

JTG

**Recommended Industry Standards of
the People's Republic of China**
中华人民共和国行业推荐性标准

JTG/T 3610—2019 (EN)

**Technical Specifications for Construction of
Highway Subgrade**

公路路基施工技术规范
(英文版)

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

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、合作、绿色、开放共同发展。在丝绸之路经济带和 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工程行业标准外文版。

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。公路工程行业标准体系是指导公路建设、管理、养护、运营全过程的顶层技术框架,以质量、安全、绿色、韧性、智慧为核心导向,覆盖了公路勘察设计、施工技术、质量检验、养护管理以及造价定额等全生命周期环节,通过统一的技术要求和流程规范,保障和提升公路工程品质、运行效率及可持续发展。

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施工相关的标准规范。20 世纪 80 年代,中国在原《公路工程技术标准》(JTJ 1—81)的基础上,开始制定公路路线、路基、路面、桥梁、涵洞等专业技术规范。1986 年 8 月,中国颁布实施了第一部《公路路基施工技术规范》(JTJ 033—86),尔后,经历了 1995 年的第一次修订(JTJ 033—95)、2006 年的第二次修订(JTG F10—2006)以及 2019 年的第三次修订(JTG/T 3610—2019),经过近四十年的技术发展,建立了内容较为完整的公路路基施工技术规范体系。本次编译的《公路路基施工技术规范》(JTG/T 3610—2019)中文版于 2019 年 9 月修订发布,并于 2019 年 12 月实施。

中国疆域辽阔,气候复杂多变,环境敏感脆弱,地形地质复杂,广泛分布软土、膨胀土、黄土、盐渍土、沙漠、多年冻土、岩溶等特殊岩土,以及滑坡、崩塌、泥石流等不良地质,山区公路存在高填深挖路基。在公路建设过程中,中国的工程技术人员解决了各种地形地质复杂条件下路基修筑的关键技术问题,积

累了丰富的工程经验,完善和发展了路基施工方法,掌握了特殊路基的建造技术,对路基施工过程中的安全和环境保护提出了明确要求。这些经验与成果在《公路路基施工技术规范》(JTG/T 3610—2019)中得到了充分的体现。本英文版的编译发布便是希望将中国的工程经验和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。

《公路路基施工技术规范》(JTG/T 3610—2019)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。

《公路路基施工技术规范》英文版标准的内容与现行中文版一致,在技术内容上出现异议时,以中文版为准。

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Introduction to English Version

Standards represent the achievements of human civilization, serve as a common technical language worldwide, and promote global connectivity. In recent years, the Chinese government has vigorously promoted standardization activities to advance innovation-driven, coordinated, green, open and shared development. Under the guidance of *the Belt and Road Initiative*, the Ministry of Transport of the People's Republic of China has organized the compilation and publication of foreign language versions of a series of Chinese highway engineering industry standards to meet the growing need for global transportation development, enhance global connectivity, and promote knowledge dissemination and experience sharing.

The highway engineering industry standards of China, designated by the code JTG and issued by the Ministry of Transport of the People's Republic of China, constitute a top-level technical framework that guides the entire life cycle of highway construction, management, maintenance, and operation. Centered on the core orientation of quality, safety, green development, resilience, and intelligent technology, Standard System for Highway Engineering (JTG system) covers all stages of the highway life cycle—including survey and investigation, design, construction technology, quality inspection, maintenance management, and cost estimation and quotas. Through unified technical requirements and procedural specifications, the system guarantees and enhances the quality, efficiency and sustainability of highway engineering.

China has always attached great importance to the development of transportation infrastructure and continuously improved the standards and specifications for highway construction. In the 1980s, on the basis of the earliest *Technical Standards for Highway Engineering* (JTJ 1—81), China began to formulate specialized technical specifications for highway alignment, subgrade, pavement, bridges, culverts, and other disciplines. In August 1986, China released and implemented the first *Technical Specifications for Construction of Highway Subgrade* (JTJ 033—86). Subsequently, it underwent its first revision in 1995 (JTJ 033—95), second

revision in 2006 (JTG F10—2006), and third revision in 2019 (JTG/T 3610—2019). After nearly 40 years of technological progress, a relatively complete system of technical specifications for highway subgrade construction has been established. The Chinese version of the *Technical Specifications for Construction of Highway Subgrade* (JTG/T 3610—2019), from which the English version is compiled this time, was revised and issued in September 2019 and took effect in December 2019.

China has a vast territory with complex and variable climates and complicated topographic and geological conditions, and is environmentally sensitive and fragile. Special soils such as soft soil, expansive soil, loess, saline soil, desert soil, and permafrost, as well as karst, are widely distributed, along with adverse geological hazards including landslides, collapses, and debris flows. Mountain highways often feature high-filled and deeply excavated subgrades. In highway construction, Chinese engineers have solved various key technical issues in subgrade construction under complex topographic and geological conditions, accumulated rich engineering experience, improved and advanced subgrade construction methods, mastered full-scale technologies for special subgrades, and provided clear requirements for safety and environmental protection during subgrade construction. Such experience and achievements are fully reflected in the *Technical Specifications for Construction of Highway Subgrade* (JTG/T 3610—2019). The publication of this English version is intended to share China's engineering experience and technical achievements with counterparts worldwide and provide references for highway projects under similar geological conditions in other countries.

The editing of the English version was conducted by China Road and Bridge Corporation under the authorization of the Ministry of Transport, and was reviewed and finalized by the Highway Department of MOT China.

The English version of *Technical Specifications for Construction of Highway Subgrade* is consistent with the current Chinese version. In the event of any ambiguity or discrepancies on the technical contents between the English version and the Chinese version of the *Specifications*, the Chinese version shall prevail.

Inquiries and suggestions are appreciated and should be addressed to the chief editing organization for the English version: China Road and Bridge Corporation (Address: Zhonglu Mansion, 88C Andingmenwai Dajie, Dongcheng District, Beijing; Postal Code: 10011; E-mail: kjb@crbc.com). The feedback will be

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Foreword to the Chinese Version

The revision of *Technical Specifications for Construction of Highway Subgrade* (JTG F10—2006), pursuant to the *Year 2013 Plan for Formulating and Revising Highway Industry Standards* (JGBZ No. [2013] 23) issued by Ministry of Transport of the People's Republic of China, was carried out by CCCC Third Highway Engineering Co., Ltd.

The guideline for revising the *Specifications* is as follows: highlighting the requirements on safety, durability and environmental protection, paying attention to the stability of subgrade and the strength of roadbed, implementing the highway construction guiding rules of being resource-saving and environment-friendly, making reasonable use of all kinds of fill materials, fully summarizing highway subgrade construction technology developed in the last decade, positively absorbing mature and reliable new technology and working process, newly developed material and equipment, trying best to reach an achievement that the *Specifications* is advanced in technology, its indexes are reasonable, it is also well operable, it could demonstrate the progresses which have been made in this country in subgrade construction, and the strictness of its requirements is also moderately ahead of time.

The main technical contents in the *Specifications* cover the whole process from construction preparation to final inspection, including 11 parts: Chapter 1, General Provisions; Chapter 2, Terminology and Symbols; Chapter 3, Construction Preparation; Chapter 4, Normal Subgrade Construction; Chapter 5, Subgrade Drainage Works; Chapter 6, Subgrade Protection and Retaining Structures; Chapter 7, Special Subgrade Construction; Chapter 8, Winter and Rainy Season Subgrade Construction; Chapter 9, Subgrade Construction Safety; Chapter 10, Environmental Protection during Subgrade Construction; Chapter 11, Subgrade Correcting and Inspection for Approval.

The revised contents in the *Specifications* are mainly:

- (1) The original Chapter 9, “Safety and Environmental Protection in Subgrade Construction” are split into Chapter 9 “Subgrade Construction Safety” and Chapter 10 “Environmental Protection during Subgrade Construction”, the original Chapter 10 is renumbered as Chapter 11. The original Chapter 8, “Subgrade Protection and Retaining Structure” is renumbered as Chapter 6, the original Chapter 6 and Chapter 7 are renumbered as Chapter 7 and Chapter 8.
- (2) In Chapter 4, the requirements for fill materials for rock fill embankment are revised, with contents supplemented such as geological condition verification for subgrade in high embankment, ground treatment, water prevention and drainage, settlement observation, and the factor of time in natural stabilization. The “filling of roadbed” is made as a separate section. Contents are supplemented and revised in stabilization and settlement control for steep slope subgrade, foamed concrete embankment, waste coal embankment, slag embankment, subgrade widening and reconstruction, observation and assessment on subgrade stabilization.
- (3) In Chapter 5, contents are supplemented by quality requirements of the top slab of a side ditch, the application of corrugated steel pipe in blind ditch, impermeable isolation layer, draining bed, drainage tunnel; contents are revised in the longitudinal slope rate for underdrain, material and processing requirements on permeable pipe; contents in drainage for median strip are supplemented.
- (4) Chapter 6 supplements and improves the process and strength requirements for arch type and diamond type slope protection, and connections for stone blocks and their strengths. The technical requirements for the construction of a retaining wall, slope anchors, anti-slide piles, and their quality inspection methods and criterions are also refined.
- (5) In Chapter 7, contents are supplemented by relative requirements for the construction of shallow lime improved subgrade, indexes of maximum CBR strength and maximum water content for subgrade in red clay and high liquid limit soil region, CBR and compaction test method for subgrade fill material

in expansive soil region, how to judge the swell level of expansive soil, its range of application, compaction criterion, water content to be controlled for compaction, the flexible slope protection for expansive soil, the construction of subgrade made from expansive soil, etc.

(6) In Chapter 11, contents of subgrade inspection and approval are added.

Chapters 1 and 2 of the *Specifications* were drafted by Yu Genshe, Chapter 3 was drafted by Liu Yuanwei, Chapter 4 was drafted by Liu Lijun, Liu Yuanwei and Deng Jie, Chapter 5 was drafted by Qian Shaojin, Chapter 6 was drafted by Wang Xueying, Chapter 7 was drafted by Liu Yuanwei, Wu Lijian, Teng Xiaoping, Zhao Chunfa, Dai Xiaodong and Deng Jie, Chapter 8 was drafted by Liu Yuanwei, Chapter 9 was drafted by Wang Jue, Chapter 10 was drafted by Liu Peng and Chapter 11 was drafted by Liu Yuanwei.

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1 General Provisions

1.0.1 The *Specifications* is developed to enhance the level of technology for highway subgrade construction, and to ensure the quality and safety of highway works.

1.0.2 The *Specifications* is applicable for subgrade construction of new highways and the upgrading or reconstruction of existing highways.

1.0.3 Highway subgrade shall meet the strength, stability and durability requirements set by the design.

1.0.4 In constructing the subgrade, relevant national laws and regulations for construction shall be abided, the quality control system shall be fully established, responsibility for quality shall be clear and definitive and quality control shall be strengthened.

1.0.5 In constructing the subgrade, relevant national laws and regulations for work safety shall be abided, a safety management system shall be fully established, responsibility for safety shall be clear and definitive, safety technical measures shall be made, safety operation rules shall be strictly implemented and the occupational health of workers shall be protected.

1.0.6 In constructing the subgrade, relevant national laws and regulations for environmental protection shall be abided with the aim to save land, occupy less farmland, reduce pollution, and protect the environment. Upon completion of the construction works, borrow pits and spoil grounds shall be trimmed as required.

1.0.7 In constructing the subgrade, reliable new technology, new working process, newly developed material or equipment shall be actively promoted and applied.

1.0.8 In constructing a subgrade, standardized operations shall be pursued to improve subgrade

construction being normalized and correctly managed.

1.0.9 Highway subgrade construction shall comply with the requirements in the *Specifications* as well as other relevant nation and industry standards.

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2 Terms and Symbols

2.1 Terms

2.1.1 subgrade

A linear structure which is built by following the road alignments and satisfying necessary technical requirements. It is the foundation of the pavement, bearing traffic loads transmitted from pavement.

2.1.2 roadbed

The part of subgrade with range between 0.8 m and 1.2 m below pavement structure layer, divided into upper roadbed and lower roadbed. Upper roadbed is 0.3 m thick, lower roadbed is 0.5 m for highway with light, medium or heavy traffic loads, 0.9 m for highway with extra or extreme heavy traffic loads.

2.1.3 embankment

Filled subgrade which is over natural ground. It is divided structurally into upper embankment and lower embankment. Upper embankment is the range of 0.7 m below roadbed, lower embankment is the embankment part below upper embankment.

2.1.4 cut

The subgrade constructed by excavating and lower than natural ground.

2.1.5 high embankment

The embankment whose maximum slope height is over 20 m.

2.1.6 embankment on steep slope

The slope of ground that is steeper than 1:2.5.

2.1.7 rock fill embankment

The embankment made with stone material, its size is over 40 mm and its content is over 70% by weight of total fill material.

2.1.8 earth-rock embankment

The soil embankment made with 30% -70% stone material by weight.

2.1.9 deep cut

The side slope height is over 20 m for cutting in soil or over 30 m for cutting in rock.

2.1.10 special subgrade

Subgrade which is over special soil region, or over adverse geological zone, where it would be affected by natural elements such as water and weather.

2.1.11 collapsible loess

The collapsible loess is a kind of soil, when soaked in water, it will rapidly collapse under its own weight or applied pressure.

2.1.12 laterite

Red or brown silt or clay, from carbonate rocks being weathered under hot and humid climate.

2.1.13 high liquid limit soil

Fine soil whose liquid limit is over 50%.

2.1.14 expansive soil

A kind of clay with high plasticity, which contains hydrophilic mineral, and will noticeably expand when absorbing water and shrink when losing water.

2.1.15 saline soil

Soil with soluble salts whose content is over a specified value.

2.1.16 permafrost

The soil which would be in frozen state for two or more years, with its temperature being below 0 °C.

2.1.17 foamed concrete

Foamed concrete is made by using a foaming agent to produce the foam by a physical method and then mixing the foam into a mixture of slurry which is made from cement slurry and additives or fine aggregates. This material is cast into required shape and is cured to form a light solid material with many evenly enclosed micro-voids.

2.1.18 Expanded Polystyrene(EPS)

Expanded polystyrene is abbreviated as EPS.

2.1.19 California Bearing Ratio(CBR)

An index representing the strength of subgrade materials. It is measured by the ratio between the testing load of a standard sample when reaching its specified penetration value to the load required for reaching the same penetration for a standard crushed stone material, expressed as a percentage.

2.1.20 maximum California Bearing Ratio(CBR_{max})

For laterite, high liquid limit soil, expansive soil and others, after a fixed number of rammer blows, when water content is low, the CBR value after sample is compacted will increase with the increase of water content, it reaches a maximum value when water content reaches a certain value, after that the CBR value will decrease with the increase of water content, this maximum CBR under the said rammer blows is called maximum California Bearing Ratio, or CBR_{max} .

2.1.21 water content at CBR_{max}

The relative moisture content at which the CBR reaches its maximum value.

2.1.22 retaining wall

The structure of wall which bears the lateral soil pressure.

2.1.23 slide-resistant pile

The pile which is made to resist the sliding force imposed by slide slope and bears lateral force.

2.1.24 soil nailing

A supporting structure to keep the slope stabilized, which is made by inserting nails of steel bars into the slope of soil or fractured weak rock.

2.1.25 pre-stressed anchor bolt(cable)

A supporting structure made of anchor head, pre-stressing anchor bolt and anchor body, made by imposing a tensile force on the anchor bolt to strengthen the rock/soil body.

2.1.26 slope netting(flexible supporting structure)

A retaining structure which supports the side slope to control large deformation, but permitting small deformation.

2.1.27 impact roller compaction

Compaction made by impact roller, mainly for the purpose to increase the density and strength of the road material being compacted.

2.1.28 wet testing method

This test method is used when the moisture content of the soil on site is higher than the target moisture content. The soil under the state of natural moisture content is made into several samples, allowed to air-dry to different target moisture contents, and then the relevant test is carried out.

2.2 Symbols

CBR—California Bearing Ratio;

CBR_{max} —maximum California Bearing Ratio;

E_0 —resilient modulus of subgrade (MPa);

e_{ps} —total swell or shrinkage ratio of expansive soil (%);

I_p —plasticity index (%);

l_0 —representative deflection of subgrade surface measured in situ (1/100 mm);

w —natural water (moisture) content (%);

w_c —natural consistency;

w_{CBR} —water content at CBR_{max} ;

w_l —liquid limit (%);

w_o —optimum moisture content for soil compaction (%);

w_p —plastic limit (%).

3 Construction Preparation

3.1 General

3.1.1 Before subgrade construction, design documents shall be fully understood to know the intentions of design.

3.1.2 Investigation and on-site verification shall be carried out before the construction organization. prepared based on the design requirements, conditions of contract and on-site situation.

3.1.3 Before subgrade construction commences, management systems for quality, environment, and occupational health and safety shall be established. All workers shall be trained for their jobs and be informed with detailed technical and safety requirements.

3.1.4 Temporary works shall meet the requirements for normal construction procedures. The service functions of existing roads or structures within the influence area of the subgrade construction shall be guaranteed. Farmland and irrigation facilities shall be protected. Temporary works should be combined with permanent works.

3.1.5 Before a new technology, new working process, newly developed material or equipment is applied, detailed testing and research shall be made.

3.2 Construction survey

3.2.1 The land survey method shall be chosen based on highway class and the survey precision requirements. Control stakes shall be handed over in the field. The original survey control network shall be resurveyed, and based on the construction requirements, the network shall be properly densified and optimized to form the construction survey control network and be properly protected.

3.2.2 Horizontal control survey shall meet the following requirements;

- 1 Horizontal control survey location shall be made by means of a satellite positioning survey, traverse survey, triangulation or trilateration.
- 2 The survey class and precision for the horizontal control survey network shall meet the requirements of Table 3.2.2-1.

Table 3.2.2-1 Class and technical requirements for horizontal control survey

Highway class	Survey class	RMSE ^① of the position of weakest points (mm)	RMSE of the relative position of the weakest adjacent points (mm)	RMSE of the relative side length of the weakest adjacent points	The reference value for average side length of adjacent points (m)
Motorway, Class 1 highway	First Order	± 50	± 30	≤ 1/20 000	500
Class 2,3,4 highway	Second Order	± 50	± 30	≤ 1/10 000	300

- 3 The main technical requirements for satellite positioning survey are listed in Table 3.2.2-2.

Table 3.2.2-2 The main technical requirements for satellite positioning survey

Survey class	Fixed error (mm)	Coefficient of proportional error b (mm/km)
First Order	≤ 10	≤ 3
Second Order	≤ 10	≤ 5

- 4 The main technical requirements for traverse survey are listed in Table 3.2.2-3.

Table 3.2.2-3 The main technical requirements for traverse survey

Survey class	Closed traverse length (km)	Legs (sides)	RMSE of leg length (mm)	RMSE of unit weight (")	Relative closure by traverse total length	Closure of azimuth (")
First Order	≤ 6	≤ 12	± 14	± 5.0	≤ 1/17 000	≤ 10 $\sqrt{n}$
Second Order	≤ 3.6	≤ 12	± 11	± 8.0	≤ 1/11 000	≤ 16 $\sqrt{n}$

Notes; 1. n in the column 'Closure of azimuth' of this Table is the number of observation.

2. RMSE of unit weight is RMSE of angle observation.

3. The length between the nodes of the traverse network shall not be greater than 0.7 times the length in the table.

- 5 The main technical requirements for triangulation are listed in Table 3.2.2-4.

① Translator's Note: RMSE is root-mean-square-error.

Table3.2.2-4 The main technical requirements for triangulation

Survey class	RMSE of angle observation(")	Relative RMSE of the length of first leg	Closure of triangle (")
First Order	± 5.0	$\leq 1/40\ 000$	≤ 15.0
Second Order	± 10.0	$\leq 1/20\ 000$	≤ 30.0

6 The main technical requirements for trilateration are listed in Table 3.2.2-5.

Table 3.2.2-5 The main technical requirements for trilateration

Survey class	RMSE of length(mm)	Relative RMSE of length
First Order	± 14.0	$\leq 1/35\ 000$
Second Order	± 11.0	$\leq 1/25\ 000$

3.2.3 Vertical control survey shall meet the following requirements:

- 1 Vertical control survey shall be made with the methods of leveling survey or trigonometric leveling.
- 2 The survey class and technical requirements for vertical control survey are listed in Table 3.2.3-1.

Table 3.2.3-1 The survey class and technical requirements for vertical control survey

Highway class	Survey class	RMSE of the elevation of weakest points(mm)	RMSE of average elevation difference per kilometer		Closed traverse length(km)
			Accidental RMSE M_{Δ} (mm)	Total RMSE M_w (mm)	
Motorway, Class 1 highways	Fourth Order	± 25	± 5	± 10	25
Class 2,3,4 highways	Fifth Order	± 25	± 8	± 16	10

3 The main technical requirements for leveling survey are listed in Table 3.2.3-2.

Table 3.2.3-2 The main technical requirements for leveling survey

Survey Order	Difference between forward run and backward run or closed traverse closure (mm)		Difference between top and bottom intervals (the survey segment has been measured) (mm)
	Relative flat area	Hilly area	
Fourth Order	$\leq 20\sqrt{l}$	$\leq 6.0\sqrt{n}$ or $\leq 25\sqrt{l}$	$\leq 30\sqrt{L_i}$
Fifth Order	$\leq 30\sqrt{l}$	$\leq 45\sqrt{l}$	$\leq 40\sqrt{L_i}$

Note: When calculating the difference between forward run and backward run, l is the route length between bench marks (km); when calculating closed traverse closure, l is the route length of traverse (km); n is the number of observation stations. L_i is the length of survey interval (km), take 1 km if it is less than 1 km.

4 The main technical requirements for EDM trigonometric leveling are listed in Table 3.2.3-3.

Table 3.2.3-3 The main technical requirements for EDM^① trigonometric leveling

Survey Order	Difference of interval in a double sighting set (mm)	Difference of interval between two double sighting sets (mm)	Difference of interval against reverse observation (mm)	Closure of closed traverse (mm)
Fourth Order	$\leq 8\sqrt{D}$	$\leq 10\sqrt{D}$	$\leq 40\sqrt{D}$	$\leq 20\sqrt{\sum D}$
Fifth Order	$\leq 8\sqrt{D}$	$\leq 15\sqrt{D}$	$\leq 60\sqrt{D}$	$\leq 30\sqrt{\sum D}$

Note: D is the length of a leg, measured in km.

3.2.4 The control points of subgrade construction shared with tunnel or bridge construction shall meet the requirements of current *Technical Specifications for Construction of Highway Tunnel* (JTG/T 3660), and/or *Technical Specifications for Construction of Highway Bridges and Culverts* (JTG/T 3650).

3.2.5 During the construction process, all the control stakes shall be well protected. Any damaged stake shall be recovered as soon as possible, and re-checking the survey point shall be done as the circumstances may require.

3.2.6 A traverse re-checking survey shall meet the following requirements:

- 1 The precision of traverse survey shall meet the requirements of Table 3.2.2-3.
- 2 If the existing traverse points cannot meet the construction requirements, additional traverse points shall be placed and these points shall meet the required precision.

① Translator's Note: EDM means Electronic Distance Measuring instrument.

- 3 Within a general project, the traverse across adjacent contracting sections shall be closed and must satisfy the precision requirements of the same survey class.
- 4 The traverse points which may be affected during construction shall be reinforced or moved to safe places, and their accuracy shall be maintained.
- 5 The traverse point stakes shall be checked from time to time and re-surveyed periodically; the period of re-survey shall be not more than 6 months.

3.2.7 The re-survey or placement of additional bench marks shall satisfy the following requirements:

- 1 The precision of bench mark shall meet the requirements in Table 3.2.3-2.
- 2 A uniform elevation system shall be used within a same highway project, and it shall be connected to the adjacent project levelling systems.
- 3 It is preferred to have a bench mark for every 500 m along the highway route. For motorway or class-1 highway, more bench marks should be placed, preferably one for every 200 m. In locations near a structure, high embankment, deep cutting, road sections with large volumes of work or with complex topography, more bench marks should be placed. Temporary bench marks shall meet the requirements of the corresponding survey class and be connected to the adjacent bench marks.
- 4 The traverse points which may be affected during construction shall be reinforced or moved to safe places, and their accuracy shall be maintained.
- 5 The traverse point stakes shall be checked from time to time and be re-surveyed periodically, the period of re-survey shall not be more than 6 months.

3.2.8 Setting out the center line shall meet the following requirements:

- 1 Before constructing the subgrade, the center line of the whole contracting section shall be set out, the main control stakes (bench marks) along the road shall be fixed firmly. The setting out survey should be made with the coordinate method.
- 2 When setting out the center line, it shall be closed with the center line of structures or the center line of adjacent contract road sections. If there are discrepancies, these shall be checked after identifying the origin of the problem.

- 3 If there are disagreements between setting out in the field and the design drawings, they shall be checked after determining the problem.

3.2.9 Setting out the subgrade shall meet the following requirements:

- 1 Before construction, re-survey the natural ground and cross-sections shall be checked or more cross-sections may be added.
- 2 Before construction, marking stakes shall clearly mark all the positions of the road boundary line, the toes of embankment slope, the tops of cutting slope, borrowing pits, berms and spoil areas.
- 3 In sections with deep cutting or high embankment, after every time a bench or 3-5 m in height of earthworks is completed, the center line and cross-section shall be rechecked.

3.2.10 Every survey result shall be re-checked. Original records shall be kept in files.

3.2.11 Besides the *Specifications*, subgrade construction survey shall also comply with the relevant provisions of current *Specifications for Highway Reconnaissance* (JTG C10).

3.3 Testing

3.3.1 Before subgrade construction, a field laboratory with appropriate testing and measurement capabilities shall be established.

3.3.2 Before compacting the original ground, the natural soil which would be under the subgrade shall be sampled and tested. There shall be at least two samples every kilometer, and more samples shall be taken if soil properties changed significantly.

3.3.3 The material to be used as fill material shall be sampled and tested before construction. The tests shall include: natural water content, liquid limit, plastic limit, grain size analysis, proctor compaction test, CBR test and others. Tests for relative density, organic matter content, soluble salt content, freezing and expansion shall also be done if applicable.

Commentary

Only those test items for normal fill materials are specified here. For special soils (loess, soft soil, saline soil, laterite, high liquid limit clay and expansive soil), additional applicable tests shall be performed to determine their properties and to identify treatment methods.

3.3.4 When using special material as fill material, corresponding tests following the relevant standards shall be made, and they may be used only after being approved.

3.4 Ground surface treatment

3.4.1 The control criteria for ground surface treatment are as follows: not less than 90% for class 2 or above highway, not less than 85% for class 3 or 4 highway. For low height embankment, extra top soil shall be excavated and then backfilled and compacted in layers. This kind of treatment shall have a depth not less than the thickness of the roadbed.

3.4.2 If there are pits, holes, voids in the natural ground surface, they shall be filled and compacted in layers after the waste material is removed. The degree of compaction shall meet the requirements in Clause 3.4.1 of the *Specifications*. If there are potential hazards of voids, appropriate treatment measures shall be taken by considering the specific circumstances.

3.4.3 If there are springs or seepage of groundwater, effective measures shall be taken according to the design requirements to lead and divert the water away from subgrade area before filling the subgrade.

3.4.4 If the subgrade is founded on farm land, loose soil, paddy field, pond, soft soil, or over-wet land, treatments shall be made following the design requirements. Effective measures shall be taken to treat the soggy area of soil.

3.4.5 In sections of steep slope, the connection zone between fill and cut sections with filling material being rock mixed with soil, or high embankment, the treatment shall be made according to design requirements.

3.4.6 If the water table level is high, treatment shall be made according to design requirements.

3.4.7 If subgrade is over the sections with special ground conditions, check with the geological investigation data to determine if the design data matches the real situation or if the treatment method (required by design) is suitable. Additional geological or hydrological investigation shall be made if necessary to confirm the treatment scheme.

3.5 Trial section

3.5.1 A trial section shall be built in the following cases:

- 1 The embankment of Class 2 or above highway;
- 2 Rock fill or earth-rock embankment;
- 3 Embankment from special fill material;
- 4 Special subgrade;
- 5 Subgrade where new technology, new construction process, newly developed material or equipment is to be used.

Commentary

Special fill material refers to those kinds of material which have different properties from normal soil, such as waste coal or foamed concrete.

3.5.2 A trial section shall be constructed on a road section which can represent typical geological conditions and cross-section types, and its length should be no less than 200 m.

3.5.3 Trial section construction summary should include the following steps:

- 1 Fill material tests, test report and other relevant material information;
- 2 Main parameters for compaction processing: combination of compaction equipment, equipment types, loose layer thickness, roller passes, roller speed, optimum moisture content and the range of moisture content during compaction, and other relevant information;
- 3 Process controlling method for the compaction;
- 4 Criteria for quality control;
- 5 Optimizing the construction organization scheme or construction process;
- 6 Original records and records of the process;
- 7 Suggestions for modification of the construction drawings;
- 8 Measures to guarantee the safety;
- 9 Measures to protect environment.

Commentary

The contents of a test report for the trial section construction may be increased or decreased based on the actual situation, but it shall fully and accurately represent the trial circumstance and provide a basis for the ensuing construction.

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4 Normal Subgrade Construction

4.1 General

4.1.1 Subgrade fill material shall satisfy the following requirements:

- 1 It is recommended to select gravelly soil, sandy soil or other coarse-grained soil with appropriate grading for fill material.
- 2 Soils which contain turf, household waste, tree roots or humus are strictly forbidden for use as fill material.
- 3 Soils containing peat, muck, frozen soil, highly expansive soil, organic soil or soluble salt and their concentration is more than allowed, shall not be directly used as fill material. In case that there is necessity to use them, they shall be treated by technical measures and tested if they can satisfy all the requirements before being used.
- 4 Silty soils should not be used as fill of the roadbed of Class 2 or above highway, or to fill the roadbed in a frost region or as fill in an embankment subject to flooding.

Commentary

Silty soil has a high capillary action and a large frost-heave. Its mechanical properties are significantly affected by its moisture content. Therefore, it is not suitable to be used in the roadbed of Class 2 or above highway, nor shall it be used in the roadbed in a frost region or in flooded parts of an embankment if it is not being treated.

4.1.2 The strength and grain size distribution of fill material shall meet the requirements in Table 4.1.2.

Table 4.1.2 The minimum CBR and maximum grain size

Applied position of fill material (depth below pavement) (m)				Minimum CBR of fill material (%)			Maximum grain size of fill material (mm)
				Motorway	Class 2 highway	Class 3,4 highway	
				Class 1 highway			
Subgrade in fill	Upper roadbed		0-0.30	8	6	5	100
	Lower roadbed	Light, medium or heavy traffic	0.30-0.80	5	4	3	100
		Super or extreme traffic	0.30-1.20				
	Upper embankment	Light, medium or heavy traffic	0.8-1.5	4	3	3	150
		Super or extreme traffic	1.2-1.9				
	Lower embankment	Light, medium or heavy traffic	below 1.5	3	2	2	150
		Extra heavy or extreme heavy traffic	Below 1.9				
	Zero fill and in cut section of subgrade	Upper roadbed		0-0.30	8	6	5
Lower roadbed		Light, medium or heavy traffic	0.30-0.80	5	4	3	100
		Extra heavy or extreme heavy traffic	0.30-1.20				

Note: 1. The strength listed in the table is the CBR determined by immersion in water for 96 h according to the requirements of compaction standards for different fill positions of subgrade and the test method stipulated in the current *Test Methods of Soils for Highway Engineering* (JTG 3430).

2. When a pavement is asphalt concrete or cement concrete in Class 3 and 4 highways, the provisions for Class II highways shall be adopted.

3. The maximum particle size is 150 mm for upper and lower embankment fill material in the table is not applicable to rock-fill embankment or earth/rock embankment.

