinion of highway operators and administrators. This means that transit bus bays may be placed off the main route of motorways, such as on ramps of interchanges (in or out of toll gates), or in service areas and rest areas where transit services or footpaths shall also be provided.

There are two types of transit bus bays, either at main route or off main route in terms of locality. This Edition gives the requirements for the transit bus bays on the main route. For the bus bays off the main-route, reference shall be made to other relevant specifications.

13.4.2 For the alignment of the main route sections where transit bus bays are located, a value of100m or 50m shall be added to the normal value of the minimum radius of a circular curve. The minimum radius of a vertical curve is the same as the normal value specified for main routes, except that the values in the column for design speeds less than or equal to40km/h, is increased by a value of 300m over the corresponding normal values as shown in Table 13.4.2, to assure good visibility and desirable horizontal and vertical alignment.

Considering the stopping and departure characteristics of buses and the safety of passengers and pedestrians, the gradient of the main route near a bus bay should not be greater than 2% in general and should be smaller than 3% in difficult terrain.

13.4.3 Class-1 highways are divided multilane highways where vehicle operating speeds are high. Physical separation such as separating strips or barriers are required and additional lanes for acceleration and deceleration with sufficient lengths shall be placed before and after the bus bay outside of the main route so as to minimize the interference to the main route functions and ensure traffic safety of transit buses and other vehicles.

13.4.4 Most class-2, class-3 and class-4 highways are two-lane highways. Bus stops are constrained by the land limitation and usually there are not many passengers getting on and off buses. Therefore, these specifications only require that the stop in a bus bay shall not occupy traveled-way of the main route, but be separated from the main route by applying road marking, and shall be provided with sufficient tapered sections for speed changing at both ends of the bus stop. The specified length of a bus stop is 15m, or 20m where passengers often get on or off.

13.5.2 On motorways, U-shaped turning facilities, usually for two directions, shall be placed where the spacing of two adjacent interchange is greater than the specified maximum spacing.

13.5.3 U-turns shall be placed in accordance with the terrain and the layout of structures on the main route by taking advantage of bridges or underpasses on the main route, or by building a U-shaped flyover or an underpass tunnel according to the needs.

13.5.4 Design speeds of the section of the return curve shall be determined in accordance with the terrain, site conditions, and the coordination with operating speed changes, and should not be lower than 20km/h. A large radius of horizontal curve and high design speeds shall be desirable where a flyover is adopted to cross over the main route.

Technical Terms in Chinese and English

序号	英文词汇	中文词汇
	A	
1	Actual capacity	实际通行能力
2	Alignment	线形，平面线形
3	Alignment design	线形设计
4	Approach nose	分流鼻
5	Approaching unstable flow	稳定流下半段
	B	
6	Base capacity	基准通行能力
7	Basic number of lanes	基本车道数
8	Behavior of traffic flow	交通流状态
	C	
9	Calculation and Verification	设计验算
10	Capacity	通行能力
11	Channelizing island or corner island	导流岛
12	Check calculation	数学验算
13	Clear roadside zone	路侧安全区
14	Clearing sight distance Corner sight distanc	侧向瞭望视距
15	Compound curve	复曲线
16	Critical length of grade	最大坡长
17	Crossover, median crossover	联络车道
	D	

18	Delay	延误率
19	Depressed median	凹形中央分隔带
20	Design-hour factor , or K-factor (K)	设计小时交通量系数
21	Directional design-hour volume (DDHV)	单向设计小时交通量（DDHV）
22	Directional Split	方向分布系数
23	Divisional island and/or splitter island	分隔岛
24	Downgrade	下坡
25	Driving task	使用任务
	E	
26	Earthworks	路基（广义），路基工程
27	Estimated capacity	设计通行能力
	F	
28	Ferry slip	渡口
29	Ferry slip with a straight apron	直线码头（渡口）
30	Ferry slip with a straight apron	直线码头（渡口）
31	Flush medians	平齐式中央分隔带
32	Forced or breakdown flow	拥堵流下半段
33	Form of median, form of central dividing strip	中央分隔带形式
34	Free flow	自由流
35	Functional area of an intersection	平面交叉范围
	G	
36	Gable	人字坡
37	Geometrics	线形指标
38	Give-way rule, yield rule	“入口让路”规则
39	Grade crossing surface	道口铺面
	H	