4.2 Roadbed

4.2.1 Fill material for the roadbed shall meet the following requirements:

1 Fill material for the roadbed shall meet the requirements in Table 4.1.2.

2 For motorways and Class 1 highways, fill material should be sandy gravel, crushed stone or

other coarse material with water stability, or gravelly soil with grading. When coarse aggregate is scarce, inorganic binder may be used to improve the fine-grained soil.

4.2.2 Roadbed construction in zero fill or in cut sections shall satisfy the following requirements:

- 1 If in the range of the roadbed the natural soil meets all the requirement, the roadbed may be constructed directly onto its formation.
- 2 If in the range of the roadbed the soil is over wet, it shall be replaced. In case the design specified the depth of replacement, follow the design requirements. In case the design does not specify the replacement, the following requirements shall be met; for a motorway or Class 1 highway, the depth of replacement should be 0.8-1.2 m, If the total depth of over wet soil is less than 1.5 m, it is recommended that it should be replaced completely. For Class 2 highway, the depth of replacement should be 0.5-0.8 m.
- 3 If in the range of the roadbed, the ground consists disintegrating rock or highly weathered rock, it shall be replaced. In case the design specified the depth of replacement, follow the design requirements. In case the design does not specify the replacement, the depth of replacement should be 0.3-0.5 m.

Commentary

In a case that an area with zero fill or cut sections has a roadbed that is over-wet, or consists of disintegrating rock or highly weathered rock, the strength of the roadbed can decrease significantly under the influence of the environment. The following recommendations can be implemented to replace the material. If the depth of replacement is 0.8 m, then the deflection value may not satisfy the requirements and replacement of 1.2 m in depth may be needed. In case that the depth of soft and weak soil is less than 1.5 m, all the material shall be replaced. The reason for this treatment is that this kind of soil is normally at the interface between rock and soil, with a high water content and very low strength. If the material it is not completely replaced, a soft and weak interlayer may occur, which is not beneficial to distribute stress from pavement structure.

4.2.3 When constructing the roadbed fill, the compacted thickness of each layer should not be more than 300 mm and the compacted thickness of the upper layer shall not be less than 100 mm.

4.3 Subgrade in cut

4.3.1 Cutting in soil shall meet the following requirements:

- 1 Cutting shall be from the top downwards, and hollowing out from the bottom is strictly forbidden.
 - 2 When the cutting approaches the slope line, a small amount of soil shall be kept. The thickness of soil retained shall guarantee that the soil in the slope line will not be disturbed in the process of slope trimming.
 - 3 The soil intended for use as fill material shall be cut and used separately based on their property. Unsuitable material to be disposed of shall be treated following the requirements in Clause 4.15.2 of the *Specifications*.
 - 4 When a cutting reaches to the zero fill or roadbed position, the roadbed shall be constructed soon. In case roadbed cannot be constructed shortly, a protective layer not less than 300 mm above the top of roadbed should be retained.
 - 5 Temporary drainage measures shall be taken to keep the construction area free from water accumulation.
- 4.3.2 In the case that groundwater is encountered in a cutting, the following requirements shall be satisfied:
- 1 Measures shall be taken to lead and discharge the water into the subgrade drainage system. The eye of a spring shall not be blocked as a makeshift measure.
 - 2 If roadbed soil has a high moisture content or is a water-bearing stratum, treatment measures shall be taken, such as providing underdrain, soil replacement, improving soil and others. Fill material for roadbed shall not only meet the requirements in Table 4.1.2 of the *Specifications*, but also have permeability and water stability.
- 4.3.3 A cutting in rock shall meet the following requirements:
- 1 The excavation plan shall be developed based on factors such as rock type, degree of weathering, rock strata occurrence, rock strata's fracture structure and construction environment.
 - 2 Excavation shall be carried out step by step, and protection measures shall be taken at each step according to the design requirements.

- 3 During the construction process, the slope edge line and rate of slope shall be re-surveyed every 3-5 m of excavation depth.
 - 4 Blasting works shall comply with the requirements of the current *Safety regulations for blasting* (GB 6722).
 - 5 Chamber blasting is strictly forbidden. Hard rock close to the side slope shall be blasted by ways of smooth blasting or pre-splitting blasting.
 - 6 Before rock excavation by blasting, investigation shall be made to locate the positions of overhead cables, underground utility lines, identify type of building structures, house conditions of local inhabitants, which are outside the excavation but may be affected by blasting. In case the safety distance cannot be satisfied, it is to use static expansive rock breaking or excavation by equipment.
 - 7 The side slope shall be trimmed at each cutting stage, and unstable rocks or loose rocks shall be cleared in this process.
- 4.3.4 Clearing a rock roadbed shall meet the following requirements:
- 1 If the roadbed has been excavated insufficiently, the excess rock shall be chipped away. An area that has been over-cut shall be leveled by gravel or crushed stone with high strength. Fine grained-soil shall not be used for leveling.
 - 2 If there is groundwater at the bottom of the roadbed, an underdrain may be constructed to drain it away. The underdrain shall be back filled with hard crushed stone.
 - 3 The side ditch at the roadbed shall be constructed at the same time as the roadbed.
- 4.3.5 Construction of a deep cutting shall meet the following requirements:
- 1 Side slope observation points shall be set based on local topographic feature. The slope stability of a deep cutting shall be monitored during the construction process.
 - 2 Geological conditions shall be checked in the construction process. If it does not conform to the design, feedback shall be reported as an urgent matter and measures shall be taken.
 - 3 The side slope shall be re-surveyed every 3-5 m depth of the cutting.

4.4 Embankment

4.4.1 Embankment construction shall meet the following requirements:

- 1 Fill materials with different properties shall be placed and compacted separately in layers or in sections. Fill material in one layer shall be the same instead of using various materials. The total compacted depth of a same kind material should not be less than 500 mm. The upper part of the subgrade should be made with fill material that has good moisture stability or is insensitive to frost heave. In the case that groundwater is present, or the embankment may be immersed, the fill material shall have a good water stability.
- 2 If the material with a high permeability is placed on a compacted layer with low permeability, the compacted layer shall have a crown slope of 2% -4% , and waterproofing measures shall be taken. The side slope of embankment constructed by better permeable material shall not be covered by fill material with poor permeability.
- 3 The loose thickness of each kind of fill material shall be determined by testing.
- 4 The width of each fill layer shall not be less than the design width after compaction.
- 5 For an embankment fill, it shall be constructed from the lowest part, layer by layer, and each layer shall be compacted.
- 6 If embankment construction is divided into several sections, in the event that adjacent sections cannot be constructed alternatively for each layer, the adjoining part of the section constructed first shall have steps with a slope of 1:1-1:2, each layer ending in a step. If the layers can be constructed alternatively, each layer shall be overlapped by staggeringly with the adjacent section. The overlap length shall be at least 2 m.

4.4.2 Subgrade construction with wet clay shall meet the following requirements:

- 1 The bottom of the subgrade shall be treated according to the design requirements.
- 2 The fill material of wet clay should be improved by lime, which can be slaked lime or quicklime powder, with a grain size less than 20 mm. The quality of lime should be Class 3 or higher.

- 3 Before construction, representative samples shall be taken to perform a mix design with lime to determine the quantity of lime.
- 4 The lime and soil may be mixed in the field. The mass of fill material with grain size over 15 mm after mixing should be less than 15%. The thickness of the fill layer should not exceed 200 mm.
- 5 The quality of the subgrade with improved wet clay shall be controlled by both indicators of quantity of lime and compaction degree. The quantity of lime shall not be less than the design quantity. The degree of compaction shall satisfy the requirements in Table 4.4.3. The maximum dry density shall be determined by the Proctor compaction test, with the content of lime being as required in the design.

4.4.3 The degree of compaction of soil subgrade shall meet the requirements in Table 4.4.3.

Table 4.4.3 The criteria of soil subgrade compaction degree

Applied position of fill material (depth below pavement) (m)				Degree of compaction(%)		
				Motorway or Class 1 highway	Class 2 highway	Class 3,4 highway
Fill subgrade	Upper roadbed		0-0.30	≥96	≥95	≥94
	Lower roadbed	Light, medium or heavy traffic	0.30-0.80	≥96	≥95	≥94
		Super or extreme heavy traffic	0.30-1.20			—
	Upper embankment	Light, medium or heavy traffic	0.8-1.5	≥94	≥94	≥93
		Extra heavy or extreme heavy traffic	1.2-1.9			—
	Lower embankment	Light, medium or heavy traffic	> 1.5	≥93	≥92	≥90
		Extra heavy or extreme heavy traffic	> 1.9			

continued

Applied position of fill material (depth below pavement) (m)				Degree of compaction(%)		
				Motorway or Class 1 highway	Class 2 highway	Class 3,4 highway
Zero fill or cutting section of subgrade	Upper roadbed		0-0.30	≥96	≥95	≥94
	Lower roadbed	Light, medium or heavy traffic	0.30-0.80	≥96	≥95	—
		Extra heavy or extreme heavy traffic	0.30-1.20			

Note: 1. The degree of compaction listed in this table shall be tested with heavy compaction test and follow the current *Test methods of soils for highway engineering* (JTG 3430).

2. If the pavement of Class 3 or 4 highway is cement concrete or asphalt concrete, the compaction degree shall adopt the specified value for Class 2 highway. If Class 3 or 4 highway being with heavy traffic, the compaction degree shall adopt the value for Class 2 or higher highway.
3. If the embankment is constructed with special material or located in a special climate zone, the criteria for the degree of compaction shall be determined by a trial section and local empirical experience to ensure that the strength of the subgrade can fulfill the requirements.
4. The degree of compaction in areas with an extreme dry climate may be reduced by 2%-3%.

4.4.4 The quality control in the process of constructing an embankment shall meet the following requirements:

- 1 In the construction process, each compacted layer shall be tested for its degree of compaction. The test frequency is at least 2 points for every 1,000 m². Degree of compaction may be tested by the sand replacement method, cutting ring method or others. Test shall meet the requirements of current *Field Test Methods of Highway Subgrade and Pavement* (JTG 3450).
- 2 During the construction process, after every 2 m increase in height, the road center line and width should be checked.

4.4.5 After an embankment is completed to its correct design height, its construction quality shall meet the requirements in Table 4.4.5.

Table 4.4.5 The criteria for construction quality of earth embankment or earth-rock embankment

Number	Test item	Specified value or allowed deviation			Test method and frequency
		Motorway or Class 1 highway	Class 2 highway	Class 3,4 highway	
1	Degree of compaction	Meet the requirements in Table 4.4.3	Meet the requirements in Table 4.4.3	Meet the requirements in Table 4.4.3	Density testing: 2 points for every 200 m in each compacted layer

continued

Number	Test item	Specified value or allowed deviation			Test method and frequency
		Motorway or Class 1 highway	Class 2 highway	Class 3,4 highway	
2	Deflection (0.01 mm)	Meet the design requirements	Meet the design requirements	Meet the design requirements	—
3	Profile elevation (mm)	+ 10, - 15	+ 10, - 20	+ 10, - 20	Level; 2 points for every 200 m
4	Center line deviation (mm)	50	100	100	Total station; 2 points for every 200 m, adding points HY, YH in curves
5	Width (mm)	≥ No less than the design value	≥ No less than the design value	≥ No less than the design value	Tape measure; 4 points for every 200 m
6	Unevenness (mm)	≤ 15	≤ 20	≤ 20	3 m straight edge; two points × 5 measurements for every 200 m
7	Cross slope (%)	± 0.3	± 0.5	± 0.5	Level; 2 cross sections for every 200 m
8	Grade of side slope	Meet the design requirements	Meet the design requirements	Meet the design requirements	4 points for every 200 m

4.5 Rock fill embankment

4.5.1 Fill material shall comply with the following requirements:

- 1 Hard rock or medium hard rock may be used as fill for an embankment or roadbed. Soft rock may be used as fill for an embankment, but not for the roadbed. Expansive, soluble or carbonized rocks shall not be used as fill for the subgrade.
- 2 The flooded parts of the subgrade shall be filled with rock that has good water stability and not prone to expansion or disintegration.
- 3 Fill material for an embankment shall have a particle size not more than 500 mm, and should not be more than the 2/3 of the thickness of the compacted layer. In the range of

400 mm below the bottom of the roadbed, the maximum particle size of fill material shall not be more than 150 mm. The content of fine material with a size less than 5 mm shall not be less than 30% .

Commentary

Rock fill materials may be classified by referring to the Table 4-1 based on the saturated compressive strength.

Table 4-1 Classification of rocks

Rock type	Saturated uniaxial compressive strength(MPa)	Representative rock
Hard rock	≥ 60	Granite, diorite, basalt and other magmatic rocks
Medium hard rock	30-60	Siliceous, ferruginous conglomerate or sandstone, limestone, dolomite and other sedimentary rocks. Gneiss, quartzite, marble, slate, schist and other metamorphic rocks
Soft rock	5-30	Tuff and other volcanic rocks. Argillaceous conglomerate, argillaceous sandstone, argillaceous shale, mudstone and other sedimentary rocks. Mica-schist or phyllite and other metamorphic rocks

4.5.2 Rock fill shall meet the following requirements:

- 1 The rock fill embankment material shall be placed and compacted layer by layer. If in an area of steep slopes where construction is difficult, or to construct the lower embankment for Class 3 or below highway whose pavement will be sand and gravel the material may be placed by rear dumping.
- 2 Rocks with different properties shall be placed in different layers or sections. Soft rock cannot be used by mixing with hard rock.
- 3 Between the top surface of a rock fill embankment and fine-grained soil fill layer, a transition layer or a separation layer of non-woven geotextiles shall be placed.
- 4 The compaction equipment should be a vibratory roller with a weight no less than 18 t.
- 5 When a dynamic compactor or impact roller is used to further compact the rock fill embankment, caution shall be taken to prevent harming adjacent structures.

4.5.3 When using medium hard or hard rock as fill for the embankment, the side slope shall be

built by laying rock blocks. The strength and size of rock block shall meet the design requirements. The processes of placing slope blocks and roadbed fill shall be largely synchronized.

4.5.4 When using easily weathered rock or soft rock as embankment fill, the side slope shall be sealed, a drainage bed layer shall be set at the bottom and an impermeable layer shall be placed at the top according to the design requirements.

4.5.5 The criteria for compaction quality of rock fill embankment shall follow Table 4.5.5.

Table 4.5.5 The compaction quality standards for rock fill embankment

Position	Depth below the top of roadbed (m)	Void ratio of hard rock (%)	Void ratio of medium hard rock (%)	Void ratio of soft rock (%)
Upper embankment	0.80-1.50	≤ 23	≤ 22	≤ 20
Lower embankment	> 1.50	≤ 25	≤ 24	≤ 22

4.5.6 The quality control for the construction process shall meet the following requirements:

- 1 Each layer of fill shall be controlled by following the process and parameters determined by the trial section. The quality of compaction may be checked by the differential settlement.
- 2 In the construction process, with each 3 m in height being completed, the subgrade center line and width should be checked.

4.5.7 After the rock fill embankment is completed to its design elevation and is checked, its construction quality shall meet the requirements in Table 4.5.7.

Table 4.5.7 Criteria for the construction quality of rock filled embankment

Number	Item	Specified value or allowed deviation		Test method and frequency
		Motorway or Class 1 highway	Other highways	
1	Compaction	Void ratio meets the design requirements		Density testing; each layer, 1 point for each 200 m
		Differential settlement $\leq$ the differential settlement determined in trial section		Precise level; a cross section for every 50 m, with 5 points in each cross section
2	Profile elevation (mm)	+ 10, - 20	+ 10, - 30	Level; 2 points for every 200 m

continued

Number	Item		Specified value or allowed deviation		Test method and frequency
			Motorway or Class 1 highway	Other highways	
3	Deflection(0.01 mm)		Meet the design requirements		—
4	Center line deviation(mm)		≤50	≤100	Total station;2 points each 200 m , adding HY ,YH in curves.
5	Width(mm)		Meet the design requirements		Tape measure; 4 points for each 200 m
6	Unevenness(mm)		≤20	≤30	3 m straight edge; 2 points × 5 measurements for each 200 m
7	Cross slope(%)		±0.3	±0.5	Level; 2 cross sections for each 200 m
8	Side slope	Grade and smoothness of slope	Meet the design requirements		Tape measure; 4 points for every 200 m

4.5.8 The appearance quality standards after the embankment is completed shall meet the following requirements:

- 1 The surface of the embankment shall have no obvious voids.
- 2 The large sized stones shall not be in a loose state.
- 3 The rock blocks on the side slope shall be tightly laid. No loose blocks must exist, the bearing surface between blocks shall tilt inwards, and the slope surface shall be smooth and even.
- 4 There shall be no bends on the subgrade edge line or its side slope with an accumulated length of more than 50 m , measured within a curve in the same direction.
- 5 There shall be no unstable rocks on the upper slope.

4.6 Earth-rock embankment

4.6.1 Fill material shall meet the following requirements:

- 1 Expansive rock, soluble rock and others should not be directly used as subgrade fill. Highly weathered rock and carbonized rock shall not be used as subgrade fill.
- 2 Fill materials from a natural mixture of earth and rock with a maximum grain size of medium hard or hard rock shall not be greater than $\frac{2}{3}$ of the thickness of the compacted layer. For highly weathered rock or soft rock, their CBR values shall meet the requirements in Table 4.1.2 and their maximum grain sizes shall not be greater than the thickness of the compacted layer.

Commentary

If the grain size of medium hard or hard rock is too large, the roller may be suspended during rolling which is not conducive to the compaction of the intermediate soil. Therefore, it is specified that the maximum grain size of medium hard or hard rock shall not be greater than $\frac{2}{3}$ of the thickness of the compacted layer.

4.6.2 Fill process shall meet the following requirements:

- 1 The roller should be a vibratory roller with the weight of not less than 18 t.
- 2 Filling and compaction shall be made layer by layer, and a large quantity of dumped material shall be avoided.
- 3 Large sized rocks shall be distributed evenly in the layer and the space between the rocks shall be filled by smaller sized rocks and soil.
- 4 If the earth/rock mixtures come from different borrow pits, and the rock properties and their earth/rock proportions are quite different, they should be used in different layers or sections.
- 5 If the fill material is to be changed from an earth/rock mixture into another fill material, the thickness of the last layer of earth/rock mixture shall be less than 300 mm. The maximum grain size of this layer should be less than 150 mm and the surface of this layer after compaction shall have no obvious voids.
- 6 When using medium hard or hard rock to construct an embankment, the side slope should be built by laying rock blocks. The progress of laying side slope blocks should be synchronized with rock filling. The slopes of earth-rock embankments with soft rocks shall be treated as earth embankment slopes.

- 7 When using dynamic compaction or impact roller to further compact the embankment, caution shall be taken to prevent damaging adjacent structures.

4.6.3 The quality control for the construction process shall meet the following requirements:

- 1 Each layer in the earth/rock embankment constructed with medium hard or hard rock shall be controlled by following the process and parameters determined during the trial section. The quality of compaction may be checked by the index of differential settlement.
- 2 For an earth/rock embankment constructed with soft rocks, the criteria for construction quality shall meet the requirements in Clause 4.4.3 of the *Specifications*.
- 3 During the construction process, with each 3 m in height completed, the center line and width should be checked.

4.6.4 After the subgrade is formed, its quality shall meet the requirements in Table 4.4.5.

4.6.5 The criteria for appearance quality shall meet the following requirements:

- 1 The surface of subgrade shall have no obvious voids.
- 2 Large rocks shall be firmly placed and shall not be loose.
- 3 The side slope of an earth/rock embankment constructed with medium hard or hard rocks shall be built by laying rock blocks tightly, and the bearing surface between blocks shall tilt inwards. The sloped surface shall be smooth and even.

4.7 High embankments or embankments on steep slope

4.7.1 A high embankment shall be given a priority and shall be constructed first in the construction plan to allow for a settlement period during a rainy season or more than 6 months.

Commentary

From experience and the results of observation, a high embankment settlement is closely connected with the quantity of rainfall. It was found that in the first rainy season, the settlement of a high embankment can reach to half of the total settlement during its life. Therefore, by arranging the subgrade construction schedule, a high embankment can experience a rainy season or 6 months to settle naturally before the pavement is constructed.

4.7.2 Material with high strength and good water stability should be used in a high embankment. The material with good water stability and permeability shall be used in the part of embankment that will be flooded.

4.7.3 During the construction of a high embankment additional height and width shall be reserved by following design requirements, and construction shall be monitored dynamically.

4.7.4 For every 2 m high of embankment being completed, additional impact compaction should be made, and for every 4-6 m high being completed, extra dynamic compaction shall be applied.

4.7.5 In the construction process, the settlement and stability of a high embankment shall be monitored.

4.7.6 If high embankments or embankments on steep slope are located on a section with poor geological conditions, the speed of construction shall be controlled. The horizontal displacement shall be monitored. If necessary, subsurface horizontal displacement monitoring on different fill layers shall also be made.

Commentary

In sections with poor geological conditions, the overall instability of high embankment is related to the filling speed. By controlling the filling speed give the subgrade a longer time to consolidation and the overall stability may be improved.

4.8 Backfill against abutment and wall

4.8.1 Back filling material should be permeable, light, or material stabilized with inorganic binder. Disintegrating rock or expansive soil shall not be used as backfill against an abutment or wall.

4.8.2 To construct the backfill against an abutment and wall, the following requirements shall be met:

- 1 For a Class 2 or above highway, a transition section shall be made by following design requirements. The transition embankment shall have a degree of compaction of at least 96%. For a highway below Class 2, benches shall be left in the connection part between embankment and backfill area.
- 2 Backfilling against an abutment and backfilling of the fill slope in front of an abutment should be constructed at the same time.
- 3 At a distance of up to 1.0 m from the abutment or wall, backfill material should be

compacted by tamping rammer.

- 4 A compacted layer should have a thickness of not greater than 150 mm, the particle size of backfill material should be less than 100 mm. The particle size of backfill material on both sides of a culvert should be less than 50 mm, and the degree of compaction shall not be less than 96%.
- 5 In an area difficult to reach a low-grade concrete, mortar rubble or others may be used as backfill material.
- 6 Backfilling on both sides of a culvert shall be compacted in layers with a similar progress.
- 7 The roadbed in the backfill area should be worked at the same pace as the embankment roadbed.
- 8 Backfilling against an abutment or wall shall be made when the strength of such a structure reaches 75% of its design strength.

Commentary

The backfilling operation behind structures such as abutments, culverts and retaining walls, is small and difficult to compact. The subgrade in these areas is backfilled after the structure has been completed. This area is also the connection between the flexible subgrade and rigid structures, and defects such as bumping will easily happen. Therefore, special requirements related to the fill and construction process of the subgrade in these areas are provided.

4.9 Fly ash embankment

4.9.1 Fly ash may be used as fill material for an embankment for every class of highway, except for the roadbed for motorway, a Class 1 highway or in the upper roadbed for a Class 2 highway.

4.9.2 The fly ash used for the subgrade shall have an ignition loss of no more than 20%, and have an SO_3 content of no more than 3%. There shall not be agglomerations, humic substances or other impurities in the fly ash.

4.9.3 The storage and transportation of fly ash shall meet the following requirements:

- 1 The moisture content of fly ash should be adjusted in the ash storage yard or ash pool.
- 2 During the process of loading or unloading, transportation and storage of fly ash, care shall be taken to prevent dust pollution by measures such as water sprinkling or covering.

- 3 It is recommended that fly ash is directly transported from factories (source) or fly ash storage yards to fill job sites.

4.9.4 The construction of a fly ash embankment shall meet the following requirements:

- 1 Construction should not be carried out on a windy day or when the temperature is below 0 °C.
- 2 If fly ash is obtained from different sources they shall be stockpiled separately and used in separate sections.
- 3 If the height of an embankment is over 4 m, an interlayer of soil may be placed in the middle of the embankment.
- 4 The edge of a fly ash embankment shall be covered for protection. The construction of the covering soil shall be carried out at a same pace as the construction of the fly ash. The soil cover width should not be less than 2 m.
- 5 In the construction process, job sites shall be regularly sprayed with water. A service road over the embankment shall be set out properly.
- 6 During a construction break the surface of the fly ash layer shall be sprayed with water. Traffic shall be stopped. If the suspension time is long, a sealing cover layer of soil shall be placed over the already compacted fly ash layer.

4.9.5 The criteria for the degree of compaction of fly ash embankment shall be obtained from a trial section and meet the requirements in Table 4.9.5. The degree of compaction for edge covering soil and upper sealing soil shall satisfy the requirements in Table 4.4.3. The tests on a fly ash embankment shall be conducted immediately before the upper layer is placed; the degree of compaction of the lower layer shall be checked at this time.

Table 4.9.5 The criteria for the degree of compaction of a fly ash embankment

Fill position	Degree of compaction (%)	
	Motorway, Class 1 highway	Class 2 or below highway
Lower roadbed	—	≥92
Upper embankment	≥92	≥90
Lower embankment	≥90	≥88

Note: The degree of compaction listed in this table shall be tested with the heavy compaction test and follow the current *Test Methods of Soils for Highway Engineering* (JTG 3430).

Commentary

As a compacted fly ash layer tends to become loose, the compaction degree tested just after it has been compacted is not precise, so the correct way to test the degree of compaction is that immediately before upper layer is placed, and the compaction degree of the lower layer is checked.

The degree of compaction of a fly ash embankment on site may range from 82% to 93% if tested in the field. Therefore, the compaction standard shall be obtained from a trial section.

4.10 Expanded Polystyrene (EPS) foam embankment

4.10.1 EPS foam may be used for constructing as embankment on soft foundation, backfilling against abutments or walls of structures, such as bridges, culverts, retaining walls, or for embankment widening and repairing an embankment which has lost its stability.

4.10.2 The density of EPS foam should be no less than 20 kg/m^3 , its compressive strength at a strain of 10% should not be less than 110 kPa, its flexure strength should be no less than 150 kPa, modulus of compression should be no less than 3.5 MPa, 7 d volumetric water absorption rate should be no more than 1.5%.

4.10.3 When EPS foam blocks are stacked on site, measures shall be taken to protect them against fire, wind, rats, accumulated water, or protect them from erosion by organic solvent or petroleum-based oils, and prevent them from direct sunlight.

4.10.4 Laying EPS foam blocks shall meet the following requirements:

- 1 The EPS material shall be checked before being laid.
- 2 Nonstandard sized EPS foam blocks should be manufactured in a factory. If processed on site heated wires should be used to cut them.
- 3 Before paving non-standard EPS blocks a bedding layer shall be placed. The width of the bedding layer should extend beyond the subgrade edge for 0.5-1.0 m. The top of the bedding layer shall be kept dry.
- 4 The connections between the lowest layer of EPS blocks and the bedding layer, lateral connections between the same layer of blocks, and the connections between blocks in different layers, all shall be firm. Connecting pieces shall be treated to prevent rust.

- 5 Each layer of EPS blocks shall be laid staggered. Joints or height differences may be leveled with sand or non-shrinking cement mortar.
- 6 Heavy construction machine is strictly forbidden to travel directly over the EPS blocks.
- 7 In the connection area with other fill material or existing subgrade, the EPS blocks shall be laid in steps. Step width and the slope shall meet the design requirements.
- 8 At the top, a thin reinforced concrete slab, geomembrane or geotextile shall cover all the EPS blocks. The cover (other than the concrete slab) shall be extended into the soil protected side slope for 0.5-1.0 m.
- 9 Both sides of an EPS foam embankment shall be covered by a soil layer, with a normal thickness no less than 0.25 m and being compacted in layers. Both sides of an impermeable geomembrane should be folded to wrap around the soil.

4.10.5 An EPS foam embankment shall meet the requirements in Table 4.10.5.

Table 4.10.5 Criteria for an EPS foam embankment quality

Number	Testing item	Allowed deviation	Test methods and frequency
1	The size of EPS foam blocks	Length	Checked by tape measure, sampling frequency: 2 blocks for EPS quantity < 2,000 m ³ , 3 blocks for 2,000 ~ 5,000 m ³ , 4 blocks for 5,000 ~ 10,000 m ³ , 1 more block for each additional 2,000 m ³ in the case of EPS quantity ≥ 10,000 m ³
		Width	
		Thickness	
2	Density of EPS foam block	≥ design value	Balance, sampling frequency is same as Number 1
3	Degree of compaction of the foundation	≥ design value	Cutting-ring or sand replacement, 2 points for every 1,000 m ²
4	The unevenness of the bedding layer (mm)	10	3 m straight edge, 3 points for every 20 m
5	The unevenness of the interface between EPS blocks (mm)	20	3 m straight edge, 3 points for every 20 m
6	The gaps, faults between EPS blocks (mm)	10	Tape measure, 1 point for every 20 m
7	The cross slope of the top surface of EPS embankment (%)	± 0.5	Level, 6 points for every 20 m
8	The width of slope protection	≥ design value	Tape measure, 1 point for every 40 m
9	The thickness of reinforced concrete slab (mm)	+10, -5	By tape measure to check the edge of slab, 2 points for each block
10	The width of reinforced concrete slab (mm)	± 20	Tape measure, 2 points for every 100 m

continued

Number	Testing item	Allowed deviation	Test methods and frequency
11	The strength of reinforced concrete slab (MPa)	Satisfy design requirements	Checked by following Appendix D of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
12	The distance between re-bars (mm)	± 10	Tape measure

Note: The gaps between EPS blocks in a curve section shall not be more than 50 mm.

4.11 Foamed concrete embankment

4.11.1 The unconfined compressive strength of foamed concrete used in a highway subgrade shall meet the design requirements; if the requirements are not specified in the design, it shall meet the requirements in Table 4.11.1.

Table 4.11.1 The unconfined compressive strength of foamed concrete

Position		The unconfined compressive strength (MPa)	
		Motorway Class 1 highway	Class 2 or below highway
Roadbed	Light, medium or heavy traffic	≥ 0.8	≥ 0.6
	Super or extreme heavy traffic	≥ 1.0	
Upper or lower embankment		≥ 0.6	≥ 0.5
Replacement in subgrade		> 0.4	

Note: The unconfined compressive strength shall be tested for a cubic specimen with a side length of 100 mm at an age of 28 d.

4.11.2 The wet unit weight of foamed concrete at the time of casting shall meet the design requirements; if not specified in the design, it shall be no less than 5.0 kN/m^3 and no more than 11.0 kN/m^3 .

4.11.3 The fluidity of foamed concrete at the time of casting should be 170-190 mm. If it is used for the roadbed of a motorway or a Class-1 highway with extra heavy or extreme heavy traffic, the mixture should be made with sand. The fluidity should be 150-170 mm, and the mass ratio between sand and cement should be 0.5-2.0.

4.11.4 The materials used for foamed concrete shall meet the following requirements:

- 1 Cement shall satisfy the requirements of the current *Common portland cement* (GB 175) and, its strength grade should be 42.5.
 - 2 The water for concrete shall satisfy the requirements of the current *Standard of water for concrete* (JGJ 63), and its temperature shall be no less than 5 °C.
 - 3 The foaming agent shall satisfy the requirements of the current *Foaming agent for foamed concrete* (JC/T 2199).
 - 4 Additives and admixtures shall satisfy the specified requirements. Before being used, they shall be tested for the effectiveness to ensure that they have no harmful effects on the foamed concrete.
- 4.11.5 The construction equipment for foamed concrete shall meet the following requirements:
- 1 The mixer for the cement slurry shall have the capacity of automatic configuration to achieve the mix ratio and automatic recording. The production capacity of each mixer should be no less than 35 m³/h.
 - 2 The mixer for foamed concrete shall have the capacity of automatic configuration to achieve the mix ratio and automatic recording. The production capacity of each mixer should be no less than 90 m³/h.
- 4.11.6 The mix proportion tests for foamed concrete shall meet the following requirements:
- 1 Foamed concrete shall be tested for its wet unit weight, fluidity and compressive strength; all the results shall satisfy the design requirements.
 - 2 The sample for testing the compressive strength of foamed concrete shall be a cube of 100 mm × 100 mm × 100 mm. The sample shall be cured in a sealed ‘freshness protection package’ and the temperature for curing shall be 20 °C ± 2 °C.
 - 3 If the design strength of the foamed concrete is no more than 1.0 MPa, its trial-mix strength shall be its design strength multiplied by 1.1. If the design strength is more than 1.0 MPa, the trial-mix strength shall be its design strength plus 0.5 MPa. The compressive strength after 7 d shall be no less than 50% of the specified strength of the foamed concrete.
- 4.11.7 The ground foundation of a foamed concrete embankment shall be excavated according to the design elevations and dimensions, and be cleared, levelled and compacted. The drainage ditch or

other drainage facilities shall also be set out. When casting work is below the groundwater level, the groundwater level shall be reduced, and casting is not allowed when there is water on the base.

4.11.8 The construction of foamed concrete embankment shall meet the following requirements:

- 1 Before casting foamed concrete, its foundation shall be divided into casting partitions with an area of no more than 400 m² for each partition. The length of a partition shall be no more than 30 m and the thickness of each casting partition should be 0.3-1.0 m. A construction joint shall be constructed for every 10-15 m of the foamed concrete embankment.
- 2 The foam should be produced by mixing compressed air with the foam agent/water solution, and cannot be produced by stirring.
- 3 Measuring the mixture proportion of constituents shall be made by an electronic device. The precision of the measurement shall be $\pm 2\%$ for the foaming agent, cement, water, additives and admixtures.
- 4 The slurry for making the foamed concrete should not be kept in the storage device for more than 1.5 h.
- 5 The foamed concrete shall be cast directly from the outlet of a soft pipe used for supplying the material. The outlet of the pipe should be submerged in the foamed concrete.
- 6 For a single casting partition the casting time for each layer shall not be more than the initial setting time of the cement slurry. The layer immediately on top of the earlier layer should only be placed after 8 h.
- 7 The foamed concrete shall not be cast on rainy days. The work has been cast but which has not fully set shall be protected from the rain.
- 8 When foamed concrete has been cast to its design elevation, it shall be cured under wet condition by covering with a plastic membrane or non-woven geotextile, and the curing time should be no less than 7 d.
- 9 No casting work is advised to be done when the temperature is below 5 °C, otherwise insulation measures shall be taken.
- 10 Before the layer on top of the foamed concrete has been paved no equipment or vehicle shall move directly on it.

4.11.9 For widening an existing road, where the side slope is the connecting part with the foamed concrete, the soil should be cleared to a depth of no less than 0.3 m. Benches shall be constructed from the slope toe of the existing road upwards following the design requirements. The benches excavated from the soil shall be dense without loose material, and the foamed concrete shall be cast in layers and in partitions. The sequence of casting each partition should not be in a transverse direction, but along the longitudinal direction. For the longitudinal connection part, benches shall be properly set out.

4.11.10 The formwork for foamed concrete constructed in partitions, shall be installed firmly and tightly, and no leakage is allowed. The expansion or settlement joints should be set out at the construction joints between partitions. A construction joint should be 18 mm plywood or 20-30 mm polystyrene board. It is not necessary for construction joints to be continuous from lower layers through the upper layers.

4.11.11 The strength of foamed concrete for subgrade or roadbed shall satisfy the requirements in Table 4.11.1. There are no requirements for CBR or deflection.

Commentary

Foamed concrete is a light weight material which is formed by the physical and chemical reactions with cementitious material. Converting the strength into a CBR value has no meaning as strength is much more than the CBR value required in the Specifications. The modulus of elasticity is also much more than required for an earth roadbed. So, foamed concrete shall be controlled by its compressive strength, whereas the CBR or deflection value is not required.

4.11.12 During the casting process of foamed concrete, the wet unit weight shall be controlled in the field. The testing method shall be by the Volumetric Cylinder Method. Not less than 6 tests shall be performed for each layer cast in a casting partition.

4.11.13 The unconfined compressive strength and density of the foamed concrete shall be tested after curing for 28 d. The compressive strength and density shall be tested according to the current *Testing Methods of Cement and Concrete for Highway Engineering* (JTG 3420). Design requirements shall also be fulfilled.

4.11.14 The construction quality of foamed concrete shall meet the requirements in Table 4.11.14.

Table 4.11.14 Criteria for foamed concrete construction quality

Number	Test item	Specified value or allowed deviation	Test method and frequency
1	Strength(MPa)	Qualified	2 sets/400 m ³
2	Dry unit weight(kN/m ³)	≤ design value	2 sets/400 m ³
3	Top surface elevation(mm)	+ 10 , - 15	Level; 1 point for every 20 m
4	Axial deviation(mm)	20	Total station; 1 point for every 20 m
5	Width(mm)	Not less than design value	Tape measure; 1 point for every 10 m

4.11.15 The appearance quality of foamed concrete shall meet the following requirements:

- 1 The surface and lines shall be smooth and even ,the construction joint shall be straight and smooth.
- 2 There shall be no non-load-induced-through-cracks with a width of greater than 2 mm on the surface.

4.12 Waste coal embankment

4.12.1 Waste coal may be used as fill for a highway embankment ,but not for an embankment of a motorway or a Class 1 highway ,and shall not be used for the roadbed. In an area where water source needs to be protected ,it is not recommended to use waste coal as filling material.

4.12.2 Waste coal used as fill for an embankment shall meet the following requirements:

- 1 Waste coal which is fully oxidized or has been stockpiled for more than 3 years may be directly used in as fill.
- 2 The CBR value of waste coal shall be more than 8% ,its disintegration resistance index shall be more than 60% and its iron sulfide content should be less than 3% .
- 3 Waste coal which will disintegrate in water shall not be used in an embankment that will be flooded.

Commentary

- 1 *Waste coal has an unusual property that it may burn spontaneously. The cause is that it contains organic matter and pyrite(FeS₂). If the waste coal has been stored for more than*

3 years under the natural environment, it shall have already burned or tend to not easily self-ignite. It is stable, and it may be used normally for subgrade fill.

- 2 *Waste coal originates from two sources. One is substandard solid waste from a coal mine or from the coal washing process, and the other is from an excavation of a cut being in the coal bearing strata. Their performance in highway construction is not the same.*

Some waste coal will disintegrate in water, which has a significant effect on subgrade performance. With rainfall, the subgrade will easily settle. Therefore, when using waste coal as fill material, it shall be checked for iron sulfide content and disintegration resistance index. The disintegration test method can be found in the current Test method of rock for highway engineering (JTG 3431).

4.12.3 If waste coal from sources have different properties, they shall be constructed in different sections.

4.12.4 Waste coal which has not undergone complete oxidization or fully aged, if used as fill, shall be sealed, and shall also meet the following requirements:

- 1 After constructing 2-3 m in height, a 300 mm isolation layer of fine-grained soil shall be placed. The upper surface of the embankment shall be sealed.
- 2 The edge of embankment shall be covered by fine grain soils for protection. To cover with soil shall have the same progress as construction of the waste coal layer. The covering soil should have a width of not less than 2 m. In the range of 0.5 m from the bottom of the covering soil, a permeable fill material should be used.
- 3 In case the waste coal self-ignites, pouring sealing lime slurry or cement slurry onto the layer may be a solution.

4.12.5 The criteria for compaction of waste coal embankment and its covering soil shall satisfy the requirements in Table 4.4.3. If the waste coal has a large grain size, its construction control may be as for a rock-filled embankment.

4.13 Slag embankment

4.13.1 Slag may be used as fill for an embankment, but shall not be used for the roadbed of a motorway or Class-I highway, nor for an embankment that is flooded.

Commentary

Slag includes flue gas desulfurization gypsum, boiler ash, gasification slag, steel slag, blast furnace slag and others.

4.13.2 Slag used in an embankment shall fulfill the national laws or regulations for environment protection. If the content of harmful substances exceed the standards, their use in an embankment fill must be strictly forbidden.

4.13.3 The transportation and storage of slag shall meet following requirements:

- 1 The process of adjusting the moisture content of slag shall be carried out at the storage yard.
- 2 The process of loading or unloading, transportation and storage creates dust. Control measures such as water sprinkling or covering shall be available.
- 3 It is recommended that slag is transported directly from the factory or the storage yard to the fill site.

4.13.4 A slag embankment shall meet the following requirements:

- 1 Slags for constructing as fill with a range of different properties shall be used in separate sections.
- 2 The edge of a slag embankment shall be covered for protection by fine-grained soil. The construction of the soil covering shall be carried out at a same pace as the slag fill construction. The width of the soil cover should not be less than 2 m. Permeable fill should be used in the bottom 0.5 m of the soil cover.
- 3 For filling every 2-3 m in height, a 300 mm isolation layer of fine-grained soil shall be constructed. The upper surface of embankment shall be sealed.
- 4 If the work is suspended, the surface of slag layer shall be sprayed with water. The site shall be closed to traffic. If the suspension time is long enough, a sealing cover layer of soil shall be constructed over the already compacted slag layer.

4.13.5 The criteria for the degree of compaction of a slag embankment shall be obtained from a trial section and satisfy the requirements in Table 4.13.5. The degree of compaction for the edge covering soil shall satisfy the requirements in Table 4.4.3. Testing a slag embankment may be that

immediately before the upper layer is being constructed, the degree of compaction of the lower layer shall be checked.

Table 4.13.5 Criteria for the degree of compaction of a slag embankment

Position	Degree of compaction(%)	
	Motorway, Class 1 highway	Class 2 or below highway
Lower roadbed	—	≥93
Upper embankment	≥93	≥90
Lower embankment	≥90	≥88

Note: The degree of compaction listed in this table shall be tested with the heavy compaction test and in the current *Test Methods of Soils for Highway Engineering* (JTG 3430).

4.14 Sand fill embankment

4.14.1 Sand may be used for embankment fill, but should not be used directly for roadbed fill.

4.14.2 Sand which contain turf, household waste, tree roots or humus shall not be used as subgrade fill material. The organic matter content in the sand shall not be more than 5%.

4.14.3 The construction of a sand fill embankment shall meet the following requirements:

- 1 Before the sand fill construction, a bottom sealing layer with clay or lime improved soil shall be placed, with a thickness not less than 400 mm. The sealing layer shall be constructed in two layers.
- 2 Sand fill embankment shall be filled and compacted in layers over the full width of the cross section. The maximum loose thickness should not be more than 400 mm. The length of the construction section shall be 400-500 m, and the overfill width shall not be less than 500 mm on either side.
- 3 Sand and soil fill shall not be mixed.
- 4 A sand fill embankment should be compacted layer by layer, by watering and compacting, or by flooding the sand by watering. In the small space equipment such as a tamping rammer can be applied, the loose thickness shall be no more than 150 mm, and it shall be compacted after it is fully watered.
- 5 Water shall be sprayed frequently and the surface shall be kept wet. Ruts shall be leveled

and compacted at the same time.

Commentary

The working length for sand filling should not be too long given that it is difficult for hauling vehicles to travel over the fine sand subgrade surface.

4.14.4 The degree of compaction for a sand fill embankment shall satisfy the requirements in Table 4.4.3.

4.14.5 The side slope protection for a sand fill embankment shall meet the following requirements:

- 1 The side slope may be protected by edge covering with soil to a width of 3 m. Edge covering soil shall be placed first, and then the soil filling shall be constructed alternatively with the sand fill.
- 2 Drainage capacity of the side slope, overall erosion resistance and coordination with the surrounding environment shall be taken into consideration. The toe of slope shall be protected by dry-laid stone guard.
- 3 If the construction of the side slope protection cannot be completed in time during the rainy season, temporary measures shall be taken, such as covering the slope with felt or plastic membrane.

Commentary

3 A sand fill embankment cannot resist erosion, so its slope shall be protected shortly after construction.

4.15 Borrowing and spoiling

4.15.1 Borrowing shall meet the following requirements:

- 1 Borrowing shall be made by following the design requirements and in combination with the requirements from subgrade drainage, land planning, environmental protection and highway development.
- 2 Borrowing shall not or occupy little farmland. The depth of borrowing shall be decided by also considering other factors, including groundwater. The stripped topsoil with vegetation from the original ground surface shall be all stockpiled in a temporary place.

- 3 Borrow pits should not be made near the ends of a bridge.
 - 4 The distance between the borrow pit and the subgrade shall meet the requirements for slope stability.
 - 5 When a borrow pit beyond the road boundary is connected with drainage ditches, fish ponds, reservoirs and other facilities, measures shall be taken to prevent erosion and pollution.
 - 6 The side slope of a borrow pit shall satisfy the stability requirements.
 - 7 The exposed earth surface created by borrowing shall be treated and protected.
- 4.15.2 Soil spoiling shall meet the following requirements:
- 1 Before construction, the spoiling scheme provided by the designer shall be checked and if there is a clash or other issues, they shall be resolved.
 - 2 Spoil should be stockpiled in a centralized place, and be harmonious with the surrounding environment.
 - 3 Stockpiled spoil near piers or abutments of a bridge or near inlets or outlets of a culverts is strictly forbidden.
 - 4 Spoil shall not be discharged into reservoirs, lakes, dolines (karst funnel) or the mouths of underground rivers.
 - 5 Spoil should be unloaded and compacted in layers. The side slope shall be no more than 1 : 1.5. On top of the spoil, there should be a slope of not less than 2% for drainage purposes.
 - 6 When spoil is used as counter-pressure protection of the subgrade, the construction should be kept at a same pace as the subgrade.
 - 7 In a section where the ground surface has a slope of more than 1 : 5 across the road, no spoil shall be placed on the higher side of the top edges of the slope cutting.
 - 8 A spoil site shall be protected and drainage facilities at the toe of the slope shall be reinforced according to the design requirements.

Commentary

- 4 *Dolines or the mouths of underground rivers in a karst region are inlets for surface water to drain from or outlets for groundwater. If they are blocked, surface water or ground water cannot be discharged, endangering the stability and safety of the subgrade.*

4.16 Subgrade widening and reconstruction

4.16.1 If during the widening of the subgrade the road is not closed to traffic, measures for traffic control and road safety shall be taken without interrupting traffic.

4.16.2 Before construction, water flowing through the widening site shall be cut off to prevent it from running into the work area. A temporary drainage ditch shall be excavated. A water barrier shall be installed on the outer side of the road shoulder where the water can accumulate. Based on the actual water flow scenario, a temporary chute with outlet can be constructed.

4.16.3 The fill material for widening should be the same as the subgrade of existing road, or can be gravel or crushed stone with good water stability. These materials shall also satisfy the requirements in Table 4.1.2. The roadbed shall be filled with material with good water stability, mainly coarse-grained soil or inorganic binder stabilized material.

4.16.4 The widening of a normal embankment shall meet the following requirements:

- 1 Before construction, existing drainage ditch, separation fence or other facilities shall be demolished. In the widening foundation area the topsoil shall be cleared to a depth of not less than 0.3 m, where after the area shall be leveled and compacted. The side slope of the existing road shall also be cleared to a normal depth of not less than 0.3 m.
- 2 The treatment of the subgrade foundation of the widening part shall satisfy the requirements of the design and of the *Specifications*.
- 3 The existing protective facilities on the upper slope (cut slope) should be demolished at the same pace same as excavating the subgrade. Measures shall be taken to ensure the stability of the existing road when demolishing the protective facilities at the downward slope (fill slope) side.
- 4 For connecting with the newly widened part, the slope toe retaining wall and anti-sliding piles of the existing embankment may not be demolished. The upper part of shoulder retaining wall should be demolished up to below the roadbed.

- 5 If there is edge covering soil in the existing subgrade, it should be removed before connection works are carried out.
- 6 From the toe of existing road upward, benches shall be excavated. The rise of the bench shall be no more than 1.0 m and the width of the bench shall not be less than 1.0 m. After benches are excavated, they shall be immediately filled back.
- 7 If the connection width is less than 0.75 m, here are two potential measures, namely to fill an extra width and then remove the extra width by slope trimming, or the existing road may be excavated with an extra width.
- 8 Geosynthetic materials should be placed in the connection part between the existing subgrade and the newly added subgrade.

4.16.5 The widening of a high embankment and steep slope embankment shall meet the following requirements:

- 1 The existing retaining structure at the toe of a slope should not be demolished. The area near structures may be compacted in thin layers with small equipment.
- 2 If there are underdrains or blind drains under the existing subgrade, the connection construction for those drainage courses shall be done.
- 3 The widening of a high embankment and a steep slope embankment shall also meet the requirements of Clause 4.7 of the *Specification*.

4.16.6 The subgrade widening in a cut section shall meet the following requirements:

- 1 Safety protection measures shall be constructed at the side of the existing subgrade to prevent flying rock or falling rock. Warning signs shall also be placed.
- 2 If the road remains open to traffic during construction, it is preferable to excavate by machinery or by static expansive rock breaking method for widening.
- 3 If blasting is used the work shall be organized and carried out by following the blasting scheme. Multiple blasting tasks should be carried out at a specified time, and in this period the road shall be closed to traffic.
- 4 The subgrade widening in a cut section shall not only meet the requirements of this Clause,

but also the requirements of Clause 4.3.

4.16.7 Settlement observations shall be made at the time of subgrade widening. Observation points shall be set up in accordance with the design requirements. In a section with a high embankment or steep slope embankment, their stability shall also be monitored.

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5 Subgrade Drainage Works

5.1 General

5.1.1 Before construction, the designed drainage works shall be checked with the real situation in the field. If there is any discrepancy, feedback shall be provided in time to address those problems. The ditches, channels, bridges and culverts along the whole road length shall form an integrated drainage system.

5.1.2 Temporary drainage facilities should be integrated with the permanent drainage facilities. Temporary drainage facilities shall be maintained regularly during construction.

5.1.3 If there are culverts in the embankment section, they should be built first. The temporary or permanent drainage facilities for surface water or groundwater shall be built in advance.

5.1.4 During the construction of an embankment, a cross slope of 2% -4% shall be maintained on the working surface, and there shall be no accumulated water on the surface. A side slope shall have temporary drainage facilities.

5.1.5 The surface water shall be drained away quickly during the construction in a cut section.

5.1.6 For the facilities such as a side ditch, drainage ditch and intercepting drain, their sides facing water running into them shall not be higher than ground level. If there are lower areas, they shall be leveled.

5.1.7 Concrete works and mortar masonry works for drainage facilities shall satisfy the requirements of the current *Technical Specifications for Construction of Highway Bridges and Culverts* (JTG/T 3650).

5.2 Surface drainage

5.2.1 For side ditches, their bottom longitudinal slopes shall be connected smoothly.

5.2.2 The construction of an intercepting drain shall meet the following requirements:

- 1 An intercepting drain shall be constructed first, and its connection with other drainage facilities shall be made smoothly, with a longitudinal slope of not less than 0.3%.
- 2 If the intercepting drain is located in sections with unfavorable geological conditions, weak and soft material, high permeability or with many rock fractures, its bottom, walls and outlets shall be reinforced and treated to prevent seepage.

5.2.3 The construction of a drainage ditch shall meet the following requirements:

- 1 The alignment of a drainage ditch shall be smooth, and the turning point should be made in a curve.
- 2 At the outlets of drainage ditches, hydraulic drops or chutes shall be constructed. Water shall be channeled away from the subgrade or flow into the drainage system.

5.2.4 The construction of a chute shall meet the following requirements:

- 1 The foundation of a chute shall be embedded into solid ground and the bottom shall have slide-resisting slabs or keys (tongues). For areas of overcut or being lower, they shall be treated with the same material as that for building the chute and shall be done at the same time as the construction of the chute.
- 2 The mortar rubble masonry for a chute shall have sufficient mortar, the joints of the rubble shall be no wider than 40 mm, and the lower inner surface of the chute shall be rough.
- 3 Chute shall be built in segments, and each segment should be 5-10 m long. The connection joint between segments shall be sealed with water-proofing material. For a precast concrete chute, each segment should be 2.5-5 m long, the connection shall be a mortice and tenon type.
- 4 The flared catch basin chute inlet shall be connected smoothly with other drainage

facilities, and the bottom of this basin shall not be higher than its shoulder surface connection.

5.2.5 The construction of a hydraulic drop shall meet the following requirements;

- 1 The construction of a drop chute shall meet the requirements of Clause 5.2.4 of the *Specifications*.
- 2 For an hydraulic drop without energy dissipater, the rise of each step shall be less than 600 mm, and the ratio of its rise to its width shall be in line with original ground slope.
- 3 The base of the stilling pond shall be protected to prevent erosion and seepage.

5.2.6 The construction of an evaporation pond shall meet the following requirements;

- 1 The distance between evaporation pond and subgrade shall satisfy the requirements for the stability of the subgrade.
- 2 The bottom and sides of an evaporation pond shall be impermeable.
- 3 The bottom of the evaporation pond should have a slope of 0.5% , and its inlet shall be smoothly connected to the drainage ditch.
- 4 Evaporation ponds shall be located far from populated areas such as towns or villages. A security fence shall be constructed surrounding the pond for protection purpose. The height of the fence shall not be less than 1.8 m, and warning sign boards shall be installed.

5.2.7 The construction of an oil/water separation tank shall meet the following requirements;

- 1 Waste shall first be treated by passing through a grill filter and settling tank.
- 2 The bottom and side walls of an oil/water separation tank shall be reinforced by mortar rubble or in-situ cast concrete.

Commentary

The waste generated from the surface of a highway contains mainly suspended solids and petroleum. To guarantee the required quality of the waste water the highway drainage shall be treated and purified.

5.3 Subsurface drainage

5.3.1 The construction of the drainable bedding layer shall meet the following requirements:

- 1 The thickness of drainable bedding layer should not be less than 300 mm. The material for the bedding layer should be natural gravel or medium-coarse sand and the silt content in the material shall not be more than 5% .
- 2 The bedding layer should be compacted in layers. If the material for the bedding layer is sandy gravel, segregation shall be prevented.
- 3 Both sides of bedding layer should be protected by mortar rubble or other measures.

5.3.2 The construction of a geosynthetic isolation layer shall meet the following requirements:

- 1 Before placing geosynthetic materials, the site shall be leveled, tree roots, shrubs or other sharp and hard debris shall be cleared. Construction vehicles shall not travel directly on the geosynthetic materials. If gravel is being placed over the geosynthetic materials, a protective layer shall be first placed to cover the geosynthetic materials. Gravel shall not be dumped directly onto the geosynthetics.
- 2 Geotextiles may be connected by way of stitching or by overlapping. The width of a seam shall not be less than 100 mm, the tensile strength of the seam shall be more than 60% of the ultimate tensile strength of the geotextile. For overlapping, the overlap length shall not be less than 300 mm.
- 3 The hot melt welding method is advised for use of a geomembrane connection. For the repair of a small area the connection may also be made by adhesive. The connection width shall not be less than 100 mm. A test connection shall be made first to ensure that the adhesive is not dissolved in water.
- 4 The geosynthetic shall be placed smoothly and there shall be no twisting, breaking or tearing. Geosynthetics shall be stretched in both directions when placed, both ends shall be imbedded into soil in a corrugated form. If a geosynthetic connects with a rigid structure, an extra length shall be provided to accommodate expansion.
- 5 When a geosynthetic is placed on a slope it shall be placed from the top downwards, and

the connection shall be made on site. A geosynthetic shall be placed tightly in contact with the protective layer of the slope and should not be stretched too tight.

5.3.3 The construction of a buried ditch or a buried pipe shall meet the following requirements:

- 1 The bottom of a buried ditch shall be buried in an impermeable layer. The lowest row of seepage holes shall be more than 200 mm above the bottom of the ditch. There shall be water interception measures at the inlet of the buried ditch to force ground water into the ditch.
- 2 If a buried drain is located at the side of the subgrade, it should be built along the road alignment.
- 3 If a buried drain is located in the lower part of a depressed area or natural gully, it should be built in the direction of this depressed area or gully.
- 4 A buried ditch in a cold region shall be insulated and protected against freezing, and the outlet slope should not be less than 5%.
- 5 If a buried ditch is built with concrete or mortar rubble, its walls contacting the aquifer shall have one or more rows of perforated holes which are inclined towards the inside of the buried ditch. The outside of the buried ditch shall be backfilled by coarse-grained permeable material or have a filter layer of geosynthetics. Along the bottom of the buried ditch, settlement joints or expansive joints shall be built every 10-15 m, or built at the interface between soft and hard rock stratum.
- 6 The top of a buried ditch shall be covered with concrete or stone slabs. The soil backfilled over the top slabs shall not be less than 500 mm thick.
- 7 The buried pipe should be made with concrete pipe, PVC pipe or corrugated steel pipes. The wall in contact with the aquifer shall have perforated holes. The outside of the buried pipe shall be backfilled by coarse-grained permeable material or have a filter layer of geosynthetics.
- 8 Buried drain and manhole shall be backfilled in layers with permeable material, each layer should not be more than 150 mm in thickness and the grain size should not be more than 50 mm.

Commentary

A settlement joint and an expansion joint are normally built at the same position. Joints are normally filled with bitumen hemp or bitumen soaked wooden board or geosynthetic elastic materials to prevent leakage.

5.3.4 The construction of an underdrain shall meet the following requirements:

- 1 An underdrain shall have a drainage layer, a filter layer and a sealing layer.
- 2 Permeable materials shall be clean gravel, coarse sand, crushed stone or rubble. The material smaller than 2 mm shall not be more than 5%. The filter layer surrounding the walls of an underdrain shall be permeable geotextile or medium coarse sand. Permeable pipe may be perforated HPPE pipe, PVC pipe, PE pipe, soft permeable pipe, no-fines concrete.
- 3 The underdrain should be excavated from the downstream upwards and in sections. The excavated trench shall be properly supported. Supporting works shall be placed immediately after excavation, and permeable material shall be backfilled at the same time.
- 4 The top of the permeable material shall not be below the original groundwater level. When it is used to drain away the interlayer water, the bottom of an underdrain shall be buried in the lowest impermeable layer. In a frost region, the buried depth of an underdrain shall not be less than the local minimum depth of freezing, and the outlet shall be protected against frost.
- 5 The bottom of an underdrain shall be buried in an impermeable bed to a depth not less than 0.5 m. A filter layer shall be constructed on one side of the underdrain to collect water, and the other side shall be filled with clay or mortar rubble to intercept water. If the bottom of underdrain cannot be buried in impermeable bed, both sides shall have filter layers.
- 6 A filter layer made with aggregate shall be constructed in layers. If the trench is in an area with clay, silt, or fine sand, then no-fines concrete may be used as a filter layer. Beyond the no-fines concrete slabs, a 100-150 mm thick medium coarse sand or a layer of permeable geotextile shall be constructed.
- 7 A sealing layer on the top of an underdrain should be made with dry masonry with its joints pointed with cement mortar, or by mortar rubble. In a cold region, an insulation layer shall be provided, and the longitudinal slope shall be increased near its outlet. An insulation layer may be made with slag, sand and gravel, crushed stone or turf.

- 8 For a blind drain(or rock filled underdrain) below the subgrade foundation ,the rocks shall be stable in water ,their compressive strength at full saturation shall not be less than 30 MPa ,and have a size of 100-300 mm.
- 9 A pipe underdrain should have manholes and crossings discharging the pipes at intervals to drain away groundwater section by section. Perforation holes in the wall of the pipe underdrain shall be arranged in a staggered pattern ,the distance between holes should not be more than 200 mm.
- 10 A sealing layer shall be positioned at the top of a tunnel sized underdrain ,and shall have a thickness not less than 500 mm.
- 11 The bottom of side slope underdrain shall be positioned in the dry soil below the moist soil. The slope of a stepped-channel on a side slope should be 2% -4% . The foundation shall be paved with an impermeable layer ,and both walls shall have filter layer. Other parts shall be filled with permeable material.
- 12 The foundation of a supporting underdrain should be buried below the sliding surface for at least than 500 mm ,and the drainage slope should be 2% -4% . If the sliding surface is not steep ,the supporting underdrain may be made with steps. The run of a step should not be less than 2 m. The side walls and the top of the underdrain should have filter layers. A headwall should be placed at the outlet ,and the elevation of the invert shall be 200 mm higher than normal water level of ground surface drainage ditch ,or over 500 mm in a cold region. The drainage ditch for receiving the discharge water from the supporting underdrain shall be reinforced.

5.3.5 The construction of upward inclined weep holes shall meet the following requirements:

- 1 The bored hole shall have a diameter of 75-150 mm ,the angle should not be less than 6° . The hole shall reach into the accumulated water zone or potential sliding surface.
- 2 The diameter of a weep hole should be 50-100 mm. Different layers of bored holes should be arranged in staggered pattern. The seepage section and the upper end of a weep hole should be wrapped with a layer or two permeable non-woven geotextiles.
- 3 When a weep hole is inserted into bore hole ,for a length of at least than 600 mm from the outlet ,the gap between the outside of a weep hole in a bored hole shall be plugged with impermeable material.

5.3.6 The construction of a seepage well shall meet the following requirements:

- 1 For seepage well construction, the supporting work shall keep pace with the excavation. Services such as lighting, ventilation and draining water away shall be installed.
- 2 Fill material shall be placed immediately after the excavation is completed. Fill material shall be single sized, but different materials shall be used for different layers. Fines content with a size less than 2 mm shall not be more than 5%. For a permeable layer, crushed stone or pebble should be used. For an impermeable layer, coarse sand or gravel should be used. Between the wall and fill material, there shall be a filter layer, which shall be constructed at the same pace as the fill material.
- 3 The surrounding area of the top part of a seepage well shall be filled with clay for protection. A seepage well shall be locked with a cover.

5.3.7 The construction of a drainage tunnel shall meet the following requirements:

- 1 Before construction, the on-site geological and hydrological conditions shall be investigated and checked against the design drawings. And special scheme for the construction of the drainage tunnel shall be prepared.
- 2 During the construction process, the work shall be monitored and measured. If the material classification differs from the design, feedback shall be given immediately to deal with the problem.
- 3 The construction shall comply with the relevant requirements of the current *Technical specifications for construction of highway tunnel* (JTG/T 3660).

5.3.8 Discharging confined groundwater shall meet the following requirements:

- 1 In an area where confined groundwater is discharged, the energy should be dissipated by constructing rubble or precast concrete blocks. The water is then drained away by a drainage ditch or underdrain, or alternatively construct a separation layer, and the water is led into a drainage ditch.
- 2 Unconfined groundwater may be drained away by underdrain, drainage ditch, seepage well, buried ditch, buried pipe or other measures.
- 3 If there is confined water below the frozen depth in cold regions, drainage facilities shall be

constructed below the frozen depth. If this cannot be achieved, insulation measures shall be taken with the covering backfill material. The drainage ditch near the outlet of the drainage facility shall be insulated. The covering insulation layer shall extend 2-5 m beyond the drain. The longitudinal slope of the drainage ditch near the outlet shall be increased.

Commentary

- 1 *If the energy of the shallow confined groundwater is not dissipated, water will flow randomly and cannot be discharged into drainage facilities.*
- 3 *In cold areas, where drainage facilities cannot be constructed below the frozen depth, slag or peat is generally used as insulation material.*

5.3.9 If the surface of the central median strip is sealed by the pavement, waterproofing measures shall be taken below the pavement. The cross slope of the pavement shall be consistent with the carriageway on both sides of it. The joints between the median strip and the carriageway shall be smooth and even, and shall be sealed.

5.3.10 If the median strip is not sealed by the pavement, the construction shall meet the following requirements:

- 1 The construction of transverse pipe drains shall be constructed with the sequence of filling and levelling first then excavating (to prevent mistakes in setting out the levels).
- 2 The construction of a permeable layer shall satisfy the relevant requirements of Clause 5.3.4 of the *Specifications*.
- 3 The construction of an impermeable geotextile shall satisfy the relevant requirements of Clause 5.3.2 of the *Specifications*.
- 4 The backfill material for trenches shall be garden soil.
- 5 In the construction process, temporary drainage measures shall be taken.

Commentary

The activities in a central median strip include transverse underdrain, longitudinal underdrain, catch basin, transverse pipe drain, impermeable layer, conduits for communication cables, backfilling and others. These activities are not suitable for mechanized construction, and proper scheduling or organizing is needed.