40	Head-on collision	迎面对撞
41	Highway geometric deaign	公路路线设计
42	Highway route	公路路线
43	Highway-railway crossing	公路与铁路的交叉
44	Hump curve	凸形曲线
	I	
45	Interchange configuration	互通式立交的类型
46	Intermittent turnouts	间隔性的紧急停车带
47	Intermodal facility	换乘点
	K	
48	Kilometer coverage ratio	里程比率
	L	
49	Lane balance	车道数的平衡
50	Laneline	车道线
51	Lateral clearance allowance, C	余宽
52	Lateral clearance outside of traveled-way	侧向余宽
53	Lateral clearance per vehicle, C;	车道余宽
54	Left-side lateral clearance	左侧侧向余宽
55	Length of grade	坡长
56	Level of roadway	路基标高
57	Location, (highway location)	（公路）选线
	M	

58	Median	中间带
59	Median end	中间段端头
60	Mode Shift	换乘
61	Multimodal	多种交通方式
62	Multiple presence factor	横向车道布载系数
	N	
63	New construction	(公路)新建
64	Nonsuperelevated	不设超高的
	O	
65	Outer separation	侧分隔带
66	Outer separations	侧分隔带
	P	
67	Pedestrian density	行人密度
68	Percentile back of queue	选定时位
69	Person capacity	人员通行能力
	R	

70	Railroad grade crossing	铁路与公路的平交，道口
71	Railway separations	铁路与公路的立交
72	Railway switch, Railway turnout	道岔
73	Raised median	凸形中央分隔带
74	Rear-end collision	追尾
75	Reasonably free flow	相对自由
76	Recreational roads	景区道路
77	Resource recovery road	采伐道路
78	Retarder	缓速器
79	Revegetation	绿化
80	Right-turn auxiliary lane	右转弯附加车道
81	Roadway cross-section	路基横断面
82	Roadway cross-section	路基横断面
83	Route continuity	路线连续性
	S	

84	Scenic overlooks	观景台
85	Scraping collision	横向剐蹭
86	Service index of road network	路网服务指数
87	Shape of median end	中间带端头形式
88	Sight distance on crest vertical curve	驶入视距
89	Sloping curb	斜式缘石
90	Special Road	特殊公路
91	Special-purpose roads	专用公路
92	Speed Limit	限速
93	Speed Zone	限速区
94	Stable flow	稳定流上半段
95	Subgrade	路基（狭义）
	T	
96	Traffic characteristics	交通特性
97	Traffic composition	交通组成
98	Traffic control devices and facilities	交通工程与沿线设施
99	Traffic density	交通密度
100	Traffic performance measures	交通流状态
101	Transfer Center	换乘中心
102	Truck population	货车混入率
103	Tunnel assorciated facilities	隧道附属设施
104	Type of interchange	互通式立交的型式
	U	

105	Unstable flow	拥堵流上半段
106	Upgrade	上坡
10	Upgrading and reconstruction (of a highway)	(公路)改扩建
	V	
108	Vehicle capacity	车辆通行能力
109	Vehicle density	车辆密度
110	Vehicle kilometer ratio	车公里比率
111	Vertical curbs	栏式缘石
112	Visualcue	视觉诱导
	W	
113	Weight/power ratio	功率重量比
114	Weight-to-power ratio	（车辆的）质量功率比
115	Width of roadway	路基宽度
116	Wrong-way entry, wrong-way movement	误行
	Y	
117	Yield line	停车线
118	Yield line at entrance to circulating roadway	停车线（交通转盘）
119	Yield-controlled roundabout	‘入口让路’环形交叉