5.4 The quality criteria for subgrade drainage works

5.4.1 The appearance quality for drainage facilities shall meet the following requirements:

- 1 Longitudinal slope shall be even, curves shall be smooth and gentle.
- 2 Walls of drainage works shall be even, stable, and no over-excavated parts where the earth slope or the wall need to be pased. The inverts shall be even such that water may be drained away without interruption. There shall be no problems with scouring or blocking.
- 3 Facilities for preventing seepage or for reinforcement shall be firm and stable.
- 4 For mortar laid stone work, the joints shall be even, full and dense. Pointed joints shall be smooth, dense, good-looking and without scaling. The width of the joints shall be even and harmonious. Masonry work shall be tightly interlocked. Finishing shall be even, smooth, even and without cracks or voids.
- 5 For dry laid rubble, the masonry work shall be tightly interlocked. It is prohibited to lay upper layer blocks in direct alignment with the lower layer blocks (they shall be laid staggered), or to add a thin pasting wall to a completed wall. Loose blocks are not allowed.
- 6 The strength of concrete blocks shall satisfy the requirements of the design. Masonry work shall be even and flat, pointed joints shall be even and firm.
- 7 The expansion joints and settlement joints of the foundation shall be vertically aligned with those joints in the wall.

5.4.2 The construction quality for soil side ditch, intercepting ditch, drainage ditch shall meet the requirements of Table 5.4.2.

Table 5.4.2 Construction quality standards for earth side ditch, intercepting ditch and drainage ditch

Number	Checking items	Specified value or allowed deviation	Checking method or frequency
1	The elevation of invert of ditch (mm)	+0, -30	Level; 4 points for each 200 m, but not less than 5 points

continued

Number	Checking items	Specified value or allowed deviation	Checking method or frequency
2	The dimensions of cross-section(mm)	Not less than the design value	Tape measure; 2 points for each 200 m, but not less than 5 points
3	The side slope	Not steeper than design requirements	Slope scale; 2 points for each 200 m, but not less than 5 points
4	The straightness of edges(mm)	50	Tape measure with 20 m tightened line, 2 points for each 200 m, but not less than 5 points

5.4.3 The construction quality for mortar masonry side ditch, intercepting ditch, drainage ditch shall meet the requirements of Table 5.4.3.

Table 5.4.3 Construction quality standards for mortar masonry ditches

number	Checking item	Specified value or allowed deviation	Checking method and frequency
1	Strength of mortar(MPa)	Being qualified	Checked by following Appendix F of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	Axial deviation(mm)	50	Total station or Tape measure; 5 points for each 200 m
3	The elevation of ditch invert(mm)	± 15	Level; 5 points for each 200 m
4	Straightness of wall(mm)	30	20 m tightened line; 2 points for each 200 m
5	Slope	Satisfy design requirements	Slope scale; 2 points for each 200 m
6	Dimensions of cross-section(mm)	± 30	Tape measure; 2 cross-sections for each 200 m, but not less than 5 cross-sections
7	Thickness of masonry works	Not less than design value	Tape measure; 4 points for each 200 m
8	Width, thickness of foundation blinding layer	Not less than design value	Tape measure; 4 points for each 200 m

Note: Hydraulic drop, chute and flared catch basin and other mortar masonry drainage works shall also satisfy the requirements of this Table.

5.4.4 The construction quality for a concrete drainage ditch ,intercepting ditch and side ditch shall meet the requirements of Table 5.4.4.

Table 5.4.4 Construction quality criteria for concrete ditches

number	Checking item	Specified value or allowed deviation	Checking method and frequency
1	Strength of concrete(MPa)	Being qualified	Checked by following Appendix D of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	Axial deviation(mm)	50	Total station or tape measure; 5 points for each 200 m
3	The invert of the ditch bottom(mm)	± 15	Level; 5 points for each 200 m
4	Straightness of wall(mm)	20	20 m tightened line; 2 points for each 200 m
5	Slope(mm)	Satisfy design requirements	Slope scale; 2 points for each 200 m
6	The dimensions of the cross-section(mm)	± 20	Tape measure; 2 cross-sections for each 200 m, but not less than 5 cross-sections
7	Concrete thickness	Not less than design value	Tape measure; 2 points for each 200 m
8	Top level of side wall(mm)	-15, 0	Level; 5 points for each 200 m

5.4.5 The construction quality criteria for a concrete drainage pipe shall meet the requirements of Table 5.4.5. The quality of corrugated steel pipe and its connection shall follow the technical standards for industrial products. The quality of the pipe seats and its installation shall be checked by referring to standards for reinforced concrete pipe.

Table 5.4.5 Construction quality standards for a concrete drainage pipe

Number	Checking item	Specified value or allowed deviation	Checking method and frequency
1	The compressive strength of concrete or strength of mortar(MPa)	Being qualified	Checked by following Appendix D, F of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)

continued

Number	Checking item		Specified value or allowed deviation	Checking method and frequency
2	Pipe axial deviation (mm)		15	Total station or tape measure; 3 points between two manholes
3	Elevation of water surface (mm)		± 10	Level, ruler; one point each at inlet and outlet of each manhole, 1 or 2 in the middle between manholes
4	Foundation thickness		Not less than design value	Tape measure; 3 points between 2 manholes
5	Pipe seat	Shoulder width (mm)	+ 10 , - 5	Tape measure; 2 points between 2 manholes
		Shoulder height (mm)	± 10	
6	Sealing rings	Width	Not less than design value	Tape measure; 10% random checking
		Thickness	Not less than design value	

Note: The construction quality standards of PVC pipe and corrugated steel pipe may refer to this Table.

5.4.6 The construction quality for an underdrain shall meet the requirements of Table 5.4.6.

Table 5.4.6 Construction quality standards for underdrain

Number	Checking item	Specified value or allowed deviation	Checking method and frequency
1	The invert elevation (mm)	± 15	Level; 2 points for each 20 m
2	Dimensions of cross-section (mm)	Not less than design value	Tape measure; 2 points for each 20 m

5.4.7 The construction quality for a seepage well shall meet the requirements of Table 5.4.7.

Table 5.4.7 Construction quality standard for a seepage well

Number	Checking item	Specified value or allowed deviation	Checking method and frequency
1	Concrete strength (MPa)	Being qualified	Checked by following Appendix D of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)

continued

Number	Checking item		Specified value or allowed deviation	Checking method and frequency
2	Plan view dimensions (mm)	Length, width	$\pm 0.5\%$, if over 24 m, ± 120	Tape measure
		Radius	$\pm 0.5\%$, if over 12 m, ± 60	
3	Central deviation of upper face, lower face (longitudinal, transverse) (mm)		1/50 height of well	Total station
4	Maximum inclination (longitudinal, transverse) (mm)		1/50 height of well	Plumb line
5	Circular angle of plan view ($^{\circ}$)		1	Plumb line; 2 perpendicular directions
6	Cutting edge elevation (mm)		Satisfy drawing requirements	Level
7	The grading of filter aggregate		Satisfy design requirements	1 sample for each seepage well
8	The strength of filter aggregate		Satisfy design requirements	1 set of samples per point or per 100 m
9	Positions of geotextile, unevenness of supporting underlayer		Satisfy design requirements	Two places for each seepage well
10	Overlap length (mm)		+ 50, - 0	5% Random check

5.4.8 The construction quality for geosynthetic isolation layer shall meet the requirements in Table 5.4.8.

Table 5.4.8 Construction quality standards for geosynthetic isolation layer

Number	Checking item	Specified value or allowed deviation	Checking method and frequency
1	Unevenness, crown slope of supporting underlayer	Satisfy design requirements	4 points for each 200 m
2	Overlapping length (mm)	+ 50, - 0	Tape measure; 2% random check

continued

Number	Checking item	Specified value or allowed deviation	Checking method and frequency
3	Staggered distance of lap joints(mm)	Satisfy design requirements	Tape measure;2% random check
4	Permeable spots of lap joint	No more than 1	Each joint

5.4.9 The construction quality for a filter layer of geosynthetics or geotextile shall meet the requirements in Table 5.4.9.

Table 5.4.9 Construction quality standards for filter layer of geosynthetics or geotextile

Number	Checking item	Specified value or allowed deviation	Checking method and frequency
1	Unevenness,crown slope of supporting underlayer	Satisfy design requirements	4 points for each 200 m
2	Overlapping length(mm)	+ 50 , - 0	2% random check
3	Staggered distance of lap joints(mm)	Satisfy design requirements	2% random check

5.4.10 The construction quality for manhole and catch basin shall meet the following requirements:

- 1 The strength of the foundation concrete shall not be less than 5 MPa. Ladders shall be fixed firmly. Frames and covers shall be stable. No accumulated water shall surround them.
- 2 The construction quality for manhole and catch basin shall meet the requirements in Table 5.4.10.

Table 5.4.10 Construction quality standards for manhole and catch basin

Number	Checking item	Specified value or allowed deviation	Checking method and frequency
1	Mortar strength	Being qualified	Checked by following Appendix F of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	Axial deviation(mm)	50	Total station;each manhole

continued

Number	Checking item	Specified value or allowed deviation		Checking method and frequency
3	Diameter(round) ,sides (rectangle) (mm)	± 20		Tape measure;each manhole
4	Invert elevation(mm)	± 15		Level;each manhole
5	Height difference between covers and surrounding ground surface(mm)	Manhole	+4 , -0	Level;each manhole

5.4.11 The location and position of a caisson of a drainage pumping station and the bearing capacity of the ground shall meet the design requirements. No leakage is allowed. The construction quality shall comply with the requirements of Table 5.4.11.

Table 5.4.11 The construction quality standards for the caisson of a drainage pumping station

Number	Checking item	Specified value or allowed deviation		Checking method and frequency
1	Concrete strength(MPa)	Being qualified		Checked by following Appendix D of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	Axial location deviation(mm)	± 50		Total station;2 points for both longitudinal and transverse directions
3	Verticality(mm)	1% of caisson depth		Plumb line; 1 point for both longitudinal and transverse direction
4	Geometric dimensions(mm)	± 50		Tape measure;2 points for each of three dimensions
5	Wall thickness (mm)	-5 ,0		Tape measure;5 points for each caisson
6	Wellhead elevation (mm)	± 50		Level;4 points for each caisson

5.4.12 The bearing strength of the ground of a settling pond shall meet the design requirements. No leakage is allowed. The construction quality shall meet the requirements of Table 5.4.12.

Table 5.4.12 Construction quality standards for settling pond

Number	Checking item	Specified value or allowed deviation	Checking method and frequency
1	Concrete strength(MPa)	Being qualified	Checked by following Appendix D of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	Axial location deviation(mm)	± 50	Total station; 2 points for both longitudinal and transverse directions
3	Geometric dimensions(mm)	± 50	Tape measure; 2 points for each of three dimensions and 2 points for thickness
4	Foundation elevation(mm)	± 50	Level; 2 points for each pond

5.4.13 The center line of reinforced concrete plates shall be in alignment with the center line of the drainage ditch covered by them. The construction quality shall meet the requirements of Table 5.4.13.

Table 5.4.13 Construction quality standards for reinforced concrete plates

Number	Checking item	Specified value or allowed deviation	Checking method and frequency
1	Concrete strength(MPa)	Being qualified	Checked by following Appendix D of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	Thickness(mm)	$+10, -0$	Tape measure; 10% random check, 1 visually thinner point of a plate
3	Width(mm)	± 10	Tape measure; 10% random check, 1 visually shorter point of a plate
4	Length(mm)	± 10	Tape measure; 10% random check, 1 visually shorter point of a plate
5	Straightness(mm)	15	20 m tightened line; 4 points for each 200 m
6	Maximum height difference between neighboring plates(mm)	5	Tape measure; 1 point for each 10 m

6 Slope Protection and Retaining Structures

6.1 General

6.1.1 Before constructing slope protection works, side slopes shall be checked and dangerous rocks and loose soil on the slope shall be cleared. The side slope after cleaning shall be even. The drainage shall be unhindered and in harmony with the surrounding natural terrain.

6.1.2 Subgrade protection works shall be closely and reasonably connected with subgrade excavation and fill. After each stage of excavation, one stage of protection works shall be constructed. Based on the geological and hydrological conditions of the slope being excavated, the design plans of subgrade protection work shall be checked section by section. If the actual situation differs greatly from the design, feedback shall be reported urgently so that it can be resolved.

6.1.3 Security protection works shall be reinforced during construction. Large scale blasting or excavation are strictly prohibited.

6.1.4 All types of protective work shall be placed on stable foundation or slope. Slope surface protection layer shall be integrated with the slope surface without leaving any gaps.

6.1.5 Effective measures shall be taken during construction to intercept surface water and drain away groundwater.

6.1.6 The quality of stones, steel bars, steel cables, cement concrete and other materials shall meet the relevant requirements.

6.1.7 Each slope protection item shall be equipped with a maintenance access path and necessary handrail.

6.2 Vegetation protection

6.2.1 The construction of vegetation slope-protection shall meet the following requirements:

- 1 After the side slope has been formed, vegetation slope protection shall be applied immediately.
- 2 The slope surface shall be cleaned before the vegetation slope protection is applied.
- 3 The topsoil layer should be a mixture of soil, fertilizer and humus. The thickness of the top soil shall meet the requirements in Table 6.2.1-1.

Table 6.2.1-1 The topsoil thickness

Vegetation type	Herbal flowers	Lawn	Undershrub	Shrub	Tree with shallow roots	Tree with deep roots	Check method and frequency
Thickness (mm)	≥30	≥30	≥45	≥60	≥90	≥150	Tape measure; 1 point for each 50 m

- 4 When planting grass, seeds shall be spread evenly, and protective measures shall be taken. The sod should be in bands or in blocks, the thickness of the sod should be 100 mm. The sod shall be laid from the bottom of the slope up.
- 5 After vegetation has been laid or planted, watering shall take place regularly until the vegetation is able to grow by itself.
- 6 The water used for spraying shall not contain oil, acid, alkali, salt or other components that hinder the growth of plants and trees.
- 7 The quality standards for slope protection by vegetation shall meet the requirements in Table 6.2.1-2.

Table 6.2.1-2 The construction quality standards for slope protection by vegetation

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Seedling type and quantity	Satisfy the design requirements	Tape measure; measure 50 m for each kilometer

continued

Number	Checking Item	Specified value or allowed deviation	Check method and frequency
2	Planting hole size(mm)	± 50	Tape measure; measure 50 m for each kilometer
3	Rate of seedling survival(%)	≥ 85	Visual inspection; measure 200 m for each kilometer
4	Lawn coverage rate(%)	≥ 95	Visual inspection; measure 200 m for each kilometer
5	Germination rate of other ground covering plants(%)	≥ 85	Visual inspection; measure 200 m for each kilometer

6.2.2 Spray seeding shall meet the following requirements:

- 1 The unevenness of working surface shall be checked before spraying. The average unevenness should be ± 100 mm, and the maximum shall not exceed ± 150 mm. If the rock slope is unstable, it shall be reinforced by using prestressed anchor rods or cables.
- 2 The spray seeding grass planting mixture shall be composed of the correct proportions of planting soil, soil stabilizer, cement, fertilizer, mixed grass seeds and water.
- 3 Before the soil seeding is sprayed, the slope surface shall be wetted. The spray mixture shall be determined based on the slope, geological conditions and local climate. The thickness of sprayed mixture shall be 20-80 mm and the seeds shall be sprayed evenly.
- 4 The anchor rods and soil nails for the soil seeding spray sections should be arranged in a staggered pattern spaced at 1 m $\times$ 1 m. When hanging the net the roll shall be unwound from the top to the bottom. The adjacent rolls of wire mesh shall be connected and fixed with binding wires. The width of the overlap of the two net rolls shall not be less than 100 mm, and the number of soil nails shall not be less than 5 per m².
- 5 Netting shall have a gap between the working surfaces and be uniform.
- 6 After the soil seeding has been sprayed, regular maintenance such as remedial seeding, watering, fertilizing and clearing weeds shall be applied. The survival rate shall be more than 90%.

6.2.3 The construction of vegetation bags shall meet the following requirements:

- 1 When laying vegetation bags, it shall be ensured that seeds are attached well to the bags. There shall be no water inside the bags.
- 2 When working on a slope, construction shall be performed from the bottom. If necessary, bracing stakes can be driven into the slope.
- 3 Vegetation bags shall be placed flat on the bedding, with their edges overlapping for 10-20 mm. A layer of about 10 mm soil or river sand shall be used to cover the bags so that they are not exposed.
- 4 After the vegetation bag has been placed, watering with a sprinkler shall be applied immediately to keep the ground wet. Direct water jets shall be avoided to prevent erosion.

6.2.4 The construction of three-dimensional landscape netting shall meet the following requirements:

- 1 Before construction, weeds, stone blocks, tree roots and other foreign objects shall be cleared. Loose soil on the slope shall be compacted.
- 2 Landscape netting shall be placed from top down to the toe of slope, and be extended 500 mm beyond the top and toe of the slope.
- 3 Landscape netting shall be fixed on slope surface by wood stakes or soil nails. All sides shall be fixed with U-shaped soil nails. The overlap length between adjacent netting strips shall meet the design requirements and also not be less than 100 mm. Landscape netting shall be in firm contact with the slope surface and without folds or wrinkles.
- 4 Construction shall not take place on rainy days.

Commentary

If the landscape netting is not connected to the slope the plant root system cannot intertwine with the netting to form a covering layer, and it cannot give subgrade slope a continuous and lasting protection.

Laying landscape netting on rainy days may cause the backfill soil and imported soil to be too wet or prone to erosion.

6.2.5 The construction of the cement concrete protection skeleton shall meet the following requirements:

- 1 Before the construction of skeletons, the surface of the slope shall be checked, and over-excavated or original depressions or voids shall be filled.
- 2 Concrete shall be cast upwards from footings. During casting, concrete shall be compacted by poker vibrators.
- 3 Skeletons should be completely embedded into the slope surface to ensure that they are in intimate contact with the slope.
- 4 After the casting is finished, curing shall be start immediately. Curing shall continue for at least 14 d.

6.2.6 The construction of a cement concrete hollow block skeleton shall meet the following requirements:

- 1 The precast blocks may be used only after being checked and approved.
- 2 Before laying blocks, the slope surface shall be levelled and compacted. Paving should be carried out after embankment settlement is stable.
- 3 Blocks shall be in intimate contact with the slope surface and no openings are allowed. The prepared surface shall be consistent with adjacent slopes.
- 4 After the blocks are placed, vegetation protection works shall be made shortly afterwards.

6.2.7 The construction of vegetation for skeleton protection shall meet the following requirements:

- 1 Vegetation shall be plants with good adaptability, tolerant of drought and infertile conditions and being able to self-regenerate.
- 2 Vegetation shall be mainly indigenous plants, supplemented by alien plants. Different plants shall be complementary in growing, and be adaptable to the native vegetation in the surrounding environment.
- 3 In the depressions inside the skeletons and under the sods there shall be planting soil of 50-100 mm in thickness. Sods shall be in intimate contact with the slope and skeletons.
- 4 After laying sods, maintenance shall be carried out regularly.

6.3 Slope protection

6.3.1 Construction of slope gunite protection shall meet the following requirements:

- 1 Grout spraying shall start from the bottom up.
- 2 After the initial set of the grout, curing shall start immediately. The curing period should not be less than 5 d.
- 3 After completion of the grout spray, the top edge of the sprayed layer shall be sealed.

6.3.2 The construction of the slope shotcrete protection shall meet the following requirements:

- 1 The strength of the concrete shall satisfy the design requirements:
- 2 Before construction a trial spray shall be made to select the proper water-cement ratio and the compressor pressure.
- 3 The thickness of the shotcrete shall satisfy the design requirements. For temporary works, the thickness should not be less than 60 mm and for permanent support, not less than 80 mm. For steel reinforcing embedded in the shotcrete for permanent support surface layer, the thickness of cover layer of shotcrete shall not be less than 50 mm.
- 4 Each layer of shotcrete shall be sprayed from the bottom up. In case the thickness of shotcrete is more than 100 mm, it should be sprayed in two layers. Before the second layer is started, the loose material on the bonding surface shall be cleared.
- 5 The final surface shall be screeded and compacted.
- 6 There shall be an expansion joint of 10-20 mm in width every 30 m along the longer side of the shotcrete layer.
- 7 After the initial set of the shotcrete, curing shall start immediately. The curing period should not be less than 7 d.
- 8 The shotcrete surface shall be dense, even, without cracks, scaling, omitted application, exposed re-bar, voids, and leakage spots. The construction shall meet the requirements in

Table 6.3.2.

Table 6.3.2 The construction quality standards for shotcrete

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Strength of concrete (MPa)	Within qualifying standards	Checked by following Appendix E of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	Thickness(mm)	Average thickness $\geq$ design thickness; thickness of 80% check points $\geq$ design thickness; minimum thickness $\geq$ specified minimum thickness by design	By drilling a hole or ground penetrating radar; one point every 50 m ² and total points not less than 5

6.3.3 The construction of protective shotcrete with anchored netting shall meet the following requirements:

- 1 Anchor rods shall be embedded into the sound bedrock, and the anchored depth shall be determined by the design requirements and the rock mass properties. The depth of the anchor rod hole shall be 200 mm deeper than the anchor rod length.
- 2 The steel wire mesh shall be firmly connected to the anchor rod. The gap between steel wire mesh and slope surface should be 30-50 mm.
- 3 Shotcrete should be constructed in layers. Before placing the wire mesh, the first layer of shotcrete shall be sprayed. After the wire mesh is placed, the second layer can be sprayed to the design thickness.
- 4 The thickness of shotcrete shall be even. Steel wire mesh and anchor rods shall not be exposed. The cover layer for steel wire should not be less than 20 mm.
- 5 The construction quality for shotcrete shall satisfy the relevant requirements in Table 6.3.2.

6.3.4 The construction of dry-laid rubble slope protection shall meet the following requirements:

- 1 The bedding layer for dry-laid rubble slope protection works shall be compacted, and the

thickness of the bedding layer shall satisfy the design requirements. If side slope is made of silt, loose sand or sandy silt, it is sensitive to erosion. The bedding layer of crushed stone or sandy gravel should have a thickness of at least 100 mm.

- 2 Stone blocks shall satisfy the relevant requirements. Their thickness shall not be less than 150 mm. The rounded or flakey stone cannot be used. The facing stones shall be constructed with larger sizes and with flatter faces. They shall also be moderately hewed. In the corner, bigger stones shall be used and be hewed into roughly cuboids.
- 3 Stones shall be laid in layers. If laid in sections, the height differences of neighboring sections shall not be more than 1.2 m. In the construction process, expansion joints or settlement joints shall be built between sections. The horizontal joints in each section shall be kept continuous.
- 4 Stones shall be closely packed. Joints shall be staggered. The gaps between blocks shall be filled with smaller stones. Large stones should be used for the foundation of slope protection.
- 5 If the foundation connects with a drainage ditch, the foundation shall be made below the bottom of the drainage ditch.
- 6 The construction standards for dry-laid rubble shall meet the requirements in Table 6.3.4.

Table 6.3.4 Construction standards for dry-laid rubble

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Thickness (mm)	± 50	Tape measure; 8 random points for each 100 m ²
2	Elevation of top surface (mm)	± 30	Level; 5 random points for each 20 m
3	Dimensions (mm)	± 100	Tape measure; for each 20 m or a section, 5 points (for both longer and shorter sides)
4	Surface unevenness (mm)	50	2 m straight edge and clearance gauge; 5 points for each 20 m
5	The distance between weep holes (mm)	Not more than design value	Tape measure; 4 points for each 20 m

Commentary

Dry-laid rubble is suitable for slopes in road cut section with a slope gentler than 1 : 1.25, or slopes that are easily eroded by surface water, or slopes in sections with a small amount of groundwater seepage.

6.3.5 The construction of mortar rubble slope protection shall meet the following requirements;

- 1 The construction should be started after the embankment has settled and stabilized. Before laying rubble the slope surface shall be levelled. A bedding layer shall be built as required by the design. Where the soil slope may be affected by freezing then under the protection layer there shall be a bedding layer of crushed stone or sandy gravel with a thickness not less than 100 mm.
- 2 Rubble shall be placed in layers. After 2 to 3 layers of rubble have been laid, a leveled horizontal joint should be formed to provide a composite layer.
- 3 All the rubble shall be seated in freshly mixed mortar.
- 4 There shall be an expansion joint with a width of 20-30 mm joint for every 10-15 m of the protective layer. If the geological conditions under the foundation are different, at the point of change there shall be a settlement joint. An expansion joint and a settlement joint may be combined into one joint.
- 5 After the initial set of the mortar, curing shall be started. Before the final set of the mortar, the masonry work shall be covered for curing.
- 6 The position of weep holes and the installation of a filter layer shall be in accordance with the design requirements. If it is not specified in the design, the following requirements shall be fulfilled:
 - 1) The size of a weep hole should be a rectangle of 50 mm × 100 mm, 100 mm × 100 mm, 150 mm × 200 mm, or a circle with a diameter of 50 ~ 100 mm.
 - 2) The distance between weep holes should be 2-3 m, with a larger distance in a dry area. A smaller distance is used in an area with more groundwater seepage. An upper row of weep holes shall be staggered with the lower row of weep holes. The arrangement of weep holes shall prevent holes being built in the expansion or settlement joints. Weep holes should be at least 500 mm away from the nearest joints.
 - 3) The weep holes shall be outward inclined, and the lowest row of holes shall be 0.3 m higher than ground surface or normal water level of side ditch, drainage ditch or area with accumulated water.

4) Coarse aggregate with a filtration function shall be built with an arrangement of 500 mm × 500 mm around the inlet of the lowest drainage hole. Under the filter layer, there shall be a waterproof layer of clay with a thickness not less than 300 mm below the filtration layer.

7 The construction quality for mortar rubble shall meet the requirements in Table 6.3.5.

Table 6.3.5 The construction quality standards for mortar rubble

Number	Checking item	Specified value or allowed deviation		Checking method and frequency
1	Mortar strength (MPa)	Being qualified		Checked by following Appendix F of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	Elevation of top surface (mm)	Dressed stone and undressed stone block	±30	Level; 5 points for 30 m and less, add 1 point for each 10 m increase
		Rubble	±50	
3	Surface unevenness (mm)	Dressed stone and undressed stone block	≤25	2 m straight edge; 5 points for each 20 m
		Rubble	≤35	
4	Slope (%)	≤ Design value		Slope measure; 5 points for 30 m and less, add 1 point for each 10 m increase
5	Thickness or dimensions of cross-section (mm)	≥ Design value		Tape measure; 10 cross-sections for 50 m and less, add a cross-section for each 10 m increase
6	The distance of wall surface to the center line of the subgrade (mm)	±50		Tape measure; 5 points for each 20 m
7	Distance between weep holes (mm)	Not more than the design value		Tape measure; 4 points for each 20 m

6.3.6 The construction of concrete precast block slope protection shall meet the following requirements:

- 1 Construction should be started after the embankment has settled and stabilized. Before placing concrete blocks, the slope surface shall be levelled, a bedding layer of crushed stone or sandy gravel shall be placed in accordance with the following design requirements. The thickness of the bedding layer shall not be less than 100 mm.
- 2 Precast blocks shall be laid in a staggered pattern. They shall form an even slope surface

and align with adjacent slopes. In regions with frost, the concrete strength of precast blocks should not be less than C25.

- 3 An expansion joint shall be built for every 10-15 m of the slope protection works, with a width of 20-30 mm. If the geological conditions under the foundation are different for adjacent works, a settlement joint shall be constructed at the dividing place. Expansion and settlement joints may be combined into one joint.
- 4 The position of weep holes shall satisfy design requirements and ensure smooth flow. If there are no design requirements, it shall be built by following the requirements of Clause 6.3.5 of the *Specifications*.

6.3.7 The construction of mortar rubble facing wall shall meet the following requirements:

- 1 Before constructing the facing wall, weathered material on the slope shall be cleared to expose the unweathered/fresh rock surface. For rock which may weather rapidly, the facing wall construction shall be started immediately after the unweathered rock surface has been excavated.
- 2 Before constructing the foundation of the facing wall, the actual foundation bearing capacity and its burial depth shall be checked. If the bearing capacity of the foundation is insufficient, reinforcement measures shall be taken. In freezing regions, the foundation shall be buried at least 250 mm below the freezing depth.
- 3 The rear of the facing wall shall be in intimate contact with the subgrade slope. In case that there are depressions on some parts of the slope, they shall be remedied by filling with masonry mortar which is the same as that used for the facing wall after the depression areas are excavated into steps. Backfilling with soil or dry-laying rubble for remediation is not allowed. At the top of the facing wall, there shall be anti-seepage measures to prevent leakage from the underside of facing wall.
- 4 The expansion joint shall be built according to design requirements. If the foundation is built on different rock strata, then, at the change, there shall be a settlement joint.
- 5 The position of weep holes and the installation of a filter layer shall satisfy design requirements. If the design gives no requirements, it shall be built by following the requirements of Clause 6.3.5 of the *Specifications*.
- 6 The slide-resisting key (tongue) for the facing wall shall be built at the same time as the

facing wall.

Commentary

If the groundwater on the slope under the facing wall cannot be drained away unhindered, the stability of the wall and its service life may be seriously affected. If there is groundwater on the slope, effective drainage measures must be taken. Weep holes and a slope underdrain shall be made.

6.3.8 The construction of joint pointing shall meet the following requirements:

- 1 The joints in the masonry mortar shall be pointed before the mortar is set. The pointing depth shall not be less than 20 mm.
- 2 For masonry construction, the vertical joints shall be staggered with the vertical joints in adjacent layers. The width of joints (both horizontal and vertical) shall not be more than 40 mm if the wall is built with cement mortar, or 30-70 mm if built with micro-aggregate concrete. The wider joints may be filled with flakey stones. The flakey stones shall be coated with mortar.
- 3 For stone blocks masonry, the width of joints shall not be more than 30 mm. Pointing shall be even and full, aesthetically pleasing, and the completed slope surface shall be smooth.
- 4 After masonry being pointed or grouted, curing shall be made for 7-14 d depending on the cement type and local weather.

6.4 Riverside subgrade protection

6.4.1 Before construction, the embedded depth of the foundation shall be checked. If the depth of foundation is less than 1 m below the local scour line and also not embedded in bedrock, feedback shall be reported immediately and measures shall be taken.

6.4.2 Before constructing diversion structures, measures shall be taken based on the actual situation to prevent farmland, village, highway or downstream subgrade being eroded.

6.4.3 The construction of riverside subgrade protection works with vegetation shall meet the following requirements:

- 1 If the slope of the embankment is often or continuously submerged, subgrade protection with vegetation should not be used.

- 2 Riverside embankment slope protection with vegetation shall be made by following construction methods specified in the design, like flat laying, overlapped laying and other techniques. The layer laid over the toe shall be constructed to the same level as the ground surface.
- 3 Planting trees for protection purpose should be arranged in strips. For protecting riverside subgrade or preventing wave erosion, tree planting should be arranged in strips which are perpendicular to the road line. For protecting road embankments of bridge approaches tree planting should be arranged in strips along the road line.
- 4 Hydrophilic varieties of trees shall be selected. The tree belt shall be made of multiple rows of trees. Trees or shrubs shall be planted close together.
- 5 After the trees are planted, effective measures shall be taken to protect the trees.

6.4.4 Riverside masonry or concrete protection works shall meet the following requirements together with the requirements of Section 6.3 of the *Specifications*:

- 1 When dry-laid or mortar-laid rubble is used, large scale flat paving without interlocking is not allowed. Dry-laid blocks for slope protection shall be staggered and tightly interlocked. Loosely inserting stones into gaps is forbidden.
- 2 For dry-laid or mortar-laid pebbles, the longest dimension of the pebbles shall be perpendicular to the slope surface. Pebbles shall be laid firmly with their second longest dimension being in contact.
- 3 For concrete slabs cast in situ, their surface shall be flat and smooth. Measures to improve early strength may be taken.

6.4.5 The construction of riprap protection shall meet the following requirements:

- 1 Stones for riprap shall be hard, frost and weather-resistant. The size of stone shall be more than 300 mm. It is advised to riprap with mixed different sizes of stone.
- 2 The slope of riprap and size of stone shall be determined based on water depth, flow rate and wave conditions. The slope shall not be steeper than the natural angle of repose of the stone aggregate after being immersed. The slope and stone size for riprap shall satisfy the requirements in Table 6.4.5-1 and Table 6.4.5-2.

Table 6.4.5-1 The relationship between slope of riprap and hydrological conditions

Hydrological conditions	Adopted slope
Water depth not more than 2 m, low flow rate	1:1.2-1:2.5
Water depth 2-6 m, high flow rate, big waves	1:2-1:3
Water depth more than 6 m, constructed on rapid flow	Less than 1:2

Table 6.4.5-2 The relationship between stone size and flow rate

Stone size (mm)	Water depth (m)				
	0.4	1.0	2.0	3.0	5.0
	Allowable flow rate (m/s)				
150	2.70	3.00	3.40	3.70	4.00
200	3.15	3.45	3.90	4.20	4.50
300	3.50	3.95	4.25	4.45	5.00
400	—	4.30	4.45	4.80	5.05
500	—	—	4.85	5.00	5.40

- 3 The thickness of riprap construction be 3-4 times the stone size. Even for stones with a large size, the thickness shall not be less than 2 times the stone size.
- 4 Except for special situations, riprap construction should take place during the low water level season.

6.4.6 The construction of gabion protection shall meet the following requirements:

- 1 Based on design requirements, actual situation or special purposes, the gabion box sizes shall be carefully selected.
- 2 In producing the gabions, the following requirements shall be met:
 - 1) Gabions may be made of heavy-duty galvanized steel wire, galvanized iron wire or normal iron wire. For permanent installations, heavy-duty galvanized steel wire shall be used. For a service life of 8-12 years, galvanized iron wire may be used, and for service life of 3-5 years, normal iron wire may be used.
 - 2) In assembling the gabion boxes, tie wire and spiral fixer shall be made from the same material as the gabions.
 - 3) After the partitioning mesh is placed perpendicular with the longer side of the gabion

box, then the tying process will be started to assemble the gabion box.

4) In assembling the gabion, the combined wire binding shall be double-stranded and be tightened firmly. The spiral fixer shall be fully turned to tie the gabion pieces firmly.

5) The completed gabion boxes shall be placed and seated in their right places.

3 The task of connecting individual gabion boxes shall meet the following requirements:

1) Assembled individual gabion boxes shall be placed in the direction of the longer side of the retaining wall. After their positions are adjusted, each individual gabion box shall be connected in order.

2) Before filling rocks into the gabions, the exposed faces of the gabions shall be tied with steel pipes or steel plates to prevent the displacement of the gabion mesh.

3) The mesh on the exposed part of the cage shall be equipped with tension wires.

4 The stone fillings shall meet the following requirements:

1) Rocks for filling shall be rubble or stone blocks which are hard, do not disintegrate and are insoluble. The particle size should be 100-300 mm. Rocks with a size less than 100 mm shall not constitute more than 15%, and shall not be placed on the exposed faces. The void space shall not be more than 30%.

2) Rocks shall be filled manually or mechanically. Rocks shall be evenly filled in batches to ensure that the gabion box is fully and evenly filled.

3) If gabion boxes in one layer are not completely finished before stoppage, the joints shall be constructed. The difference in filled heights of neighboring boxes shall not be more than 350 mm to prevent lateral deformation of the gabion boxes.

4) Rocks on the exposed face shall be flat and be overlapped with each other.

5) After the gabion box is filled with rocks to the required height, the gabion box shall be closed by its covering mesh.

5 After a layer of gabion boxes reached the correct height the upper layer shall be installed. Different layers of gabion boxes shall be staggered or constructed with a T-type joint, and

the upper and lower layers of gabion boxes shall be connected. No through joint is allowed.

6 The construction standards of gabion boxes shall meet the requirements in Table 6.4.6-1.

Table 6.4.6-1 The construction quality standards for gabion boxes

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Length(mm)	± 30	Tape measure;4 sections for each 50 m
2	Width(mm)	± 30	Tape measure;4 sections for each 50 m
3	Height(mm)	± 30	Tape measure;4 sections for each 50 m
4	Mesh opening(mm)	20	Tape measure;4 sections for each 50 m

7 The construction quality of gabion protection shall comply with the requirements in Table 6.4.6-2.

Table 6.4.6-2 The construction quality standards of gabion protection

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	The deviation of planimetric position(mm)	≤ 300	Total station; checking with the design control coordinates
2	Length(mm)	$\geq \text{Design length}-300$	Tape measure;5 points for each gabion(section)
3	Width(mm)	$\geq \text{Design width}-200$	Tape measure;5 points for each gabion(section)
4	Height(mm)	Not less than design value	Level or tape measure; 5 points for each gabion (section)
5	Bottom elevation(mm)	Not more than design value	Level;5 points for each gabion(section)

Commentary

Wire gabions can withstand a high flow rate erosion current, normally with a flow rate of 4-5 m/s. A large volume can withstand even a flow rate of 5-6 m/s and with a wave height of 1.5-1.8 m. When the current transports a lot of sediments, the voids in the gabion can be filled quickly to form an integrated protection work.

6.4.7 The construction of geomembrane bags protection works shall meet the following requirements:

- 1 The slope shall be levelled as required by the design. Positions for the geomembrane bags shall be set out and boundary channels shall be excavated.
- 2 After geomembrane bags are placed, they shall be tightened and fixed to prevent movement at the time of being filled.
- 3 Filling material shall be identified based on the design requirements and actual field situation. The filling process shall be continuous.
- 4 In case the slope requires drainage and the need for draining out water, holes shall be made at defined positions in the geomembrane bags for installing the weep pipes.
- 5 The top of the geomembrane bags should be protected and should be sealed with mortar rubble. If there is surface runoff, the top shall have protective measures to prevent surface water from running behind the geomembrane bags and cause erosion.
- 6 The foot of the geomembrane bags shall have ballast or a prismatic-formed toe protector. In the places where scouring may occur, anti-scouring measures shall be taken.
- 7 Both flanks of the geomembrane bags should have channels for ballasting the sides of geomembrane bags.
- 8 Between geomembrane bags and the slope surface there shall be a filter layer of geotextile. It shall be placed as required by the design.
- 9 The thickness of the geomembrane bag shall be determined by a stability analysis on float resistance and on freezing force of ice. The main technical indicators shall meet the requirements in Table 6.4.7.

Table 6.4.7 Main technical properties of geomembrane bags

Checking item		Quality criteria
Mass of single layer(g/m ²)		200
Tensile strength(N/50 mm)	Lengthways	1 500
	Widthways	1 300
Ductility(%)	Lengthways	14
	Widthways	12

continued

Checking item		Quality criteria
Mass of single layer(g/m ²)		200
Tearing strength(N/50 mm)	Lengthways	600
	Widthways	400
Burst strength(N)		800
Permeability coefficient(mm/s)		0.28
Thickness of single layer(mm)		0.45

6.4.8 The construction of a spur dike protective work shall meet the following requirements:

- 1 The construction schedule shall be reasonable.
- 2 The head of the spur dike shall be protected as required by the design.
- 3 The root of the spur dike shall be connected with the stratum or other protection works.
- 4 After the spur dike protective work is completed, the flow rate past the river bank or by the slope of the subgrade shall be checked. If the flow rate of the reverse current is higher than the allowable flow rate, feedback shall be provided immediately.
- 5 The construction quality of a spur dike shall meet the requirements in Table 6.4.8.

Table 6.4.8 The construction quality criteria of a spur dike or a longitudinal dike

Number	Checking item		Specified value or allowable deviation	Check method and frequency
1	Mortar strength(MPa)		Being qualified	Checked by following Appendix F of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	The deviation of planimetric position(mm)		30	Total station; checking with the design control coordinates
3	Length(mm)		≥ Design length-100	Ruler; for every dike
4	The dimensions of the cross section(mm)		≥ Design values	Tape measure; 5 cross sections
5	Slope(%)		≤ Design value	Slope scale; 5 points
6	Elevation (mm)	bottom	Not more than design value	Level; 5 points
		top	± 30	

Commentary

When constructing diversion structures, try to avoid restricting too much of the riverbed cross section. Otherwise, the water level will be increased, affecting the safety of the upstream and downstream subgrade, farmland or buildings.

If a spur dike restricts the cross section and thus the water flow, the original nature of the flow is disturbed, especially at the head or beginning of a spur dike which suffers from local erosion or impact from floating objects. Thus the foundation at the head of a spur dike shall be buried deeply and shall also be protected. The protection measures are normally mortar rubble, gabions or other sturdy and durable works.

6.4.9 Constructing the protection work of a longitudinal dike shall comply with the following requirements:

- 1 The water flow shall be smooth at the place where the longitudinal dike connects with the river bank (both upstream and downstream).
- 2 The depth the dike root is buried into the stable riverbank shall meet the design requirements, and the river bank near the dike root shall be reinforced as required by the design to a place upstream till reaching a place where the river bank will not be affected by the water flow.
- 3 The quality of construction shall comply with the requirements in Table 6.4.8.

Commentary

The dike root is the part most affected by the impact of water flow. Special attention needs to be paid to insert the dike root into and connect it with the ground or other protective facilities to ensure the functionality of the dike.

6.4.10 The construction of a river diversion shall comply with the following requirements:

- 1 A river diversion should be constructed during a low water level period. When the diversion cannot be completed in a dry season, flood control measures shall be taken.
- 2 The middle part of the river shall be excavated first, and then the two ends. The upper reach of the new river bed shall be cut-through after confirming that the new river bed meets the requirements.
- 3 When the old river channel is to be filled with the soil/rock excavated from the new river

channel, the old river channel shall keep an appropriate cross section for water flow before the new river is opened.

- 4 The longitudinal slope of the new river in its upper reach, where the water flows into it, should be slightly larger than the designed slope.
- 5 The construction of the riverbed reinforcement facilities and diversion structures shall be reasonably arranged and completed in time.

6.5 Slope anchorage

6.5.1 In the process of slope excavation and drilling bolt holes, the lithology and structure of the rocks shall be recorded and analyzed in detail. Immediate feedback shall be provided in case there are large deviations from the design.

6.5.2 Before construction, the geological conditions shall be checked, loose stones shall be removed from the slope, and holes, depressions and cracks shall be filled with masonry mortar or concrete, but not with sandbags. After the slope is trimmed, it shall be even and dense, without slipping, creeping or loose rocks.

6.5.3 Drilling bolt holes shall comply with the following requirements:

- 1 The setting out for hole positions shall be accurate, and the deviation of the hole axis shall be carefully controlled during the drilling process. The final hole depth shall not be less than the design hole depth.
- 2 In the process of drilling, suitable drilling equipment and methods shall be selected according to different rock and soil conditions. The drilled hole diameter shall meet the design requirements.
- 3 For sand, silt, pebble, organic soil and high plastic clay materials the technique of protective casing for drill holes should be used.
- 4 When the hole is below the groundwater table, it is not appropriate to use dry drilling technology.
- 5 It is not appropriate to use the slurry retention technique to make holes in a layer of saturated clay with a high plasticity index.

- 6 When an unknown obstruction is encountered during the drilling process, drilling shall be suspended to determine the nature of the obstruction.
- 7 After the hole is made, the debris in the hole shall be cleared quickly. In case it is not ready to insert the anchor rod or cable immediately after the hole is made, a temporary seal should be inserted into the hole to avoid water or other debris from entering the hole.
- 8 After the hole is made, the anchor rod shall be inserted and grouting shall be completed at the same time.

6.5.4 The manufacture of an anchor bolt from steel wire strands or from ordinary steel bars shall comply with the following requirements:

- 1 The steel strands shall be parallel to each other and evenly spaced when the anchor bolt is tightened. When the anchor bolt is inserted into the hole, bending or twisting inside the hole shall be avoided.
- 2 When the steel bar for making the anchor bolt is to be connected, the connection should be a mechanical connection, lap connection (both sides welded) and double lap connection (both sides welded). The weld length shall not be less than 5 diameters when welding on both sides is used.
- 3 When manufacturing and placing the anchor bolt, rust and oil shall be removed and bending of the anchor bolt shall be avoided.

6.5.5 Bolt installation shall comply with the following requirements:

- 1 Before construction, the pull-out force verification test shall be carried out according to the design requirements.
- 2 The bolt shall be installed in the center of the hole.
- 3 When installing the anchor bolt in an area with groundwater, the water in the hole shall be removed before installation.
- 4 When the casing wall protection technology is used to make holes, the anchor bolt shall be inserted into the hole before pulling out the casing. When the hole is without casing wall protection, the anchor bolt shall be pushed into the hole at a constant speed.

6.5.6 Grouting shall comply with the following requirements:

- 1 When using cement slurry, the ratio of water to cement should be 0.5-0.55. When cement mortar is used, the water-cement ratio should be 0.4-0.45, and the cement-sand ratio should be 0.5-1.0. Sand should be medium-coarse sand.
- 2 The mortar shall be used immediately after being mixed, and the mortar shall not be used after its initial setting time.
- 3 The anchor bolt should be inserted first and then grouting should be made by using the from-bottom-grouting method. The grouting duct shall be inserted into the hole till 50-100 mm away from the bottom of the hole and gradually pulled out with the cement mortar being grouted. The grouting pressure should not be less than 0.2 MPa.
- 4 The distance between the nozzle of the grouting duct and the bottom of the hole should not be greater than 200 mm. In the process of grouting and pulling out the duct, the nozzle of the grouting duct shall always be buried below the surface of grout, and the grouting shall stop when the cement grout overflows from the hole mouth. When the level of the grout drops after grouting is stopped, additional grout shall be filled from the mouth of hole.
- 5 When the two stage pressure grouting process is used, the pressure at the time that grouting is terminated shall not be less than 1.5 MPa.
- 6 When the length of the anchor bolt is less than 3 m, the construction method of grouting before inserting the anchor bolt may be used.
- 7 After the bolt is installed, it shall not be knocked or shaken. The anchor bolt grouted with ordinary mortar shall not be disturbed within 3 d after grouting.

Commentary

Grouting is an important process in the construction of an anchor bolt, and the quality of grouting directly affects the pulling out strength of the bolt. Therefore, during construction the quality of the grout or other materials, grout properties, workmanship and grouting process shall be strictly controlled.

6.5.7 The construction quality of an anchor bolt shall comply with the requirements in Table 6.5.7.

Table 6.5.7 The criteria for construction quality of an anchor bolt

Number	Checking item		Specified value or allowed deviation	Check method and frequency
1	The strength of grout(MPa)		Being qualified	Checked by following Appendix F or M of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	Depth of drilled hole(mm)		$\geq$ Design value	Tape measure;every hole
3	Diameter of drilled hole(mm)		± 10 (for diameter ≥ 60) ± 5 (for diameter < 60)	Caliper;every hole
4	Hole position(mm)		± 50	Tape measure;every hole
5	Dip angle of hole(°)		≤ 3	Geological compass;every hole
6	Length of bolt(mm)		$\geq$ Design value	Tape measure;every hole
7	The length of part of bolt inserted into hole(mm)	Prestressed	Not less than 97% of design length	Tape measure;every hole
		Non-prestressed	Not less than 98% of design length	Tape measure;every hole
8	Bolt pull out resistance(kN)		Average pulling out resistance $\geq$ design value, Minimum pulling out resistance ≥ 0.9 design value	Pulling out force test;5% of all bolts,but not less than 3

6.5.8 The prefabrication of an anchor cable shall comply with the following requirements;

- 1 A steel strand with mechanical damage, arc burn or serious corrosion shall not be used. Before being processed, the steel strand shall be cleaned and rust removed. Do not place the steel strand and anchor cable directly on the ground or in open storage to avoid getting wetted or corroded.
- 2 The fabrication of an anchor cable should be carried out under the on-site factory roof, and shall be installed at the pace of production to avoid long-term storage.
- 3 The length of the anchor cable shall be determined according to the actual depth of the drilled hole, and the steel strand shall be cut mechanically and shall not be spliced.
- 4 The finished anchor cable shall be numbered according to the design.

6.5.9 Installing an anchor cable shall comply with the following requirements:

- 1 Before construction, the anchoring performance test for the anchor cable shall be carried out according to the design requirements to select the construction technology.
- 2 An anchor cable shall be installed according to the design. The steel strands shall be evenly arranged and straight during installation.
- 3 Before the anchor cable is put into the hole, determine whether the number of the anchor cable is consistent with the hole number.
- 4 The anchor cable shall be placed straight in the center of the borehole.
- 5 The hole shall be grouted immediately after the anchor cable is installed. No heavy objects shall be placed on the end of the anchor cable within 3 days after grouting.

6.5.10 Tensioning shall be carried out in accordance with the design requirements and shall also comply with the following:

- 1 The tensioning equipment shall be calibrated according to specification, and the calibration interval should not exceed 6 months or 200 tensioning activities. After the tensioning equipment is disassembled for repairs or its pressure gauge has received a hard blow, it must be re-calibrated.
- 2 No tensioning shall be carried out until the strength of the grout reaches the allowable tensile strength specified in the design.
- 3 Dual control of the tensile stress and elongation shall be applied for tensioning. When the actual elongation is greater than 10% (and the design tensile stress is not reached) or less than 5% of the design elongation (but the tensile stress is more than the design value), the tensioning shall be stopped and locked.
- 4 If, after the tensioned anchor cable is locked, there is obvious prestress relaxation before grouting, the cause shall be found and the compensation tensioning shall be carried out.

6.5.11 The construction quality of prestressed anchorage for slope protection shall comply with the requirements in Table 6.5.11.

Table 6.5.11 The criteria for construction quality of prestressed anchorage for slope protection

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Anchor cable tensile stress(MPa)	Meet the design requirements	Pressure gauge;every cable
2	Elongation in percent(%)	Meet the design requirements; if not required, ± 6	Tape measure;every cable
3	Number of broken and slipped wires	1 wire in each tendon, and not more than 1% of all the wires in a cross section	Visual inspection;every cable

6.5.12 After grouting is completed, the anchor head shall be sealed for protection or be treated to prevent corrosion according to the design requirements. The seal shall be made of concrete with the same strength as the skeleton structure. Anti-rust measures shall be taken for anchors that will be exposed for a long time.

6.5.13 Skeleton construction shall comply with the following requirements:

- 1 Before construction, the slope shall be trimmed and compacted, and there shall be no sliding, creep or loose rock material.
- 2 When the trench is excavated manually, the height of the exposed part of the skeleton shall be 150 mm. Depressions on the slope shall be filled with soil and compacted during trench excavation. The degree of compaction shall not be less than 90% ,and the surface should be smooth.
- 3 The size, type, spacing of reinforcement bar, its welding strength, and thickness of cover layer shall comply with the design and specification requirements. After the reinforcement bar is fixed, the bend of the rebar for the head of anchor bolt shall be effectively connected to the skeleton rebar, and the concrete shall be cast immediately after passing the inspection. The rebar shall not be exposed over a long time.
- 4 During the concrete pouring process the concrete surface shall be kept smooth, wet and burnished, without dry spots or being liquid. The surface shall be manually screeded and floated. After casting, it shall be covered and cured by watering. The curing time is not less than 7 d.
- 5 An construction joint shall be arranged at a certain distance for the skeleton. The construction joint is arranged along the slope direction. The distance between construction joints should

be 20-25 m, and the width of the construction joint should be 20-30 mm.

6.6 Gravity retaining wall

6.6.1 Excavation of foundation pit shall comply with the following requirements:

- 1 The foundation pit should be excavated section and then after next section in an interval jump sequence. The position of each section should be determined in combination with the position of expansion joints and settlement joints.
- 2 When the bottom of the retaining wall is designed as an inclined surface, its elevation shall be strictly controlled and shall not be over-excavated and then backfilled.
- 3 When the foundation pit is excavated in a soil layer or soft rock that can weather easily and is excavated in the rainy season, the bottom of the pit shall be sealed with concrete immediately after being excavated.

6.6.2 Inspection shall be carried out immediately after the excavation is completed, and the next step in the construction process shall be carried out after passing the inspection.

6.6.3 Foundation construction shall comply with the following requirements:

- 1 Before construction, the bottom of the foundation shall be checked and the weathered rock and soft soil and other debris on the base of the foundation pit shall be removed.
- 2 The mortar masonry for a foundation over hard rock should be laid such that the pit is being fully filled with mortar masonry. The bottom of a stone block shall have sufficient mortar when being laid, and the vertical joint shall be filled with mortar. There shall be no unfilled gaps or vertical joints that are through.
- 3 The process of laying a stepped foundation should be consecutive with the process of laying the wall. The foundation and the step at the toe of the wall shall be made integrally and have no vertical through joints, and any gap between the masonry work and the riser of the step shall be fully filled with mortar.
- 4 The foundation shall be backfilled and compacted in layers immediately after the strength of the mortar reaches 75% of the design strength. The backfilled surface shall have a 3% outward slope.

6.6.4 Wall construction shall comply with the following requirements:

- 1 The blocks for a masonry wall shall be laid staggered. The stagger length shall not be less than one quarter of the length of the block, and there shall be no through vertical joints.
- 2 The rubble and blocks shall be laid with largest face down, and the blocks shall not be in direct contact with each other. The spacing should not be less than 20 mm.
- 3 Concrete walls shall be cast and compacted in horizontal layers. Layer thickness shall not exceed 300 mm.
- 4 Concrete shall be cast continuously. If interrupted, the time shall be less than the initial setting of the previous layer of concrete, otherwise it shall be treated as a construction joint.
- 5 During the casting process, a dedicated person shall check the formwork and support work, and deal with problems immediately.
- 6 The end of the retaining wall that extends into the embankment or is embedded in the cut slope shall be laid at the same time as the wall. The top of the retaining wall shall be leveled with mortar or its joints shall be pointed, and the gap between the wall and the slope shall be filled and compacted with clay or other materials.
- 7 The wall shall be cured for the correct time after completion of construction.

6.6.5 The inner faces of the expansion joints and settlement joints shall be vertical and flush, without overlapping. The waterproof material in the joints shall be constructed according to the design requirements.

6.6.6 The joints between retaining walls, bridge abutment and tunnel portals shall be constructed in a coordinated manner. If necessary, temporary supports may be set up to ensure the stability of the fill or cut connected to the wall.

6.6.7 When the strength of the concrete or mortar of the retaining wall reaches 75% of the design strength, the back of the wall shall be backfilled. Heavy vibratory rollers shall not be used for compaction within 0.5-1.0 m from the back of the wall.

6.6.8 The backfill material for the wall shall comply with the following requirements:

- 1 It is recommended to use materials with good water permeability and high shear strength such as sandy soil, pebbly soil, gravel soil or blocky soil.
- 2 When clay is used as the filler, a drainage layer of sand gravel or other permeable material with a thickness of not less than 300 mm shall be built against the back of the wall. The top of the drainage layer shall be sealed with a clay layer, and the thickness of the clay layer should not be less than 500 mm.
- 3 The filler shall not contain organic matter, ice, grass, tree roots and domestic garbage. Humus, saline soil, mud, chalk, diatomaceous earth, domestic garbage and organic matter shall not be used as wall backfill.

6.6.9 The weep holes in the wall shall be constructed according to the design during the wall construction process and they shall not be blocked.

6.6.10 The construction of a retaining wall that becomes flooded shall comply with the following requirements:

- 1 The stone material used for the submersible retaining wall shall be hard and unweathered which will not disintegrate if soaked in water.
- 2 During the construction process, the connection between the submersible retaining wall and the river bank slope shall be well treated.
- 3 When laying bricks, the joints shall be fully filled with mortar and the pointing shall be dense, so that water erosion of the wall is avoided.

6.6.11 When building retaining walls in areas with broken rock, soft soil or abundant groundwater, it is recommended that construction shall not take place during the rainy season.

Commentary

In the dry season, the water content in rock and soil is low, their strength is high, and the stability of the slope is easy to be guaranteed when the foundation pit is excavated. Therefore, the retaining wall in the area with poor geological conditions or with water is safer to be built in the dry season than in the rainy season.

6.6.12 The construction quality standards of a gravity retaining wall shall comply with the requirements in Tables 6.6.12-1, 6.6.12-2 and 6.6.12-3.

Table 6.6.12-1 The construction quality standards for mortar masonry retaining wall

Number	Checking item		Specified value or allowed deviation	Check method and frequency
1	Mortar strength(MPa)		Being qualified	Checked by following Appendix F of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	Planimetric position(mm)		≤ 50	Total station;measure the outer edge of the top of the wall,5 points for a length not more than 30 m,1 more point for each additional 10 m
3	Slope of wall face(%)		≤ 0.5	Plumb;5 points for length not more than 30 m,1 more point for each additional 10 m
4	Cross-section dimensions(mm)		$\geq$ Design value	Tape measure: 10 cross sections for length not more than 50 m, 1 more cross section for each additional 10 m
5	Top elevation(mm)		± 20	Level;5 points for length not more than 30 m,1 more point for each additional 10 m
6	Base elevation(mm)		± 50	Level;5 points for length not more than 30 m,1 more point for each additional 10 m
7	Surface unevenness (mm)	Precast concrete block, dressed	≤ 10	2 m straight edge and clearance gauge;3 points for each 20 m,both vertical and horizontal directions for each point
		stone block	≤ 20	
		Stone block	≤ 20	
		Rubble	≤ 30	
8	Distance between weep holes(mm)		$\leq$ Design value	Tape measure;4 points for each 20 m

Table 6.6.12-2 The construction quality standards for dry laid retaining wall

Number	Checking item		Specified value or allowed deviation	Check method and frequency
1	Planimetric position(mm)		≤ 50	Total station; outer edge of top of the wall, 5 points for length not more than 30 m, 1 more point for each additional 10 m
2	Verticality or slope(%)		≤ 0.5	Plumb;5 points for length not more than 30 m,1 more point for each additional 10 m
3	Cross-section dimensions(mm)		$\geq$ Design value	Tape measure: 10 cross sections for length not more than 50 m, 1 more cross section for each additional 10 m

continued

Number	Checking item	Specified value or allowed deviation	Check method and frequency
4	Top elevation (mm)	± 50	Level; 5 points for length not more than 30 m, 1 more point for each additional 10 m
5	Base elevation (mm)	± 50	Level; 5 points for length not more than 30 m, 1 more point for each additional 10 m
6	Surface unevenness (mm)	≤ 50	2 m straight edge and clearance gauge; 3 points for each 20 m, both vertical and horizontal directions for each point

Table 6.6.12-3 The construction quality standards for concrete retaining wall

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Concrete strength (MPa)	Being qualified	Checked by following Appendix D of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	Planimetric position (mm)	≤ 50	Total station; outer edge of the top of the wall, 5 points for length not more than 30 m, 1 more point for each additional 10 m
3	Verticality or slope (%)	≤ 0.3	Plumb; 5 points for length not more than 30 m, 1 more point for each additional 10 m
4	Top elevation (mm)	± 20	Tape measure; 10 sections for length not more than 50 m, and 1 more section for each additional 10 m
5	Base elevation (mm)	± 50	Level; 5 points for length not more than 30 m, 1 more point for each additional 10 m
6	Cross-section dimensions (mm)	$\geq$ Design value	2 m straight edge and clearance gauge; 3 points for each 20 m, both vertical and horizontal directions for each point
7	Surface unevenness (mm)	≤ 8	Total station; outer edge of the top of the wall, 5 points for length not more than 30 m, 1 more point for each additional 10 m
8	Distance between weep holes (mm)	$\leq$ Design value	Tape measure; 4 points for each 20 m

6.7 Gabion retaining wall

6.7.1 The foundation soil quality and its bearing capacity shall meet the design requirements.

6.7.2 Gabion fabrication shall comply with the requirements in Clause 6.4.6 of the *Specifications*.

6.7.3 The back of the gabion retaining wall shall be covered with a layer of permeable geotextile.

6.7.4 After each layer of gabion retaining wall is constructed, the back of the wall shall be filled immediately. The level of the fill shall be the same as the top surface of the stone gabion. The backfill behind the wall shall be compacted, and the degree of compaction shall not be less than 95%.

6.7.5 The construction quality for gabion retaining wall shall comply with the requirements in Table 6.7.5.

Table 6.7.5 The construction quality standards for gabion retaining wall

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Planimetric position (mm)	≤ 50	Total station; outer edge of the top of the face, 5 points for length not more than 30 m, 1 more point for each additional 10 m
2	Verticality or slope (%)	≤ 0.5	Plumb; 5 points for length not more than 30 m, 1 more point for each additional 10 m
3	Cross-section dimensions (mm)	$\geq$ Design value	Tape measure; 10 cross sections for length not more than 50 m, 1 more cross section for each additional 10 m
4	Top elevation (mm)	± 50	Level; 5 points for length not more than 30 m, 1 more point for each additional 10 m
5	Base elevation (mm)	± 50	Level; 5 points for length not more than 30 m, 1 more point for each additional 10 m
6	Surface unevenness (mm)	≤ 50	2 m straight edge and clearance gauge; 3 points for each 20 m, both vertical and horizontal directions for each point

6.8 Cantilever and counterfort retaining walls

6.8.1 The excavation of the foundation pit shall be carried out in order, section by section, layer by layer from top to bottom. Temporary drainage facilities shall be made during excavation, and drainage shall be done at any time to ensure that the working surface is dry and the bottom is not immersed. The retaining wall shall be constructed immediately after the pit is excavated and foundation pit shall not be left without work for a long time.

6.8.2 The mortice and tenon part shall be excavated at the same time as the foundation pit and shall be cast together with the bottom slab.

6.8.3 When the assembly method is used for construction, the foundation part shall be cast integrally in a single process, and the embedded steel bars shall be in place. Prefabricated wall panels shall not be installed until the foundation concrete reaches 75% of the design strength.

6.8.4 Curing shall be applied immediately after concrete is cast, and the curing time should not be less than 7 d.

6.8.5 Backfilling of the wall shall be carried out after the wall concrete reaches 75% of the design strength and shall be placed in layers and compacted. The backfilling of a counterfort retaining wall shall be carried out in the order of the toe first and the heel next.

6.8.6 The construction quality of a cast-in-place cantilever and counterfort type retaining wall as well as a retaining wall made with the assembly method shall comply with the requirements in Tables 6.8.6-1 and 6.8.6-2 respectively.

Table 6.8.6-1 The construction quality standards of cast-in-place cantilever type and counterfort type retaining wall

Number	Checking item	Specified value and allowed deviation	Check method and frequency
1	Concrete strength (MPa)	Being qualified	Checked by following Appendix D of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	Mortar strength (MPa)	Being qualified	Checked by following Appendix F of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)

continued

Number	Checking item	Specified value and allowed deviation	Check method and frequency
3	Planimetric position(mm)	≤ 30	Total station; 5 points for length not more than 30 m, 1 more point for each additional 10 m
4	Verticality or slope(%)	≤ 0.3	Plumb; 5 points for length not more than 30 m, 1 more point for each additional 10 m
5	Cross-section dimensions(mm)	$\geq$ Design value	Tape measure; 10 cross sections and 10 counterforts for length not more than 50 m, 1 more cross section and 1 more counterfort for each additional 10 m
6	Top elevation(mm)	± 20	Level; 5 points for length not more than 30 m, 1 more point for each additional 10 m
7	Base elevation(mm)	± 30	Level; 5 points for length not more than 30 m, 1 more point for each additional 10 m
8	Surface unevenness(mm)	≤ 8	2 m straight edge and clearance gauge; 3 test points for every 20 m, both vertically and horizontally for each test point
9	Distance between weep holes(mm)	$\leq$ Design value	Tape measure; 4 points for each 20 m

Table 6.8.6-2 The quality standards for assembly construction method

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Concrete strength(MPa)	Being qualified	Checked by following Appendix D of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	Verticality or slope(%)	≤ 0.3	Plumb; 5 points for length not more than 30 m, 1 more point for each additional 10 m
3	Top elevation(mm)	± 20	Level; 5 points for length not more than 30 m, 1 more point for each additional 10 m
4	Height difference between two neighboring panels(mm)	8	Tape measure; 5 points for length not more than 30 m, 1 more point for each additional 10 m

continued

Number	Checking item	Specified value or allowed deviation	Check method and frequency
5	Cross-section dimensions(mm)	$\geq$ Design value	Tape measure: 10 cross sections and 10 counterforts for length not more than 50 m, 1 more cross section and 1 more counterfort for each additional 10 m

6.8.7 The construction quality of prefabrication and installation of wall panels shall comply with the requirements in Table 6.8.7.

Table 6.8.7 The construction quality standards for prefabrication and installation of wall panels

Number	Checking item		Specified value or allowed deviation	Check method and frequency
1	Concrete strength(MPa)		Being qualified	Checked by following Appendix D of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTGF80/1)
2	Side length (mm)	Side length less than 1 m	± 5	Tape measure; one check for both length and width, 10% of total panels to be checked randomly
		Others	0.5% of side length	
3	Difference between two diagonals (mm)	Side length less than 1 m	≤ 10	Tape measure; two diagonals, each panel
		Others	0.7% of the greater diagonal	
4	Thickness (mm)		+5, -3	Tape measure; 4 points for each panel, 10% of total panels to be checked randomly
5	Surface unevenness(mm)		≤ 5	2 m straight edge and clearance gauge; one check for each panel, 10% of total panels to be checked randomly
6	Position of embedded bar(mm)		≤ 5	Tape measure; 10% of bars, random check
7	Top elevation of panel of each layer(mm)		± 10	Level; 5 panel sets to be randomly checked for each 20 m

continued

Number	Checking item	Specified value or allowed deviation	Check method and frequency
8	Axial deviation (mm)	≤ 10	Tightened line , ruler ; 5 points for each 20 m
9	Verticality or slope of panel (%)	+ 0 , - 0.5	Plumb or slope scale ; 5 points for each 20 m
10	Faulting of neighboring panels (mm)	≤ 5	Tape measure ; 5 points at connecting places of panels for each 20 m
11	Joint width between panels (mm)	≤ 10	Tape measure ; 5 points for each 20 m

Note : two neighboring panels installed on the same layer is defined as a panel set.

6.9 Anchor bolt retaining wall

6.9.1 During construction , a drilling rig suitable for the stratum and rock characteristics of the construction site and capable of drilling obliquely shall be used. A drill bit shall be selected according to the rock properties.

Commentary

For a soldier beam anchored retaining wall a drilling rig is usually used to drill holes. For hard rock , a steel alloy or emery bit may be used for coring ; for soft rock , a conical four-wing steel alloy bit may be used for full cutting and drilling.

6.9.2 The diameter of the anchor hole shall meet the design requirements , and the hole wall should be roughened.

6.9.3 The construction of the retaining panel and anchor bolt shall be carried out at the same pace from bottom to top and layer by layer. The joints between installed retaining panels shall be uniform , and the width of the joints should be less than 10 mm. The net distance between the panels of two adjacent spans meeting at the same soldier beam should not be less than 30 mm , and the joint between them shall be treated as a construction joint.

6.9.4 When installing the retaining panel , it shall be prevented from colliding with the soldier beam to avoid corner damage or cracks.

6.9.5 The drainage facilities and filter layer behind the retaining panel shall be installed at the same pace as the retaining panel.

6.9.6 The construction quality of the anchor bolt shall comply with the requirements of Section 6.5 of the *Specifications*.

6.9.7 The construction quality of the anchored retaining wall shall comply with the requirements in Table 6.9.7.

Table 6.9.7 The overall construction quality standards of the anchored retaining wall

Number	Checking item		Specified value or allowed deviation	Check method and frequency
1	The planimetric position of the top face of the wall and soldier beam (mm)	Embankment wall	+50, -100	Total station; 5 points for length not more than 30 m, 1 additional point for an increase in 5 m
		Soldier wall	±50	
2	The elevations of the top of the wall and top of the soldier beam (mm)	Embankment wall	±50	Level; 5 points for length not more than 30 m, 1 additional point for an increase in 5 m
		Shoulder wall	±30	
3	The distance between soldier beams (mm)		±15	Tape measure; each distance between soldier beams
4	Slope of wall face (mm)		+0.5% H but not more than +50, -1% H but not less than -100	Plumb or slope scale; 5 points for length not more than 30 m, 1 additional point for an increase in 5 m
5	The joint width between retaining panels (mm)		≤10	Tape measure; at least 5 joints for each 20 m
6	Wall face unevenness (mm)		≤15	2 m straight edge; 3 points for each 20 m, both vertical and longitudinal directions for each point
7	The degree of compaction of the backfilled soil within 1 m away from the panel (%)		≥90	1 point for each layer in each 50 m, and not less than 1 point in total

Number	Checking item	Specified value or allowed deviation	Check method and frequency
8	The thickness of the filter layer(mm)	$\geq$ Design thickness	Tape measure; 5 points for length not more than 50 m, 1 additional point for an increase in 10 m

6.10 Retaining wall with anchor plate

6.10.1 Screw rod, anchor head and other steel items shall be treated with anti-rust and waterproofing.

6.10.2 An anchor plate shall be a reinforced concrete plate, with an area not less than 0.5 m^2 for a retaining wall with a soldier beam, and not less than 0.2 m^2 without soldier beam.

6.10.3 Installing soldier beams shall conform to their design positions and inclinations. When installing the anchor plates, the plates shall be vertical and at the same elevation.

Commentary

The anchor plates are placed at the same elevation in order to let the tie rods withstand tension along the same straight line and prevent the tie rods from twisting.

6.10.4 The anchor plate shall be constructed by the ‘reverse trench excavation method’, with soil being filled and leveled first and then the trench is excavated. For excavation, the anchor plates should be placed 30-50 mm higher than their design positions.

6.10.5 The fill into the trench and over the anchor plate shall be compacted simultaneously, and the tie rod and anchor plate shall not be compacted by direct contact with the roller.

6.10.6 The bench (of a bench retaining wall) shall be sealed according to the design requirements, and shall have a 2% outward drainage slope.

6.10.7 The construction quality of a retaining wall with anchor plate shall comply with the requirements in Table 6.9.7.

6.11 Reinforced soil retaining wall

6.11.1 Before the construction of the reinforced soil retaining wall, its foundation treatment shall

be carried out according to the design requirements. When there is groundwater affecting the stability of the foundation, it shall be intercepted or drained away from the wall.

6.11.2 The reinforcement for the retaining wall shall be made of materials with high tensile strength, low elongation and low creep, good aging resistance, good corrosion resistance and good chemical stability, and its surface shall have sufficient roughness. The steel reinforcement shall be treated to prevent corrosion according to the design. The construction quality of the reinforcement strip shall comply with Table 6.11.2.

Table 6.11.2 The construction quality standards of reinforcement strip

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Length of strip	Not less than the design value	Tape measure; 5 strips for each 20 m
2	The connection between the strip and face panel	Satisfying the design requirements	Visual inspection; 5 points for each 20 m
3	The connection between the strips	Satisfying the design requirements	Visual inspection; 5 points for each 20 m
4	Placement of the strip	Satisfying the design requirements	Visual inspection; 5 points for each 20 m

6.11.3 The construction of a reinforced soil retaining wall shall comply with the following requirements:

- 1 The fill material in the anchorage section behind the wall should be sand soil or gravel soil with a specific gradation and good permeability. The coarse particles in the soil shall not contain particles with sharp points that may damage the reinforcement during the compaction process.
- 2 The reinforcement shall be laid horizontally in its design position on the soil layer that has been leveled and compacted. The single reinforcement shall be perpendicular to the panel, and the multiple reinforcement shall be laid in a fan-shape according to the design. The polypropylene geosynthetic strip shall be laid smoothly, not folded, distorted and not directly in contact with hard, angular fill. Other requirements shall meet the relevant provisions of the current *Technical Specification for the Application of Geosynthetics in Highway* (JTG/T D32).
- 3 The installation of the wall panel shall be with a proper inward inclination according to the height and fill material, and the slope should be 1:0.02-1:0.05. The installed panel shall not tilt outwards.

- 4 The connection between the strip and the panel shall be firm, and the strength of the connection shall not be lower than the strength of the strip. When the strip runs through the entire subgrade, it is advised to use a single strip to pull the panels together on both sides.
- 5 The spreading and rolling of the fill shall be parallel to the wall starting from the middle of the strip, and shall not be parallel to the direction of the strip. It shall be gradually spread and compacted towards the tail of the strip first, and then towards the wall.
- 6 The thickness of each subgrade layer and the number of roller passes for each layer shall be determined by testing according to the spacing of the reinforcement, roller and required degree of compaction. A sheep foot roller shall not be used. Within 1 m from the wall panel, small compactors or manual ramming shall be used; heavy compaction equipment shall not be used. Vehicles shall not travel over uncompacted fill.
- 7 During the construction process the deformation of the wall shall be carefully monitored, and any abnormal changes shall be dealt with immediately.

6.11.4 The construction quality of a reinforced soil retaining wall shall comply with the requirements in Table 6.9.7 of the *Specifications*.

6.12 Anti-slide pile

6.12.1 Before the construction of an anti-slide pile, the engineering geological data shall be known in detail, and the following preparation shall be made:

- 1 Before construction, measures such as reducing the sliding load, adding a counter pressure load or drainage shall be taken to keep the landslide mass basically stable. It is strictly forbidden to carry out anti-slide pile construction during the rapid deformation stage of a landslide body.
- 2 During construction, the preventive reinforcement measures shall be considered according to the actual geological conditions.
- 3 The ground surface around the hole mouth shall be levelled, and surface water interception, drainage and anti-seepage facilities shall be installed.
- 4 Monitoring points for landslide deformation and movement shall be installed and continuous

observation shall be carried out.

- 5 During construction in the rainy season, an awning shall be built over the hole mouth. A circular retaining wall at the hole mouth shall be made, and a soil barrier with an appropriate height shall be built on the ground around the hole mouth.

6.12.2 Excavation and support shall comply with the following requirements:

- 1 Adjacent piles shall not be excavated at the same time. The pile group shall be excavated from both ends towards the axis of the landslide at intervals. Adjacent piles may be excavated only after the strength of the pile reaches 75% of the design strength.
- 2 Excavation shall be carried out in sections. The sections should not be too long, and each section should be 0.5-1.0 m. Sections shall not be divided where the soil or rock layer changes or where there is a sliding surface.
- 3 Each section shall be excavated and supported. Loose stones and soil on the hole wall shall be removed before casting concrete. When the surrounding rock is soft, broken or where there is water, weep holes should be built in the protective wall.
- 4 The excavation shall be carried out after the final setting of the concrete in the previous section. The formwork of the concrete may only be removed after the strength of the concrete reaches the level that the structure of the protective wall can stand without deformation.
- 5 In a section which has soft and broken surrounding rocks or has a sliding surface, temporary supports crossing the hole against the protective wall shall be built up in the sliding direction to strengthen the protection. Observation of its stress condition shall be monitored to be able to further strengthen in time.
- 6 During excavation, adequate measures such as lighting and drainage shall be in place to ensure construction safety.
- 7 Excavated spoils shall not be placed within the immediate landslide area.

6.12.3 During the process of excavating the pile hole, the sliding surface shall be monitored all the time. The lithology data shall be recorded continuously, and when the actual situation is inconsistent with the design, the information shall be reported.

6.12.4 Concrete construction for a pile body shall comply with the following requirements:

- 1 Before casting, the cross-sectional clearance shall be checked and the protective concrete wall shall be cleaned.
- 2 The lap joint of the steel cage shall not be placed at the soil-rock dividing surface or the sliding surface. The thickness of the bar covering layer shall meet the design requirements.
- 3 Casting shall be carried out continuously without interruption.

6.12.5 The retaining structure between piles, the soil retaining and drainage facilities adjacent to piles shall be correctly connected with the anti-slide piles and they shall be completed at the same time.

6.12.6 A pile-and-panel type anti-sliding retaining wall shall comply with the following requirements:

- 1 The retaining panel shall be installed after the concrete of the pile reaches the design strength. When installing the panel, backfill shall be added at the same pace. The drainage facilities behind the panel shall be well constructed.
- 2 When a soil nailing wall or shotcrete anchor is used between piles, the soil between the piles shall be excavated and the trench be protected in layers.
- 3 The degree of compaction of the backfill behind the wall shall be strictly controlled, and the anchor cable shall be protected during compaction.

6.12.7 During the construction process, the groundwater level and the displacement and deformation of the landslide mass shall be monitored.

6.12.8 The construction quality of anti-slide piles shall conform to the requirements in Table 6.12.8.

Table 6.12.8 The construction quality standards of anti-slip piles

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Concrete strength(MPa)	Being qualified	Checked by following Appendix D of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)

continued

Number	Checking item		Specified value or allowed deviation	Check method and frequency
2	Pile length(m)		$\geq$ Design value	Measuring string;every pile
3	Diameter or cross-section dimensions(mm)		$\geq$ Design value	Bore hole inspector or tape measure;every pile
4	Pile position(mm)		+ 100	Total station;every pile
5	Verticality (mm)	Bored pile	1% pile length, but not more than 500	Verticality detector or plumb;every pile
		Dug pile	0.5% pile length, but not more than 200	Plumb;every pile
6	Bottom elevation of steel cage(mm)		± 50	Level; every pile, calculated from measured top elevation of steel cage

6.12.9 Slope drainage shall be reinforced and drainage pipes shall be cleared regularly to prevent underground water from accumulating inside the slope.

6.12.10 If there are multiple rows of anchor cables that are attached on the top of the anchor pile, the soil behind the pile of the lower layer shall be excavated after the previous row of anchor cables is constructed.

6.12.11 The construction quality of a prestressed anchor cable anti-slide pile shall comply with the requirements in Section 6.5 of the *Specifications*.

6.12.12 The installation of sonic logging pipes in anti-slide piles shall meet the following requirements:

- 1 The sonic logging pipes shall be welded or tied to be fixed on the inner side of the steel cage, and the pipes shall be parallel.
- 2 The sonic logging pipes shall be installed in sections together with the steel cage. The joint shall be firm, and the two ends of the pipe socket shall be wrapped and sealed with rubberized fabric.
- 3 When the steel cage is put into the pile hole, the pipes shall be upright, the pipe wall shall be straight without deformation, and shall be clear without foreign matter inside.

6.13 Soil nailing protection

6.13.1 If during excavation and drilling, changes in geology and soil/rock displacements shall be observed at any time measures shall be taken if abnormalities are found.

6.13.2 For surface drainage, an interception ditch should be excavated to within 3-5 m from the top of side slope. Drainage pipes should be installed inside the slope body. Temporary drainage ditches and water collection wells shall be installed at places with an appropriate distance from the slope foot of each excavated layer. Temporary drainage facilities shall be built by taking account of permanent drainage facilities.

Commentary

The drainage system for soil nailing protection works is of great significance to the quality, stability and service life of the works, so special attention shall be paid to the action and effect of water in the construction process. The drainage system shall be arranged on the surface of and inside the protected slope during construction to drain away the surface water and groundwater.

6.13.3 Slope excavation shall be carried out in stages. Each stage shall be protected after excavation. The depth and length of each excavation stage shall not be greater than the design value.

6.13.4 Soil nail construction shall comply with the following requirements:

- 1 Before construction an in-situ pull-out strength verification test of the soil nail shall be carried out.
- 2 After drilling is completed, the residual mud, debris and other foreign material in the hole shall be removed.
- 3 The soil nail and air escape pipe for grouting shall be inserted into the borehole at the same time, and the grout shall be fully filled.
- 4 Shotcrete shall comply with the relevant requirements of Clause 6.3.2 of the *Specifications*.

6.13.5 Construction of ground beams and grid beams shall comply with the following requirements:

1 The rebar of the soil nail and the rebar of the grid beam shall be firmly connected.

2 Ground beams and grid beams shall be completely cured.

6.13.6 The construction quality of soil nail protection works shall comply with the requirements in Table 6.13.6.

Table 6.13.6 The construction quality standards of soil nail protection

Number	Checking Item	Specified value or allowed deviation	Check method and frequency
1	Grout strength (MPa)	Being qualified	Mortar, checked by following Appendix F, others by Appendix M of the current <i>Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering</i> (JTG F80/1)
2	The length of borehole (mm)	+200, -50	Tape measure; 10% random check
3	The inclination angle (°)	2	Inclinometer; 10% random check
4	Distance between boreholes (mm)	±100	Tape measure; 10% random check
5	Diameter of borehole (mm)	+20, -5	Tape measure; 10% random check
6	Pull-out strength	Average value $\geq$ design value, the number of nails with strength less than the design value $< 20\%$, minimum pull-out strength $\geq 90\%$ design value	Pull-out test; 1% of total nails, but not less than 3

6.14 Slope netting (for slope stabilization)

6.14.1 The construction of an active protection system shall be carried out according to the sequence of drilling, installing anchor rods, installing vertical and horizontal support ropes, installing nets, and net panel connection, and shall comply with the following requirements:

1 The hole position for the anchor rod shall be accurate, and more rods shall be added in the depressed parts of slope to ensure that the protective net is attached firmly to the slope.

- 2 In case there are a few holes that cannot be drilled due to loose or broken rocks, the loose parts shall be removed and repaired with concrete with a strength not less than C15.
- 3 The vertical and horizontal support ropes shall be connected and fixed to the collar on the exposed head of the anchor rod one by one, and shall be tightened after installation to attach it firmly to the slope.
- 4 Installing the nets shall be carried out from top to bottom, and shall meet the requirements on overlap width and connection between the nets. When the flexible protective net has two layers, the smaller aperture net shall be installed first, and the larger aperture net shall be installed next.
- 5 The connection shall be carried out from top to bottom, and the connection shall be firm, with the connecting rope being fixed to the net wire.
- 6 After installation it shall be confirmed that the steel wire mesh is tightly attached to the mountain face. In case there are large detachments between mesh and rock mass, more anchor rods shall be added in such areas.

6.14.2 The construction quality of the support rope installation and mesh panel installation shall comply with the requirements in Table 6.14.2-1 and Table 6.14.2-2 respectively.

Table 6.14.2-1 The construction quality standards for netting support rope installation

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Rope diameter(mm)	Satisfying design requirements	Randomly check 6 points for each 900 m ²
2	Rope fastening form	Satisfying design requirements	Randomly check 6 points for each 900 m ²
3	Rope tensioning	Satisfying design requirements	Randomly check 6 points for each 900 m ²
4	Rope clamps(number)	Satisfying design requirements	Randomly check 6 points for each 900 m ²

Table 6.14.2-2 The construction quality standards for mesh panel installation

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Connecting rope winding form	Satisfying design requirements	Randomly check 6 points for each 900 m ²
2	Connecting rope fixing	Satisfying design requirements	Randomly check 6 points for each 900 m ²
3	Connecting rope tensioning	Satisfying design requirements	Randomly check 6 points for each 900 m ²
4	Mesh panel lap width	Satisfying design requirements	Randomly check 6 points for each 900 m ²
5	Tying number of mesh panel and rope(number/m ²)	≥4	Randomly check 6 points for each 900 m ²

6.14.3 A passive protection system shall be built in the sequence of construction of foundation anchor bolts, installation of steel posts and anchor rods, installation of support ropes and accessories, and installation of nets, and shall comply the following requirements:

- 1 Steel shall be treated with corrosion protection.
- 2 Steel post and anchor rod foundations shall be set out accurately.
- 3 The position and angle of steel posts shall comply with the design requirements.
- 4 After the support rope is installed, it shall be fixed by clamps and other accessories. The lateral tie cable shall be installed after the upper support rope is installed. The lower support rope shall be attached to the ground without a gap.
- 5 After the flexible net is installed, it shall be fixed with the connecting rope. The lower side of the net shall be attached to the ground without a gap.

6.14.4 The construction quality of steel post foundation, steel post and footing installation, tie cable installation and support rope installation shall comply with the requirements in Table 6.14.4-1, Table 6.14.4-2, Table 6.14.4-3 and Table 6.14.4-4 respectively.

Table 6.14.4-1 The construction quality standards for steel post foundation

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Concrete strength (MPa)	Being qualified	2 sets of samples per working day
2	Footing spacing (mm)	Satisfy design requirements	Tape measure; 1 check for each span
3	Plan view sizes (mm)	$\geq$ Design value	Tape measure; 1 check for each foundation (both length and width)
4	Pit depth (mm)	$\geq$ Design value	Tape measure; 1 check for each side
5	Axial deviation (°)	≤ 15	Protractor; 1 check for each foundation
6	Deviation of embedded parts (mm)	≤ 100	Tape measure; 2 checks for each footing, (both in length and in width)

Table 6.14.4-2 The construction quality standards for steel post and footing installation

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Steel post inclination angle (°)	≤ 5	Protractor; 1 check for each post
2	Footing axial deviation (°)	≤ 15	Protractor; 1 check for each foundation
3	Deviation of embedded parts (mm)	≤ 100	Tape measure; 2 checks for each footing, (both in length and in width)

Table 6.14.4-3 The construction quality standards for tie cable installation

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	The diameter of tie cable (mm)	Satisfying design requirements	One point for every tie cable
2	Tie cable fastening position	Satisfying design requirements	Check every fastening
3	Number of pressure relief rings (number)	Satisfying design requirements	Check every ring
4	Number of clamps of tie cable (number)	Satisfying design requirements	Check every clamp

Table 6.14.4-4 The construction quality standards for support rope installation

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Diameter of support rope (mm)	Satisfying design requirements	Tape measure; 1 point for each rope
2	Sagging of support rope	$\leq 3\%$ span	Tape measure; 1 point for each span
3	Number of pressure relief rings (number)	Satisfying design requirements	Check every span
4	Number of support rope clamps (number)	Satisfying design requirements	Randomly check 6 points for each 900 m ²

7 Special Subgrade Construction

7.1 General

7.1.1 Before constructing a subgrade in special areas, basic tests shall be carried out to check geological data, treatment scope and parameters required by the designer, and special construction plans shall be made.

7.1.2 If during construction the geological conditions do not conform to the design or the design treatment plan cannot be implemented for some reason, prompt feedback shall be provided.

7.1.3 Dynamic monitoring should be carried out for special subgrade construction.

7.1.4 The construction of a special subgrade shall not only comply with the requirements of this section, but also comply with the relevant requirements of Section 4 of the *Specifications*.

7.2 Subgrade over potential landslide area

7.2.1 Landslide treatment shall comply with the following requirements:

- 1 Before construction, the topography, geology, nature, cause and scale of the landslide area shall be checked. A special construction plan and emergency plan for the landslide area shall be prepared.
- 2 Before implementing landslide treatment measures, it is strictly prohibited to reduce the load in the resistance section or to add a load in the sliding area.
- 3 Landslide treatment should not be carried out during the rainy season.

- 4 During construction, stability monitoring and geological recording shall be made, and actual geological conditions shall be recorded. If the geological situation is inconsistent with the design, or signs of a landslide or other abnormal conditions are found, the information shall be reported and resolved immediately. Emergency measures shall be implemented immediately when a landslide occurs.
- 5 Other works and facilities in the affected landslide area shall be protected during the construction of the landslide treatment.
- 6 During and after a rainfall, the inspection around the landslide area shall be intensified.

Commentary

Landslide treatment measures include slide mitigation and slide resistance measures. Removing material to reduce weight of the sliding body is a slide mitigation measure, and adding counter load is a slide resisting measure.

7.2.2 Measures such as water interception, drainage, load reduction, counter loading and retaining shall be considered as landslide treatment. The treatment measures may be used individually or in combination. For landslide treatment, water interception and drainage facilities shall be applied first, and the construction sequence of load reduction, counter loading and retaining measures shall be determined according to the specific conditions at the landslide.

7.2.3 Water interception and drainage works shall comply with the following requirements:

- 1 Impermeable circular interception ditches and drainage ditches shall be constructed on the stable slope body behind the landslide body.
- 2 The cracks and fissures on the landslide body shall be sealed by grouting, or by excavation and then backfilled and compacted. The depressions and loose areas of the landslide body shall be leveled and compacted.
- 3 When the landslide area is large, a temporary or permanent impermeable drainage ditch shall be constructed on the landslide slope.
- 4 When there is groundwater, a water interception ditch shall be constructed. When the filter material is gravel, the gravel particle size shall meet the requirements and the mud content shall be less than 3%.

7.2.4 Cutting slope and load reduction construction shall comply with the following requirements:

- 1 Cutting shall be constructed from the top to bottom and in benches. Blasting is strictly prohibited.
- 2 The cutting slope shall not be over-excavated. If there are cracks on the excavation surface, they shall be sealed by grouting or backfilled and compacted.
- 3 The retaining and drainage works shall be constructed on each bench separately. They should be constructed after the excavation for this bench is completed.

7.2.5 Counter load construction shall comply with the following requirements:

- 1 The counter load shall be added ahead of the sliding body and in the slide resistance area.
- 2 The counter load material shall not block the groundwater opening, and the underground drainage facilities shall be completed before the counter load is filled and compacted.
- 3 Measures shall be taken to keep the affected natural river flow remains unblocked.

7.2.6 The construction of anti-slide retaining works shall comply with the following requirements:

- 1 The construction of anti-slide retaining works shall comply with the relevant requirements of Section 6 of the *Specifications*.
- 2 The construction shall be carried out when the landslide body is in a relatively stable state. When the slope has signs of sliding or has already slid, measures such as counter load shall be undertaken.
- 3 When an anti-slide pile and retaining wall are jointly used to support the slope, the anti-slide pile shall be installed first. If behind the retaining wall, there are supporting underdrains or other drainage facilities, they shall be constructed first.
- 4 The construction of anti-slide piles and anchor cables shall be carried out from both ends to the axis of the landslide.
- 5 When using reinforcing measures such as micro steel pipe pile or mountain slope grouting or when grouting is used as a complementary measure for other treatment schemes, appropriate hole forming equipment and grouting methods shall be adopted.

- 6 The base of the any retaining structure shall be located below the sliding surface and shall be embedded in stable strata.

Commentary

Anti-slide retaining structures include anti-slide retaining wall, anti-slide pile, pre-stressed anchor cable anti-slide pile, grouted anchor rod, pre-stressed anchor cable and open cut tunnel. Micro-pile, mountain slope grouting and other measures may control small and medium-sized soil landslides.

7.2.7 The subgrade construction in the landslide section shall be carried out after the completion of the retaining works. The excavation works may be carried out in combination with load reduction measures, and the filling works may be carried out in combination with adding counter load measures. The drainage or protection works for the subgrade shall be constructed in advance.

7.2.8 The stability of the mountain slope and side slope shall be monitored in large landslide areas. The layout of monitoring points or networks, monitoring content and monitoring accuracy shall comply with the relevant requirements of the current *Standard for engineering surveying* (GB 50026). Long-term monitoring should be carried out after completion of the construction.

7.3 Subgrade construction over rockslide and rock pile areas

7.3.1 Before construction, the topography, landform and geological conditions of the rockslide section shall be checked. The type, extent and hazard degree of dangerous rocks and rockslides shall be identified. The composition, type, distribution range, origin and cause of formation of the rock pile shall be determined. The stability of the collapsible body and rockpile shall be analyzed, the feasibility of the design treatment plan shall be checked and a special construction plan shall be prepared.

Commentary

A landslide is the collapse, toppling or falling rock under the action of gravity from a high and steep slope. Rockpile refers to the loosely accumulated body which is transported by gravity to the foot of the slope or where slope becomes gentler.

7.3.2 During construction, water interception, drainage and seepage control facilities for infiltrated water and groundwater in the collapsible and rockpile areas shall be provided.

7.3.3 Continuous monitoring and inspection shall be carried out during subgrade construction in a rockpile area. When backfilling the subgrade, vibratory rollers should not be used.

7.3.4 The following measures shall be taken to deal with dangerous rock collapses:

- 1 A single dangerous rock shall be treated according to topography and rock formation. When the ground slope is steeper than 1:1.5, single boulders shall be treated.
- 2 Slope protection should be carried out for side slopes or natural slopes with sporadic rock falls.
- 3 When the collapsible dangerous rock body is small, measures such as removal, support, netting with shotcrete and anchor, and flexible protection may be applied. Alternatively, rock retaining walls and rock catching ditches may be used and other interception measures can be taken. Rock interception measures such as rock retaining walls and rock catching ditches should be used together. Depending on the terrain, a buffer layer shall be placed behind the rock retaining wall.
- 4 A dangerous rock mass which is a hazard to the subgrade shall be cleared or measures such as retaining and prestressed anchorage shall be taken. It is not suitable to cut a high and steep slope where exists crushed zones or developed joints.
- 5 When the collapsible body is large, falling rock may occur frequently as it is close to the road and it is difficult to set up the interception structures, open cut tunnels and shed tunnels or other shielding structures shall be used according to the design requirements, and the roof of the tunnel shall have a buffer layer.

7.3.5 For the subgrade in a section where the rockpile is developing, excavation shall be reduced, and protective measures such as retaining wall and slope sealing shall be taken according to the design requirements, and a rock retaining wall, rock catching ditch, open cut tunnel, shed tunnel and other shielding structures may be constructed.

7.3.6 The following treatment measures should be taken for the subgrade through an area where the rock pile is stable:

- 1 When the subgrade is through the upper part of the rock pile, it is recommended to remove the rock pile deposits along the bedrock surface.
- 2 When subgrade is through the middle part of the rock pile, retaining walls and other retaining structures should be constructed in the cut slope according to the design requirements.
- 3 When the embankment is constructed over the rock pile, it is advisable to remove the

surface deposits and excavate benches. The filling rate should be controlled and stability observation should be carried out.

7.3.7 For a large and unstable rock pile combined treatment measures shall be adopted according to design requirements. Works such as anti-slide retaining wall or anti-slide pile shall be constructed first, and then the benched slope shall be made or a facing wall shall be built. Finally, cement mortar shall be injected into the rock pile section by section.

7.4 Subgrade over debris flow areas

7.4.1 Before construction, the origin, scale, characteristics, movement patterns and degree of hazard of the debris flow shall be investigated in detail in conjunction with the design. The formation zone, transport zone and accumulation zone of debris flow shall be checked, and a special construction plan shall be prepared.

7.4.2 For subgrade construction in debris flow areas, measures shall be taken to strengthen monitoring, and any abnormal situation shall be handled timeously to ensure construction safety.

7.4.3 When a bridge is used to cross the debris flow area, the protective reinforcement facilities shall be completed in a timely manner according to the design requirements.

7.4.4 When drainage channels, open cut tunnels, culverts, aqueducts and other structures with drainage functions are used, and their main functions are discharging and regulating debris flow, they shall comply with the following provisions:

- 1 The foundation of the structure shall be firm, and its strength, cross-section and height shall meet the design requirements.
- 2 The plane alignment of the structure shall be a smooth and gradual curve. Its upstream and downstream shall have a sufficiently long transition. The channel of the flow traveling section should not be too restricted, and the discharging outlet should not be suddenly widened. The turning angle at the place where flow changes direction should not exceed 15° to avoid sediment deposit caused by sudden contraction and expansion of sharp bends.
- 3 The longitudinal slope of the flow section and discharging outlet section (of the structure) shall meet the design requirements or be greater than the sediment equilibrium gradient of the channel.

7.4.5 When mortar rubble masonry is used for a permanent regulating structure, hard rubble that can resist weathering shall be used, and the foundation shall be placed at the depth required by the design and the strength shall meet the design requirements.

7.4.6 When vegetation is used to control debris flow, plant species shall be selected that have a short growth period, quick results, well-developed roots and are suitable for growth in the region.

7.5 Subgrade in karst region

7.5.1 Before construction, the karst distribution, topography, surface water and groundwater activity patterns shall be checked, and a special construction plan shall be prepared.

7.5.2 Karst funnels, water caves, karst caves and other underground passages connected with underground rivers shall not be blocked. The regulating and drainage measures of karst water that may affect the stability of the subgrade shall comply with the following requirements:

- 1 For a karst spring and water cave located above the subgrade, the water shall be intercepted by a drainage ditch to divert to outside the subgrade.
- 2 For karst water with multiple outlets and dispersed flow, interception facilities such as seepage ditch, cut off wall and drainage tunnel may be installed. The position of interception facilities shall be identified and the flow of intercepted water or drained water shall be smooth.
- 3 For concentrated, constant or intermittent karst water, drainage facilities such as an open ditch, culvert pipe and drainage tunnel may be installed. The water flow shall be designed to ensure smooth drainage.
- 4 For a karst spring or water cave located at the base of the subgrade, it is advisable to design drainage facilities such as bridges and culverts to drain water out of the subgrade.
- 5 When water needs to be drained from a depressed area after being intercepted, a drainage culvert shall be provided to guide water to the sinkhole in the depression. If there is no obvious sinkhole, it shall be drained to the lowest part of the depression. It is not permitted to change the catchment area of the depression. If it is necessary to change the water discharge capacity of the depression, special evidence shall be provided.

7.5.3 For treatment on dry karst caves under the subgrade footprint, the following measures shall be taken:

- 1 Stalagmites, clints, isolated stones and irregular calcium carbonate deposits in the cave shall be removed, and the base shall be leveled. Sand gravel, gravel, rubble or stone block and other water-permeable fillers with a certain grade shall be used to backfill the hole.
- 2 The wet and soft fine-grained soil inside a stone forest, clints, grykes, karrens and depressed areas shall be removed.
- 3 Shallow funnels, sinkholes, soil caves (all which have no drainage functions anymore), dry karst hollows, like karrens, grykes, which are small in scale and without connection to the underground karst water, may be filled with gravel or concrete.
- 4 The exposed and shallow buried karst caves located below the base of the subgrade may be treated by backfilling and sealing, reinforced concrete cover plates spanning, supporting and strengthening with structures.
- 5 For karst caves filled with foreign material reinforcement measures such as grouting, rotary jet grouting and other strengthening measures may be adopted. When the requirements cannot be met, it is advisable to use structures to span the depression.
- 6 When the soil cavity in the covering layer is shallow, the treatment measures such as backfill plus ramming or dynamic compaction may be adopted. Treatment measures such as grouting and composite foundation should be used when the soil cavity in the overburden layer is deep.

7.5.4 When filling the subgrade in a karst depression area, sand, gravel, gravel soil and other materials with good water permeability shall be used, and the filled height shall be 0.5 m above the water table level.

7.5.5 For the soft soil foundation in a karst depression or in an area with abundant groundwater, the soft soil may be replaced with rubble, crushed stone or gravel when the thickness is shallow. When the thickness of soft soil is deep, other soft foundation treatment measures such as jet grouting pile, cement fly-ash gravel pile (CFG) and powder spray pile may be used.

7.5.6 When the subgrade crosses a karst cave with roof, the treatment scheme shall be determined according to the design requirements.

7.5.7 The following measures shall be taken for slope treatment in karst areas:

- 1 For the side slope with alternate soil and rock in an area of clints or stone forest, or where the side slope is composed of soil mixed with rock which is formed when excavating in the area of karst crushed zone between overburden layer and bed rock. The intruded soil inside grykes or karrens between clints or rocks of stone forest, and isolated stones on the slope shall be removed till the natural stable slope of the cutting is reached, and the natural form of the rocks of stone forest and clints which are protruding out of slope shall be preserved.
- 2 Gunnite and shotcrete should be applied on a karst rock slope which is not severely weathered, has developed joints, is broken and has good stability.
- 3 The rock slope with a potential sliding risk after being cut out from the karst ground shall be retained or anchored.
- 4 For a dry karst depression and cave on the cutting slope, it is advised to remove the sediment in the hollow, and use dry masonry or mortar masonry or reinforced concrete slab to block it off. When the stability of the slope is affected by the dry hollow and cave, the reinforcement measures such as supporting pillars of mortar masonry and concrete shall be adopted.
- 5 For a karst slope which is steep with developed fractures, easily broken and spalled by weathering, or the large-scale alternate soil-rock karst slope, the protective measures such as mortar masonry retaining wall shall be adopted.
- 6 When the slope is cut from hard karst rock with good overall stability, smooth blasting or presplitting blasting is advised.

7.6 Subgrade in soft soil region

7.6.1 Before the treatment of a soft soil foundation, the conditions of the site engineering geology, underground pipelines and structures shall be known. If necessary geotechnical tests shall be performed. The feasibility of the design treatment plan shall be reviewed, and a special construction plan shall be prepared.

7.6.2 Soft soil foundation treatment shall be based on local conditions and local materials.

7.6.3 Shallow replacement construction shall comply with the following provisions:

- 1 Soft soil with a thickness less than 3.0 m should be replaced by means of shallow replacement.

- 2 The high strength sand gravel, gravel soil and other materials with good water stability and water permeability should be selected for replacement. During construction the fill shall be compacted in layers.

7.6.4 Shallow improvement construction shall comply with the following provisions:

- 1 The soft surface layer of unsaturated clay may be improved by adding lime or cement.
- 2 Drainage facilities shall be installed well before construction, and no water shall be accumulated during construction.
- 3 Lime or cement shall be mixed evenly with the soil, and the moisture content shall be strictly controlled. During construction, filling and compaction shall be executed in layers.

7.6.5 The construction of riprap and silt removal shall comply with the following provisions:

- 1 Rubble and stone blocks that do not weather readily shall be used, and the size of the stone should be at least 300 mm.
- 2 When the soft soil layer is flat and its transverse slope is less than 1:10, the filling pattern shall be an isosceles triangle with the road center line being at the leading point. Gradually the material is filled symmetrically on both sides until the full width is filled, squeezing away the soft soil to each side; when the soft soil layer transverse slope is steeper than 1:10, it shall be gradually filled with rocks from the higher side to the lower side. More rocks shall be filled on the lower side to form an extended platform with a width not less than 2 m.
- 3 When the riprap is out of the water, heavy machinery shall be used for compaction.

Commentary

When the layer of mud and soft soil is less than 3.0 m in thickness and under water, it is difficult to replace it. Riprap to replace them is an economical and effective treatment method. When the thickness of soft soil is greater than 3.0 m, this treatment method shall be used with caution.

7.6.6 Displacing mud by blasting shall comply with the following provisions:

- 1 It is advisable to use an explosive loading machine to load explosive. When the top surface of the mud is high and above the water surface for a long time, and the loading depth is less than 2.0 m, the manual loading method may be used.

- 2 Before filling with rocks, the height, width and advance of rock fill shall be determined based on environmental conditions such as the soft soil depth, width, water depth and construction equipment. The fill height shall be higher than the water table level. The minimum fill advance should not be less than 3 m, and the maximum should not be more than 10 m.
- 3 Environmental protection measures such as on noise, harmful gases and flying rocks, and the reduction of dust shock waves shall be adopted during construction.
- 4 The thickness of the replaced layer and the residual mud-rock mixed layer shall be detected by drilling or geophysical exploration after blasting. The thickness of the residual mud-rock mixed layer between the bottom of the replaced layer and the top of the design underlying foundation layer shall not be more than 1 m.

7.6.7 The construction of gravel or crushed stone cushion layer shall comply with the following requirements:

- 1 Gravel cushion layer should be built from graded medium coarse sand, gravel or crushed stone. The clay content shall not be more than 5%, and the maximum particle size should not be more than 50 mm.
- 2 The gravel cushion layer should be placed in horizontal layers and compacted. Benches shall be excavated in an undulating site, and the width of the benches should be 0.5-1 m.
- 3 The width of the gravel layer shall be 0.5-1 m wider than subgrade width (from the toe of the side slope), and both sides should be protected by rubble masonry or other methods.

7.6.8 The laying of geosynthetic materials shall comply with the following requirements:

- 1 The technical specifications of geosynthetic materials shall meet the design requirements. Geosynthetic materials shall not be exposed to sunlight for a long-time during storage and construction. Fill in direct contact with geosynthetic materials shall not contain strong acidic or alkaline substances.
- 2 Measures shall be taken to prevent damage to geosynthetic materials during construction. Repair or replace them when they are damaged.

7.6.9 The construction of sand bag wells shall comply with the following requirements:

- 1 Medium and coarse sand should be used. The percentage of particles greater than 0.5 mm should be greater than 50% ,the clay content shall be less than 3% ,and the permeability coefficient shall be greater than 5×10^{-2} mm/s. The permeability coefficient of the sand bag shall not be less than that of the sand.
- 2 The casing shall be lifted vertically to prevent dragging out or damaging the sand bags. When a sand bag is dragged out or damaged ,a replacement well shall be made near the original well.
- 3 The length of the sand bag outside the well mouth shall not be less than 300 mm ,and this part shall be extended straight into the gravel cushion layer.
- 4 The construction quality of a sand bag well shall comply with the requirements in Table 7.6.9.

Table 7.6.9 The construction quality of a sand bag well

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	The distance between wells (mm)	± 150	Randomly check 2% ,but not less than 5 points
2	Well depth(mm)	$\geq$ Design value	Check construction log
3	Well diameter (mm)	$+10,0$	Dig 2% of the well ,but not less than 5 points
4	Sand filling rate (%)	-5	Check construction log

7.6.10 The construction of a prefabricated vertical drain (PVD) shall comply with the following requirements:

- 1 The technical indexes of the PVD shall meet the design requirements, and it shall be covered when stacked outside.
- 2 Dirt and other debris shall be prevented from entering the casing during construction.
- 3 The PVD shall not be overlapped. The extra length shall not be less than 500 mm ,and it shall be bent at the time of construction and buried in the gravel cushion layer.
- 4 The construction quality shall comply with the requirements in Table 7.6.10.

Table 7.6.10 The construction quality of prefabricated vertical drain

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Distance between PVDs (mm)	± 150	Randomly check 2% ,but not less than 5 points
2	Length of PVD (mm)	$\geq$ Design value	Randomly check 2% ,but not less than 5 points

7.6.11 The construction of vacuum preloading and vacuum-surge-combined preloading shall comply with the following requirements:

- 1 The geo-membrane sealing film shall be made of air tight materials, with good aging resistance, good toughness and puncture resistance.
- 2 The sealing geo-membrane should be connected by a thermocompression bonding joint, and the lap width shall not be less than 15 mm.
- 3 The filter tube shall prevent sand from entering. The distance between the filter tube and the top of soil or sand layer shall be both greater than 50 mm. The permeable tube shall be firmly filled with sand, and no unfilled space shall be allowed.
- 4 The perimeter of the geo-membrane shall be buried in the clay sealing trench. The width of the clay trench should be 0.6-0.8 m, and the depth should be 1.2-1.5 m.
- 5 The vacuum gauge probe shall be buried in the middle of the sand cushion layer, and each isolated consolidation area shall have at least 2 vacuum gauge probes.
- 6 Vacuum preloading construction shall be carried out in the sequence of drainage system construction, vacuum system construction, sealing construction and air extraction.
- 7 When vacuum-surge combined with preloading is used, vacuuming shall be drawn first. When the vacuum pressure reaches the design requirements and is stable, the surge is then added, and the vacuuming is continued. Protective materials such as geotextiles shall be laid on the membrane during loading.
- 8 Construction monitoring shall comply with the following requirements:
 - 1) During the process of preloading, the pre-loading parameters such as vacuum under the membrane, pore water pressure, surface settlement, deep settlement and horizontal

displacement shall be monitored. The vacuum under the membrane shall be measured every 4 h, and the surface settlement shall be measured every 2 d.

- 2) When the measured ground settlement is less than 0.5 mm/d for five consecutive 24-hour periods, and the degree of foundation consolidation has reached 80% of the design requirements, the vacuum may be terminated on acceptance.
- 3) Surface rebound shall be measured 24 h after the vacuum pump stops and the surcharge is removed.

7.6.12 Gravel pile construction shall comply with the following requirements:

- 1 Sand piles should consist of medium and coarse sand, with particle size greater than 0.5 mm accounting for more than 50% of the total weight. The clay content shall be less than 3%, and the permeability coefficient of greater than 5×10^{-2} mm/s. Sand mixed with gravel may also be used, provided the clay content is less than 5%.
- 2 Gravel piles should be constructed from weather-resistant graded crushed stone or gravel, with a maximum particle size of 50 mm, and a clay content shall be less than 5%.
- 3 Pile construction technology and pile compaction tests shall be tested before construction.
- 4 Granular piles may be made by the vibro-displacement method or vibration driving casing method. Construction should be started from the middle towards both sides or follow an interval jump sequence. When constructing in the area near structures, the construction sequence shall be in a direction away from the structures.
- 5 The construction quality of a gravel pile shall comply with the requirements in Table 7.6.12.

Table 7.6.12 The construction quality of a gravel pile

Number	Checking item	Specified value or allowed deviation	Check method and frequency
1	Distance between piles (mm)	± 150	Randomly check 2% but not less than 5 points
2	Pile length (m)	$\geq$ Design value	Check construction log
3	Pile diameter (mm)	$\geq$ Design value	Randomly check 2%
4	Granular material filling rate	$\geq$ Design value	Check construction log
5	Ground bearing capacity	Satisfying design requirements	Randomly check 0.1% of total piles, but not less than 3 points

- 6 The frequency of random checks on the density of the gravel pile shall be 2% , and the heavy type II dynamic penetration test shall be used. When the penetration volume is 100 mm, the number of blows shall be greater than 5 times.

Commentary

Pile filling material should be locally available crushed stone , gravel , pebbles , sand gravel and slag are all acceptable , but materials that weather or disintegrate readily shall not be used. The clay content of all types of fillers shall not be greater than 5% . There is no special requirement for the filler particle grading , and the maximum particle size of the filler is generally not more than 63 mm. Particles larger than this can easily cause blockage and severe wear on the vibrator housing.

When the quality requirements for sand piles are strict or when small diameter casing is used to drive large diameter sand piles , the double casing impact-driving method or the single casing by repeated vibration driving and pulling method may be used.

Common methods for construction quality inspection , include single pile load test and dynamic penetration test. For reinforcement inspection , commonly used methods are the load test on a single-pile composite foundation and the large-scale load test on multi-pile composite foundation.

7.6.13 The construction of stabilized soil piles shall comply with the following requirements :

- 1 Quicklime or cement should be used as stabilizing agent. Quicklime shall be finely ground Grade I , free of impurities , and with a maximum particle size less than 2 mm. The cement should be ordinary Portland cement with a strength grade of not less than 32.5 MPa.
- 2 Before the construction of reinforced soil piles a pile test shall be carried out. The number of test piles should not be less than 5 , and the following requirements shall be met :
 - 1) Various technical parameters shall be obtained in order to match the design injection volume , such as drilling speed , lifting speed , mixing speed , jet pressure and injection volume per unit time.
 - 2) A process shall be determined to ensure the uniform mixing of the stabilizer and the soft soil.
 - 3) Understanding the resistance conditions of drilling down and lifting permits selecting the most appropriate technical measures.
 - 4) The range of jet re-mixing of piles shall be determined according to stratum and

geological conditions.

- 3 If it is found that the amount of powder or grout is insufficient, the whole pile shall be jet-mixed again, and the amount of re-mixing agent shall not be less than the design amount. When the construction is interrupted, the depth shall be recorded promptly and the pile work shall be restarted within 12 hours, and the re-mixed length shall be greater than 1 m; If the time exceeds 12 hours, additional piles shall be made.
- 4 The construction quality of stabilized soil piles shall comply with the requirements in Table 7.6.13.

Table 7.6.13 The construction quality for stabilized soil piles

Number	Checking item	Specified value or allowable deviation	Check method and frequency
1	The distance between piles (mm)	± 100	Tape measure: randomly check 2% , but not less than 5 points
2	Pile diameter (mm)	$\geq$ Design value	Tape measure: randomly check 2% , but not less than 5 points
3	Pile length (m)	$\geq$ Design value	Check construction log
4	Amount of slurry (powder) per meter of a single pile	$\geq$ Design value	Check construction log
5	Strength (MPa)	$\geq$ Design value	Coring: randomly check 0.5% of piles, but not less than 3 piles
6	Foundation bearing capacity	Satisfying design requirements	Check 0.1% of piles, but not less than 3 piles

7.6.14 The construction of cement fly-ash gravel pile (CFG) shall comply with the following requirements:

- 1 Aggregates may be crushed stone or gravel. When the mixture is placed by pumping, the maximum particle size of gravel should not be more than 25 mm. The maximum particle size of crushed stone should not be more than 20 mm. The maximum particle size of the aggregate should not exceed 50 mm when the mixture is placed by vibration driven casing method. The cement should be Grade 32.5 ordinary Portland cement. Fly ash should be Grade II or III.
- 2 A pile test shall be carried out before construction. From the test, the construction technology, piling speed, amount of feeding material and quality criteria shall be determined.

- 3 For the construction of pile groups, the piling sequence shall be developed and the piling speed shall be controlled. It is advised to use the interval jump piling sequenced the time between neighboring piles shall not be less than 7 d.
- 4 The construction quality of CFG piles shall comply with the requirements in Table 7.6.14.

Table 7.6.14 The construction quality for CFG piles

Number	Checking Item	Specified value or allowable deviation	Check method and frequency
1	Distance between piles(mm)	± 100	Tape measure; randomly check 2% , but not less than 5 points
2	Pile diameter(mm)	$\geq$ Design value	Tape measure; randomly check 2% , but not less than 5 points
3	Pile length(mm)	$\geq$ Design value	Check construction log
4	Strength (MPa)	$\geq$ Design value	Coring; randomly check 0.5% , but not less than 3 piles
5	Bearing capacity of composite foundation	$\geq$ Design value	Check 0.1% ,but not less than 3 points

7.6.15 The construction of large diameter cast-in-place concrete pipe piles shall comply with the following requirements:

- 1 Gravel should be preferred as coarse aggregate. When crushed stone is used, the sand content shall be increased. The maximum particle size of aggregate should not be greater than 63 mm. Concrete slump should be 80-100 mm, and there shall be no segregation and bleeding during transportation and casting.
- 2 The concrete strength grade of precast pile tip and pile cap should not be less than C30. The surface of the pile tip shall be smooth and dense, the deviation of the roundness of its inner and outer side shall not be greater than 1% , and its bearing face shall be flat.
- 3 When there are buildings or structures nearby, effective vibration isolation measures shall be taken.
- 4 In pile group construction, the pile driving sequence shall be designed practically, piling speed shall be controlled, and the quality of adjacent piles shall not be affected.
- 5 The construction quality of large diameter pipe pile of cast-in-place concrete shall comply with the requirements in Table 7.6.15.

Table 7.6.15 The construction quality of large diameter pipe pile of cast-in-place concrete

Number	Checking item	Specified value or allowable deviation	Check method and frequency
1	Concrete compression strength(MPa)	Within qualifying standards	2 set samples for a single pile ,at least 2 set samples in a working day
2	Distance between piles (mm)	± 100	Tape measure; randomly check 2% of piles, but not less than 5 points
3	Pile diameter(mm)	$\geq$ Design value	Tape measure; randomly check 2% of piles
4	Pile length(m)	$\geq$ Design value	Check piling log
5	Verticality (%)	1	Check piling log
6	Bearing capacity of a single pile	Satisfying design requirements	Randomly check 0.1% of piles, but not less than 3 piles
7	Pile integrity	Without obvious defects	Low strain test; randomly check 10% of piles

7.6.16 Precast pipe pile construction shall comply with the following requirements:

- 1 The site for stacking pipe piles shall be flat and compacted, with drainage measures in place and no uneven settlement.
- 2 The precast pile shall be checked before construction, and the pre-tensioned thin-wall prestressed concrete pipe pile shall comply with the current *Pretensioned spun concrete pile* (GB 13476) and the *Prestressed spun concrete thin-walled piles* (JC/T 888).
- 3 Precast pipe piles should be driven by static pressure, or by hammer.
- 4 The order of driving piles should be from the center line of the subgrade to both sides, and from near the structure to away from the structure.
- 5 The verticality of pile shall be strictly controlled during the process of driving a pile.
- 6 Each pile should be continuously driven to the design elevation at one time. An interruption during the pile sinking process shall not be too long.
- 7 Driving a pile should be stopped when the penetration requirements are reached.
- 8 The pile cap reinforcement cage shall be inserted into the pipe pile, and the connecting concrete shall be cast together with the pile cap concrete. The construction quality of a precast pipe pile shall comply with the requirements in Table 7.6.16.

Table 7.6.16 The prefabricated pipe pile construction quality

Number	Checking item	Specified value or allowable deviation	Check method and frequency
1	The distance between piles (mm)	± 100	Tape measure; randomly check 2% of piles, but not less than 5 points
2	Pile length (m)	$\geq$ Design value	Tape measure; randomly check 2% of piles, but not less than 5 points
3	Verticality (%)	1	Randomly check 2% of piles
4	Bearing capacity of a single pile	Meeting design requirements	Randomly check 0.1% of piles, but not less than 3 piles
5	The height of pile cap (mm)	+20, -10	Tape measure; randomly check 2% of piles
6	The length and width of pile cap (mm)	+30, -20	Tape measure; randomly check 2% of piles
7	The position of pile cap (mm)	50	Tape measure; randomly check 2% of piles

Commentary

A soil squeezing effect will occur during the pile driving process. It is therefore recommended to first drive the pile for soft ground treatment, and then proceed with the structure foundation. If the structure foundation is constructed first, the piling sequence shall be from the structure towards the embankment to minimize the impact on the structure foundation. If there are buildings near the subgrade, the sequence of piling shall be from near the building to away from the building. Measures such as vibration mitigation trenches or holes may be made if necessary.

7.6.17 Dynamic compaction and dynamic replacement construction shall comply with the following requirements:

- 1 The material for dynamic compaction replacement shall be hard coarse-grained particles such as well-graded stone, crushed stone and slag. The particle size should not be greater than 0.2 times the diameter of the bottom face of the tamper. The clay content should not be greater than 10%, and the particle size greater than 300 mm should not be greater than 30% of the total mass.
- 2 Vibration isolation and vibration prevention measures shall be taken to eliminate the harmful effects of dynamic compaction on adjacent buildings.
- 3 Before construction, a representative road section that is not less than 500 m² shall be selected for testing tamping to determine the optimal tamping energy, frequency, tamping

spacing and other parameters.

- 4 The tamping points may be arranged in a square or equilateral triangle, with a spacing of 5-7 m. For a given dynamic compaction energy level, a heavier tamper and lower dropping height is preferred.
 - 5 Before the construction of dynamic compaction and dynamic compaction replacement, a given thickness of a cushion layer shall be laid on the surface. The cushion material for dynamic compaction should be sand, gravel, stone chips, crushed stone, and soil. The cushion material for dynamic replacement should be the same as that of the replacement column. The cushion layer should be spread and compacted in layers.
 - 6 Before construction, the tamper weight and drop height shall be checked, and the tamping energy of a single blow shall meet the design requirements.
 - 7 About 30 days after completion of the dynamic compaction, standard penetration, static penetration and other in-situ tests shall be carried out to measure whether the bearing capacity of the foundation after being compacted meets the design requirements.
 - 8 About 30 days after the completion of dynamic replacement, it is advised to use a dynamic penetration test to check the bottom condition and bearing capacity of the replacement column. The number of inspections shall not be less than 1% of the columns, or not less than 3 columns. The diameter and depth of the replacement column shall be checked to determine if they meet the design requirements.
- 7.6.18 Embankment construction in soft soil areas shall comply with the following requirements:
- 1 Embankment construction in soft soil areas shall be arranged as early as possible, and the time required for foundation consolidation shall be considered in the construction plan.
 - 2 During the process of filling, the filling rate shall be strictly controlled and frequent observations shall be carried out.
 - 3 During the construction period, the ground surface settlement rate at the center line of the embankment shall not be greater than 10-15 mm per 24 h, and the horizontal displacement rate at the slope toe shall not be greater than 5 mm in 24 h. A comprehensive analysis of the foundation stability shall be conducted based on observations of settlement and displacement. The filling rate shall be controlled mainly by the horizontal displacement, and the filling shall be stopped immediately if the allowed value is exceeded.

- 4 Abutments, culverts, pathways and retaining works shall be constructed after the pre-loading settlement is completed.
- 5 Preloading shall be carried out according to the load and time required by the design. It is advised to use the material for filling the upper roadbed as pre-load material, and it shall be filled and compacted in layers.
- 6 Directly constructing an embankment over a soft soil foundation shall comply with the following requirements:
 - 1) The part below the water surface shall be filled with permeable material, and the part above the water surface may be filled with normal soil or lightweight materials.
 - 2) The soil for filling the subgrade should be taken from a borrow pit. When borrowing soil on any road side, the distance between the borrow pit and the toe of the embankment slope shall meet the requirements for the stability of the embankment.
 - 3) The loading berm should be filled at the same time as the embankment. When they are filled separately, the loading berm shall be made before the embankment reaches the critical height.

Commentary

- 1 *The longer the consolidation time for soft soil, the smaller the post-construction settlement, which significantly improves the highway quality. Therefore, early consolidation needs to be arranged.*

7.6.19 The soft soil treatment for existing road widening shall comply with the following requirements:

- 1 For widening the subgrade in a section with soft soil, the benches shall be excavated in the way that one bench shall be filled after excavation before the upper bench can be excavated. The bench excavation shall meet the design requirements on bench width and on handling the new and old subgrade connection.
- 2 The influence of soil extrusion and vibration on the old embankment or adjacent structures induced by treating the soft soil shall be considered when determining the construction technology and scheme for soft soil treatment in existing road widening.
- 3 During the construction period, the excavated slope of the old road shall be covered and the necessary temporary drainage facilities shall be provided.

- 4 The settlement measurements on the new subgrade and the old subgrade should be carried out simultaneously in the widened road section. The measuring points should be arranged on the same cross-section. Measuring points should be located as follows: the middle of the old road, the shoulder of the old road, the middle of the new subgrade and the outer side of the new subgrade. The measuring points in the middle and shoulder of the old road may be located on the road surface, but the settlement plates should be located on the new part.

7.6.20 Embankment settlement and stability observation shall comply with the following requirements:

- 1 Dynamic observation of the settlement and stability shall be carried out for the embankment construction of Class 2 or higher highway. The observation items, content and frequency shall meet the design requirements.
- 2 The surface settlement and surface horizontal displacement shall be monitored. The horizontal displacement of soil with depth may be measured according to the needs of the project, and the measurements shall comply with the requirements in Table 7.6.20.

Table 7.6.20 Dynamic observation of settlement and stability

Observation item	Common instruments	Observation content and purpose
Surface settlement	Settlement plates	Adjust the filling rate according to the measured data. Predict the settlement tendency, determine unloading time for preloading and time for constructing the structure and pavement. This is used to provide the basis for calculating the quantity of settled earthwork during construction
Surface horizontal displacement and uplift	Surface horizontal displacement peg	Monitor surface horizontal displacement and uplift to ensure the safety and stability of the embankment during construction
Horizontal displacement with depth	Inclinometer	Measure the horizontal displacement with depth and estimate the position of soil shear failure

- 3 The observation instrument shall be buried after the soft soil foundation is treated, and the embankment shall be filled after the stable initial value is observed.
- 4 Measurement points shall be located in places with poor foundation conditions, large changes in topography and large differential deformations. The measurement points for different observation items on the same road section should be arranged along the same cross section.

- 5 If the stability of the foundation is abnormal, the loading shall be stopped immediately, the cause shall be determined and measures shall be taken to handle it. The embankment can be filled again after the stability is restored.
- 6 During construction, tracking measurements for settlement and stability shall be carried out according to the design requirements, and the observation frequency shall be appropriate with the deformation rate of the subgrade (including the foundation), and it shall be increased when the deformation rate is large, and vice versa. During the filling period, one measurement shall be made for every filled layer. When the filling interval between two layers is long, it shall be observed every 3-5 days. After the embankment is completed during the preloading period, it should be observed every 3 days in the first month, every 7 days in the second and third months, and every 15 days from the fourth month until the end of the preloading period.
- 7 Effective measures shall be taken to protect all types of observation points and benchmark points during the observation period, and conspicuous warning signs shall be painted on the benchmark poles.

Commentary

Stability and settlement are the most prominent problems in building highway embankment on soft soil foundation. To understand the deformation dynamics of an embankment during construction, dynamic observation is needed. Besides the items clearly required in the design, the dynamic observation items are generally determined according to the importance of the project, the specific nature of the foundation and the degree that they will influence the construction. For motorways, Class 1 and 2 highways their design speeds are high, and the requirements for pavement evenness are high. Therefore, settlement and stability observations are needed in the construction process, on the one hand to ensure the safety and stability of the embankment, and on the other hand to accurately predict the post-construction settlement, so that the post-construction settlement is controlled within the permissible design range, while also providing a basis for paving.

7.7 Subgrade in red clay and high liquid limit soil region

7.7.1 When red clay or high liquid limit soil are expansive, they shall be controlled according to the construction requirements for an expansive soil subgrade.

7.7.2 The applicable range of red clay or high liquid limit soil shall comply with the requirements of Table 7.7.2. A high fill and steep slope subgrade should not be filled with red clay or high liquid limit soil. The submersible part of a subgrade, behind an abutment or retaining wall, or the part

surrounding a culvert and other parts shall not be filled with red clay or high liquid limit soil.

Table 7.7.2 The applicable area of red clay and high liquid limit soil

Motorway, Class 1 highway			Class 2 highway			Class 3 or below highway		
Subgraded	Upper embankment	Lower embankment	Subgrade	Upper embankment	lower embankment	Upper subgrade	Lower subgrade	Embankment
×	×	○	×	○	○	×	○	○
×	×	○	×	○	○	×	○	○

Note: ○ means applicable; × means inapplicable.

Commentary

The natural water content of red clay and high liquid limit soil is generally high, and their modulus and strength are low. For this reason, the subgrade and upper embankment of a Motorway and Class 1 highway, as well as the subgrade of Class 2 highway shall be filled with coarse particle materials with good water stability such as sand gravel or crushed stone to ensure that the subgrade deflection and modulus meet the requirements.

7.7.3 The subgrade of red clay or high liquid limit soil should be constructed during the dry season. The subgrade should be filled continuously, and the next layer shall be paved immediately after the underlayer is rolled and passed the test, so as to prevent cracking in the underlayer surface due to water evaporation. If the next layer is filled after a long time interval, anti-cracking measures may be taken, such as blending not less than 30% of gravel in the top of underlayer and then rolling it. The subgrade layer with obvious cracking in the surface shall be broken up and mixed and rolled again.

7.7.4 When a rock fill embankment is used as the foundation below the subgrade, the rock fill material shall have good water stability. Rock fill shall be layered horizontally along the subgrade from the lowest point.

7.7.5 The compaction test and CBR test of red clay and high liquid limit soil shall be conducted by the wet method.

Commentary

Red clay or high liquid limit soil will lose part of the bound water after drying. This kind of loss is irreversible. The maximum dry density of red clay or high liquid limit soil obtained by the wet compaction test is lower than that obtained by dry compaction test, and the optimum water content is higher than that obtained by the dry compaction test. The CBR value obtained by the wet method is higher than that by dry method, and the expansion is lower than that by dry method. The situation where the filler is dried and then mixed with water does not occur in practice. Thus the test results obtained by the wet method are related to practice and close to reality.

7.7.6 Before filling the subgrade with red clay or high liquid limit soil, a trial section shall be paved to determine the corresponding construction technology and compaction criteria.

7.7.7 Red clay or high liquid limit soil embankment should be rolled by a light roller. The compaction criteria shall be determined by the trial section combined with engineering experience, and the degree of compaction shall not be less than 90% of the heavy compaction standard.

Commentary

The natural moisture content of red clay or high liquid limit soil is generally high, and they are not suitable to be compacted by large heavy weight rollers. Too large compaction energy destroys their structure, and the soil is defined as "cotton" in engineering. The compactability of red clay or high liquid limit soil mainly depends on their natural water contents. When the water content is low, high compactability can be achieved. Conversely, when the moisture content is high, the achievable degree of compaction is low, but in this case the subgrade soil is highly saturated, with low permeability, good stability, and the long-term performance of the subgrade is good. Guizhou, Fujian and other provinces have formulated and released corresponding local standards based on their local soil properties and engineering characteristics, which may be used as a reference.

7.7.8 Conventional protection methods such as the arch framework slope protection may be adopted to protect the side slope of red clay or high liquid limit soil embankment.

Commentary

Red clay and high liquid limit soil are crack readily due to water loss. Engineering investigations show that the embankment crack is not completely continuous between each layer. The cracks in the surface layer will not penetrate into the soil layer below, and the influence range of cracks is limited, which is the difference between the remolded soil and the undisturbed soil after being compacted. The stability of the embankment side slope of red clay or high liquid limit soil is generally good, and the conventional protection method can meet the engineering requirements.

7.7.9 For motorways and Class 1 highways over a red clay or high liquid limit soil area, the zero filling and cut sections may be treated by replacement as in the following ways:

- 1 Limestone pillars and stalagmites within 1.5 m below the surface shall be removed.
- 2 When the thickness of red clay or high liquid limit soil is not more than 1.5 m, the red clay and high liquid limit soil shall be completely removed and replaced.
- 3 If the thickness of red clay or high liquid limit soil is greater than 1.5 m, the red clay and high liquid limit soil in the range of the road bed shall be removed and replaced.

- 4 The replacement material shall be gravel, crushed stone and other materials with good water stability, and the particle size of the fill shall meet the requirements in Table 4.1.2.
- 5 After the cut section reaches the bottom, the replacement work shall be carried out at the same time, otherwise, it is advised to keep a 300 mm soil layer above the elevation of the bottom surface.

7.7.10 The cut slope shall be protected all the time and integrated drainage works shall be built according to design requirements, and the slope should be 1:1.25-1:1.5 when structural protection and ecological protection are combined; when structural protection is adopted, the slope inclination should be 1:1-1:1.25; when ecological protection is adopted, the slope inclination should be 1:1.75-1:2.

Commentary

The cut slope of red clay or high liquid limit soil is prone to collapse in the natural state, and the slope collapse is related to the slope inclination. The slope in the Specifications is based on the investigation of slope collapse of red clay and high liquid limit soil from many highways in China.

7.7.11 The cut slope shall be protected all the time after excavation and shall not be exposed for a long period. The retaining structure shall be constructed at the toe of slope according to the design requirements.

7.7.12 If a cut slope collapses during construction, it should be treated by removing more soil to reduce the slope or construct retaining walls.

7.8 Subgrade in expansive soil region

7.8.1 The construction of the subgrade in an expansive soil region shall meet the following requirements:

- 1 The subgrade should be constructed in the dry season. Site drainage shall be in place, and its foundation and the already constructed subgrade shall not be immersed in water.
- 2 Before the cut section is constructed, water interception and drainage facilities shall be constructed first to drain water to outside the road width.
- 3 Construction shall take place section by section. Each process shall be closely connected, construction shall be continuous, with each section being sealed shortly after its completion.

- 4 Before large-scale construction commences, the distribution, quantity and expansion severity class of the expansive soil shall be checked, and its road performance shall be defined. If changes to the expansive soil shall occur during construction, these changes shall be monitored.
- 5 The laboratory compaction test and the CBR test of an expansive soil shall be conducted by the wet method.

7.8.2 The classification of expansive soil shall comply with the requirements in Table 7.8.2.

Table 7.8.2 Classification of expansive soil

Class indicator	Slightly severe	Moderately severe	Very severe
Free swell ratio F_s (40%)	$40 \leq F_s < 60$	$60 \leq F_s < 90$	$F_s \geq 90$
Plasticity index I_p	$15 \leq I_p < 28$	$28 \leq I_p < 40$	$I_p \geq 40$
Standard hygroscopic moisture content ω_f	$2.5 \leq \omega_f < 4.8$	$4.8 \leq \omega_f < 6.8$	$\omega_f \geq 6.8$

Note: Standard hygroscopic moisture content refers to the moisture content of the expansive soil sample after constant weight at the standard temperature (normally 25 °C) and standard relative humidity (normally 60%)

7.8.3 When expansive soil is used as subgrade fill, it shall comply with the following requirements:

- 1 The application scope of moderately severe expansive soil and slightly severe expansive soil is shown in Table 7.8.3. The modified expansive soil mixed with lime may be used as subgrade fill, but this expansive soil treated with lime is not suitable to be used as roadbed fill for motorway or Class 1 highway, or for the upper roadbed fill for a Class 2 highway.

Table 7.8.3 The applicable area of use of moderately severe and slightly severe expansive soil

Class of highway, position	Motorway, Class 1 highway	Class 2 highway	Class 3 highway
Upper subgrade	—	—	—
Lower subgrade	—	—	Slightly severe
Upper embankment	—	Moderately, slightly severe	Moderately, slightly severe
Lower embankment	Moderately, slightly severe	Moderately, slightly severe	Moderately, slightly severe

- 2 A high fill and steep slope subgrade should not be constructed with expansive soil.
- 3 Very severe expansive soil shall not be used as subgrade fill.

- 4 The submersible part of the subgrade shall not be filled with expansive soil.
- 5 Expansive soil cannot be used behind an abutment, retaining wall and the part surrounding a culvert.

Commentary

Expansive soil generally has a high natural moisture content, clumps into lumps, and is difficult to mix evenly with lime, so this Clause is included.

7.8.4 For Class 2 or higher highways, if the embankment fill is less than the thickness of the roadbed, it shall be treated according to the requirements for roadbed.

7.8.5 The paving of a trial section shall comply with the following requirements:

- 1 Before constructing a fill with the expansive soil subgrade, a trial section shall be constructed, and the construction technology and compaction criteria shall be agreed on.
- 2 The moisture content and degree of compaction measured in the trial section shall be compared with the results of the laboratory test, and the site CBR value of the subgrade shall be determined by interpolation. The applicable areas, water content for compaction, construction technology and compaction criteria of expansive soil shall be determined according to the CBR values required by various subgrade layers.
- 3 For an expansive soil treated with lime the compaction test shall be carried out for the design lime content. The mixing method, mixing time and curing time of the compaction test shall be consistent with the actual construction conditions on site.
- 4 Through the construction summary, the following shall be determined: mixing technology, mixing time, curing time, equipment and required processes for crushing clumps and mixing, clump size control and number of roller-passes.

Commentary

There is a great difference in the maximum dry density between the untreated soil and the lime soil, so the compaction test on the lime soil is needed to determine the compaction standard of the lime soil. After the expansive soil is mixed with lime, the soil and lime will have reactions of ion exchange, carbonation, crystallization and lime stabilization under the chemical and physicochemical interaction. Over time, the content of effective calcium and magnesium in the mixture will reduce and eventually reaches zero. The dry density of the lime soil will also decrease, while the strength of the lime soil will increase. Considering that the degree of compaction of lime

modified expansive soil will decrease with the increase in age after the embankment is formed, the change curve of compaction-age may be made in the trial section if necessary, so as to provide the corresponding testing standard of age-compaction for future sampling check.

7.8.6 The embankment filling process for mechanically improved expansive soil shall meet the following requirements:

- 1 The expansive soil subgrade on a longitudinal slope section shall be filled layer by layer starting from the lowest point. When there are structures such as culverts at the bottom of the longitudinal slope, it shall be filled symmetrically on both sides of the structure.
- 2 When being rolled, the moisture content of the fill shall be in the range determined by the trial section, and its consistency should be controlled between 1.0 and 1.3.
- 3 The thickness of each layer shall not be greater than 300 mm.
- 4 When a cover soil edge treatment is adopted, the non-expansive cover soil or the expansive soil after lime treatment shall be filled first at both edges, and then the expansive soil shall be filled, both of them shall be filled alternately. The width of the cover soil edge should not be less than 2 m, and shall be the width of a road roller if possible.
- 5 When the roadbed is filled with coarse grained material, a 3%-4% transverse slope shall be started at the top surface of the expansive soil, and waterproof isolation measures shall be taken.

Commentary

The stability of the soft and weak expansive soil foundation at the longitudinal slope section is relatively low, and when the culvert and other structures are set at the bottom of the gradient, the subgrade is sometimes filled first along the gradient on both sides of the culvert, because culvert construction is restricted by the time and the working face. Even if the subgrade is filled with non-expansive soil, a slide of the expansive soil foundation may be induced when the fill speed is fast. Engineering cases in this respect occur from time to time and need attention.

7.8.7 When lime is used to treat an expansive soil, and if the natural moisture content of the soil is high, quick lime powder should be used. The addition of lime should be made in two passes. The mixing depth shall reach the bottom of the layer, and the particle size of the soil after mixing shall be less than 37.5 mm.

Commentary

The first pass of adding the lime is to make soil more “sandy” and workable and to lower its plasticity index, so that it is easy to pulverize; the second pass of adding lime is to improve its strength and to control the expansion. The two-pass mixing with lime improves uniformity.

7.8.8 After the subgrade is completed, the sealing layer shall be placed. The thickness shall not be less than 200 mm, and the transverse slope shall not be less than 2%.

7.8.9 The compaction standard for mechanically treated expansive soil shall be determined from the trial section and local engineering experience. The degree of compaction shall not be less than 90% of the heavy compaction standard. The degree of compaction of the subgrade fill with moderately severe expansive soil and slightly severe expansive soil after chemical treatment shall comply with the requirements in Table 4.4.3 of the *Specifications*.

7.8.10 When placing the expansive soil embankment, the embankment side slope and top surface shall be protected at all times.

7.8.11 Excavation of a cutting shall meet the following requirements:

- 1 During side slope construction, temporary waterproofing and sealing measures may be taken to maintain the original moisture content of the soil when necessary.
- 2 The side slope shall not be excavated to the design line in one operation. A thickness of 300 to 500 mm shall be kept. After the cutting is completed, the remaining part of the side slope shall be cut in sections and the protective and sealing activities shall be carried out immediately.

7.8.12 Side slope protection in a cutting shall meet the following requirements:

- 1 Cutting slope protection activities shall be made in sections according to the construction capacity.
- 2 When non-expansive soil cover is used to replace part of the expansive soil or flexible protection structure is constructed for slope protection, the cover thickness over the side slope shall not be less than 2.5 m and shall meet the requirements of being compacted by roller. The degree of compaction shall not be less than 90%. Between the cover layer and the underlying expansive soil layer, a drainage bed layer and an underdrain shall be installed.

- 3 Broad-leaf species shall not be used for vegetation protection in this case.
- 4 For masonry protection, the back of the wall shall be provided with a buffer layer, which shall not exceed 0.5 m. The depth of the foundation of the retaining structure shall be greater than the depth of climate influence, and the thickness of the filter layer shall not be less than 0.5 m.
- 5 The construction techniques of different types of structures for side slope protection in a cut section, such as impermeable layer, drainage bed layer, underdrain, filter layer and masonry structure shall conform to the corresponding requirements in other sections of the *Specifications*.

7.8.13 The roadbed in zero-fill and cut section shall meet the following requirements:

- 1 Expansive soil within the 0.8-1.2 m depth of the roadbed for a motorway and Class 1 highway in their zero-fill and cut sections shall be replaced. For very severe expansive soil in cut section, the replacement depth of the roadbed should be increased to 1.2-1.5 m. If the bedrock can be reached within 1.5 m, expansive soil shall be removed to reach the bedrock.
- 2 The expansive soil within a depth of 0.3 m of the roadbed for Class 2 and Class 3 highway in their zero-fill and cut sections shall be replaced. When the replacement material is permeable, an impermeable layer shall be constructed below this layer. The roadbed depth of very severe expansive soil shall be replaced for a Class 2 highway to a depth of 0.5 m.
- 3 After the over-excavation of the cutting, the cut part shall be replaced immediately and shall not be exposed for a long time.

7.9 Subgrade in loess regions

7.9.1 Before construction, the zone classification and foundation treatment methods for collapsible loess shall be checked or identified, and special construction plans shall be prepared.

7.9.2 The side slope of the subgrade shall meet the following requirements: the slope surface shall be flat and even, and the construction of protection works and retaining works shall be matched with the construction of the subgrade fill or cut. When strengthening drainage ditches by treating the base by tamping or adding lime then tamping, the degree of compaction shall be more than 90%.

- 7.9.3 The treatment of collapsible loess foundation shall comply with the following requirements:
- 1 When the foundation is a non-self-weight collapsible loess, the ground surface treatment shall comply with the relevant requirements of Section 3.4 of the *Specifications*.
 - 2 Before the treatment of a collapsible loess foundation, the water interception and temporary drainage facilities shall be completed, and the depressions and sinkholes close to the foundation of the embankment shall be filled. In low-lying and waterlogged areas or irrigation areas, plain soil or lime soil shall be used as fill. The compaction in such areas within a range of 5-10 m outside the toe of both side slopes of the embankment shall be more than 200 mm above the original surface, and no water shall be accumulated on either side of the subgrade.
 - 3 Trial sections shall be constructed for all foundation treatment methods. When there is a structure near the foundation treatment site, the minimum horizontal safety distance between the edge of the site and the structure shall meet the specified requirements. At an impact rolling or dynamic compaction treatment section, the degree of compaction, settlement coefficient and permeability coefficient of the foundation shall be tested 7 days after the completion of construction, and the strength test shall be carried out 15 days after construction.
 - 4 Untreated materials used for foundation treatment shall meet the design requirements. Lime shall be Grade III or higher slaked lime; cement shall be Grade 32.5 or higher ordinary Portland cement. The soil material should be clay without organic matter with a plasticity index of 7-15, and the soil particle size should not be larger than 15 mm.
 - 5 When the replacement method is used to treat collapsible loess foundation, lime soil bed layer or cement soil bed layer, or untreated soil bed layer can be used. Ground quicklime powder should be used for the lime soil bed layer. Lime or cement content shall meet the design requirements. The bed layer shall be placed and rolled in layers. The thickness of each layer should not be more than 300 mm, and the degree of compaction shall meet the requirements specified for each functional layer.
 - 6 When a collapsible loess foundation is treated by impact rolling, the length of a construction section of impact rolling treatment shall not be less than 100 m. When the safety distance from a structure does not meet the requirements, an isolation trench should be excavated. The moisture content of the foundation soil shall be controlled within the optimum moisture content $\pm 3\%$. The compaction method shall be such that the traces of the impact roller is controlled laterally to ensure that the area is compacted evenly. During the compaction process, the settlement value and degree of compaction of the foundation shall

be tested.

- 7 When dynamic compaction is used to treat a collapsible loess foundation, then for the same dynamic compaction energy level, heavy weight and low drop height methods should be adopted. The moisture content of the foundation soil should be controlled between 8% and 24%. Construction should be divided into three processes: main tamping, auxiliary tamping, and overall tamping, and there should be a given time interval between any two processes. The number of passes at a tamping point shall be determined according to the relationship curve between number of passes and penetration obtained by test tamping. When the safety distance from the structure does not meet the requirements, an isolation trench shall be excavated.
- 8 When using the compaction pile method to treat a collapsible loess foundation, and the depth of the compaction pile is less than 12 m, a pile hole may be made by driving a closed end hollow pipe into ground. When the pile depth is more than 12 m, the boring method may be used. Quicklime shall not be used for a lime soil compaction pile. For a dry-mix cement crushed gravel compaction pile, the particle size of the stone chips should be 0-5 mm, the particle size of the crushed stone should be 5-20 mm, and the clay content shall not be more than 5%. The bottom of the hole shall be compacted before filling; the pile shall be filled and compacted in layers. The degree of compaction of the filled material should not be less than 93%. After the compacted pile is completed, a cushion layer on top of the piles shall be constructed immediately with lime soil.
- 9 When using a pile foundation to treat the collapsible loess foundation, the pile cap over the top of the pile shall be cement concrete, and the pile head should enter into the pile cap to a depth not less than 50 mm. The reinforced lime soil cushion layer over the pile caps shall be constructed immediately, the geogrid shall be connected by binding, and be tightened and anchored during laying. It shall be covered with lime soil after laying is completed. In the process, the deviation of pile position, the quality of the pile, the quality of the pile cap, the raw material for the geogrid and its laying quality, and the quality of the cushion layer shall be inspected. The bearing capacity test for a single pile shall be carried out when required. Precast piles shall be tested 15 days after the pile construction is completed. For cast-in-place piles the bearing capacity test is conducted 28 days after the pile construction is completed.

Commentary

- 2 *Water is the main cause of loess collapse, and special attention shall be paid to preventing water infiltration into collapsible loess areas.*

- 3 *Foundation treatment is an important task in collapsible loess areas. The common treatment methods include loess being replaced by a cushion layer, impact rolling, dynamic compaction, compaction pile and pile foundation.*
- 7 *The criteria for when dynamic compaction blows can stop is based on the condition that the settlement of the latest blow is less than the settlement of the previous blow. The criteria for stopping compaction is shown in Table 7-1.*

Table 7-1 The criteria for when dynamic compaction tamping can stop

Tamping energy from a single blow	Average settlement of last two blows
Less than 2,000 kN · m	Not more than 50 mm
2,000-4,000 kN · m	Not more than 100 mm
More than 4,000 kN · m	Not more than 200 mm

- 9 *Types of pile foundation include: pile formed without densifying the surrounding soil, dry-made pile without densifying the surrounding soil, pile made with supportive slurry and partly densifying surrounding soil, cast-in-place pile which partly densify surrounding soil, precast pile which densify surrounding soil, and others.*

7.9.4 The treatment of loess sinkholes shall comply with the following requirements:

- 1 Outside the embankment toe line or the top of the side slope of cut section, a loess sinkhole within 80 m of the upper side and 50 m on the lower side of the original ground surface shall be treated. Beaded sinkholes and open sinkholes on the cut slope shall be treated. Sinkholes inclined towards the subgrade, even beyond the specified distance, should be treated.
- 2 Before treating a sinkhole, precautions shall be taken to intercept the surface water and groundwater flowing into the sinkhole.
- 3 For a sinkhole being treated by filling with sand, it shall be sealed with a layer of 6%-8% lime soil up to within 0.5 m below the ground surface and then compacted.
- 4 Appropriate methods shall be applied to deal with a loess sinkhole that endangers the safety of the subgrade based on their depth and size. Table 7.9.4 lists common treatment methods.

Table 7.9.4 Sinkhole treatment methods

Treatment method	Backfill and compaction	Open cut and then backfill and compaction	Excavating a shaft and then backfill	Grouting or blasting/backfill	Filling with sand
Application condition	Open sinkhole	Filled depth of sinkhole ≤ 3 m	$3 \text{ m} < \text{Filled depth of sinkhole} \leq 6 \text{ m}$	Filled depth of sinkhole $> 6 \text{ m}$	Filled depth of sinkhole $\leq 3 \text{ m}$ 、diameter $\leq 2 \text{ m}$ 、hole shaft is straight

- 5 A sinkhole opening that is still exposed after treatment shall be treated with an impervious material such as lime soil. The thickness of the impervious layer shall not be less than 500 mm, and the surface of the sinkhole opening shall be above the surrounding ground.

Commentary

An underground ditch, underground hole and or an underground cave in a loess region formed by water erosion are collectively referred to as sinking holes, and the sinking holes are generally in the shape of a shaft or beads-on-a-string. Sinkhole treatment is a special task in a loess area. Water is the main factor in the formation of sinkholes, and the incoming water flow needs to be completely blocked.

7.9.5 Fill for a loess embankment shall comply with the following requirements:

- 1 Filling of loess shall comply with the requirements of Table 4.4.3 of the *Specifications*. When the CBR value does not meet the requirements, it may be improved by adding lime.
- 2 Loess shall not be used in a flooded part of a subgrade, and aged loess should not be used as roadbed fill.
- 3 Topsoil and loose soil layers shall be removed from the joint between fill and cut. The top should be excavated into benches with the height of a bench not exceeding 2 m and width of not less than 2 m, and the benches shall be compacted.
- 4 The moisture content of loess during rolling should be controlled within the optimum moisture content $\pm 2\%$.
- 5 When the soil in a roadbed is replaced with a non-loess filler, it shall be carried out according to the requirements of Section 4.4 of the *Specifications*.
- 6 The slots in the slope from rain erosion shall be excavated into benches and be compacted.

- 7 Compaction of a high embankment shall be proof-rolled by impact rolling or dynamic compaction.

Commentary

- 2 *The permeability of Q1 and Q2 aged loess is poor, and the large soil clumps are not readily crushed, therefore this material is not suitable for use in the roadbed.*
- 3 *A loess area is full of gullies and loess has a good vertical joint morphology. Most of the natural gullies are steep and deep, so it is necessary to excavate benches at the top of the connection between fill and cut.*

7.9.6 The construction of road cut section in a loess area shall comply with the following requirements:

- 1 Before construction, the unsuitable loess sinkholes on both sides of the top edges of the cutting slope shall be treated. The cracks and depressions with accumulated water near the top edge of a cut section shall be filled and compacted. The impermeable interception ditch or water barrier shall be constructed on the top edge of the cut section when the ground surface is flat or the natural slope inclines to the embankment.
- 2 When approaching the elevation of the roadbed, the cutting should be made by from top down. If the roadbed needs to be treated, the roadbed shall be formed after treatment.
- 3 During construction, the stratum occurrence and groundwater shall be recorded. If there are conditions that are harmful to the stability of the slope or there are signs of severe slope deformation, immediate feedback shall be given in order to deal with them.
- 4 The side ditch of the subgrade should be completed after the foundation is treated and before the roadbed is constructed.

7.9.7 The settlement and displacement of the side slope and its top should be monitored on a high embankment constructed with loess, an embankment on a steep slope section, embankment over the collapsible loess foundation, and deep cut section. The arrangement of monitoring points, observation frequency and monitoring period shall meet the requirements. Deformation monitoring shall be carried out in a deep cutting slope s when required.

7.10 Subgrade in saline soil region

7.10.1 The original ground surface and subgrade foundation treatment shall comply with the

following requirements:

- 1 Before constructing the subgrade fill, the salt content and water content of the topsoil shall be remeasured and be compared with the design data, and the groundwater level shall be clearly determined. If it does not conform to the design data, feedback shall be provided for processing.
- 2 The shallow salt crust shall be removed and the ground shall be compacted.
- 3 For wet depressions, waterlogged depressions or soft and weak ground, drainage works shall be constructed. Foundation treatment such as dredging and replacement, dynamic consolidation, replacement, gravel pile and other foundation treatment methods shall be adopted.
- 4 Rock salt may be used as a fill material for an embankment in the section with a dry salt-lake. Areas with salt caverns, ponds and ditches shall be replaced with gravel, drift sand, pebbles or salt cap rocks.

7.10.2 Embankment fill shall comply with the following requirements:

- 1 Saline soil shall be classified according to Table 7.10.2-1 and Table 7.10.2-2 based on the nature of the salt properties and degree of salinity.

Table 7.10.2-1 Saline soils classified based on the nature of the salt properties

Saline soil classification	Ratio of ions	
	$\text{Cl}^-/\text{SO}_4^{2-}$	$\text{CO}_3^{2-} + \text{HCO}_3^-/\text{Cl}^- + \text{SO}_4^{2-}$
Chlorine saline soil	> 2	—
Sub-chlorine saline soil	1-2	—
Sub-sulphate saline soil	0.3-1.0	—
Sulphate saline soil	< 0.3	—
Carbonated saline soil	—	> 0.3

Note: Ion content is measured by the Millimolar number of ions per 1 kg of soil (mmol/kg).

Table 7.10.2-2 Saline soils classified based on the degree of salinity

Saline soil classification	Average salt content of fine grain soil layer (in percentage of mass)		Average salt content of coarse grain soil through 1 mm sieve (in percentage of mass)	
	Chlorine saline, Sub-chlorine saline soil	Sulphate saline, Sub-sulphate saline soil	Chlorine saline, Sub-chlorine saline soil	Sulphate saline, Sub-sulphate saline soil
Weakly saline soil	0.3-1.0	0.3-0.5	2.0-5.0	0.5-1.5

continued

Saline soil classification	Average salt content of fine grain soil layer (in percentage of mass)		Average salt content of coarse grain soil through 1 mm sieve (in percentage of mass)	
	Chlorine saline, Sub-chlorine saline soil	Sulphate saline, Sub-sulphate saline soil	Chlorine saline, Sub-chlorine saline soil	Sulphate saline, Sub-sulphate saline soil
Medium saline soil	1.0-5.0	0.5-2.0	5.0-8.0	1.5-3.0
Intensely saline soil	5.0-8.0	2.0-5.0	8.0-10.0	3.0-6.0
Super saline soil	>8.0	>5.0	>10.0	>6.0

Note: The ion content is measured by the total salt content in 100 g dry soil.

2 The saline soil embankment fill shall comply with the requirements in Table 7.10.2-3.

Table 7.10.2-3 Applicability of saline soil as subgrade fill

Soil class	Saline type	Degree of salinity	Motorway, Class 1 highway			Class 2 highway			Class 3,4 highway	
			Roadbed	Upper embankment	Lower embankment	Roadbed	Upper embankment	Lower embankment	Roadbed	Upper embankment
Fine grain soil	Chlorine saline soil	Weakly saline soil	×	○	○	○	○	○	○	○
		Medium saline soil	×	×	○	×	▲ ²	○	×	○
		Intensely saline soil	×	×	×	×	×	▲ ³	×	▲ ³
		Super saline soil	×	×	×	×	×	▲ ³	×	×
	Sulphate saline soil	Weakly saline soil	×	×	○	×	○	○	▲ ²	○
		Medium saline soil	×	×	×	×	×	○	×	▲ ²
		Intensely saline soil	×	×	×	×	×	×	×	×
		Super saline soil	×	×	×	×	×	×	×	×
Coarse grain soil	Chlorine saline soil	Weakly saline soil	▲ ¹	○	○	○	○	○	○	○
		Medium saline soil	×	▲ ¹ ▲ ²	○	▲ ¹	○	○	○	○
		Intensely saline soil	×	×	○	×	▲ ³	○	×	○

continued

Soil class	Saline type	Degree of salinity	Motorway, Class 1 highway			Class 2 highway			Class 3,4 highway	
			Roadbed	Upper embankment	Lower embankment	Roadbed	Upper embankment	Lower embankment	Roadbed	Upper embankment
Coarse grain soil	Chlorine saline soil	Super saline soil	×	×	×	×	×	▲ ³	×	▲ ³
	Sulphate saline soil	Weakly saline soil	▲ ¹ ▲ ²	○	○	▲ ¹	○	○	○	○
		Medium saline soil	×	×	○	×	○	○	▲ ¹	○
		Intensely saline soil	×	×	×	×	×	▲ ¹	×	▲ ³
		Super saline soil	×	×	×	×	×	×	×	×

Note: ○ means applicable; × means inapplicable.

▲¹: Coarse grain soil other than sand gravel containing fine grain soil is applicable.

▲²: Applicable in a road section where there is no long-term accumulated water on the surface, and the groundwater level is below 3 m.

▲³: Applicable in extremely arid area after verification.

- 3 Soil on the surface that does not meet the design requirements shall be removed. When the moisture content of the soil in a borrow pit is too high, temporary drainage ditches or water barriers shall be made by adapting to the landform and actual conditions to drain away or intercept surface water and reduce the groundwater level. Alternatively, methods like excavating trenches or turning the subsoil to facilitate drying may be used to reduce the moisture content.
- 4 The fill shall not contain grass roots, salt blocks or other debris, and the content of organic matter should not be greater than 1%.
- 5 When the material is from a single source, a set of salt content samples shall be tested for every 5,000 m³ of roadbed fill and every 10,000 m³ of embankment fill. Fill from different material sources shall be tested separately.
- 6 When gypsum is used as fill, its honeycomb structure shall first be destroyed, and there is no restriction on the gypsum content, but the degree of compaction shall be ensured.

7.10.3 Embankment fill shall comply with the following requirements:

- 1 Soil borrow pits at the side of the road shall be well-drained according to the design

requirements and shall meet the environmental protection requirements.

- 2 A saline soil embankment shall be filled and compacted in layers. The loose layer thickness should not exceed 300 mm, and the moisture content should be controlled at the optimum moisture content $\pm 2\%$ for the process of rolling. The compacted layer thickness of coarse-grained soil should not exceed 300 mm, and the compacted layer thickness of drift sand should not exceed 400 mm. Rainy days are not suitable for construction.
 - 3 Saline soil should not be filled behind both bridge abutments and on both sides of a culvert.
 - 4 The compaction criteria for saline soil shall comply with the requirements in Table 4.4.3.
 - 5 The construction of a saline soil embankment shall be carried out continuously from starting the foundation treatment. In a section where a separation layer is placed, the fill shall be continuously built to the top of the separation layer.
 - 6 In a cohesive saline soil area with high groundwater level, the construction should be carried out in summer. In an area of sandy saline soil construction should be in spring and early summer. In an area with intensely saline soil, construction should be carried out in spring when the surface salt content is low.
 - 7 For sections with a berm, the berm should be filled in layers, and the degree of compaction shall not be less than 90%.
- 7.10.4 A geosynthetic material separation layer shall comply with the following requirements:
- 1 The geosynthetic materials shall comply with the design requirements and the relevant provisions of the current *Technical Specifications for the Application of Geosynthetics in Highway* (JTG/T D32).
 - 2 The surface unevenness and transverse slope of the subgrade shall meet the requirements. The surface of the subgrade shall not have sharp points from broken aggregate, so as to avoid puncturing the geomembrane.
 - 3 Geosynthetic materials shall be laid over the full cross-sectional width of the subgrade, be laid flat and tightly attached to the underlying layer and without folds. After being laid, it shall be checked for damage, and any damaged area shall be reinforced by covering with a piece of geosynthetic material to prevent water leakage.

- 4 After completion of laying the geosynthetic materials, pedestrians, livestock and any kind of vehicles are strictly prohibited to travel on it, and the upper subgrade layer shall be filled immediately to avoid sunlight exposure.
- 5 A section to be filled with a coarse-grained soil over the geomembrane shall have a protective layer over the geomembrane. The thickness of the upper protective layer should not be less than 200 mm. After the protective layer is placed, it shall be rolled 2 to 3 times, and then a layer of coarse grained soil shall be placed over it, and they shall be rolled together. The total thickness of the two layers shall not exceed 400 mm.

7.10.5 A gravel and crushed stone separation layer shall meet the following requirements:

- 1 The filter layer should be made of permeable geotextile.
- 2 A gravel and crushed stone separation layer shall be made by first laying the edge covering with sand gravel soil, and then the whole layer shall be paved at one time. The crown slope shall be 2% to 5%.
- 3 The compaction of a gravel and crushed stone separation layer shall be rolled from each edge of the subgrade to the center line.

7.10.6 A drift sand separation layer shall comply with the following requirements:

- 1 The thickness should not be less than 400 mm, and the silt and clay content shall be less than 5%.
- 2 Filling and dry compaction may be adopted, and the degree of compaction shall comply with the requirements in Table 4.4.3.
- 3 When the design thickness is greater than 600 mm it shall be placed in layers, and the thickness of each layer should be 300-400 mm. When the design thickness is not more than 600 mm, the full thickness may be placed at one time.

7.10.7 When a soil road bed in a cut section is treated by replacement, the fill shall comply with the requirements of Clause 7.10.2 of the *Specifications*.

7.10.8 Subgrade drainage shall comply with the following requirements:

- 1 During the construction process, the drainage system shall be installed first. There shall be

no water accumulation in or near the subgrade.

- 2 In areas that are difficult to drain or where the soil borrow pit may be flooded, a longitudinal barrier with a height not less than 0.5 m and a top width not less than 1 m shall be built outside the soil borrow pit, which is on one or both sides of the subgrade.
- 3 In an area with a high groundwater level, besides diverting the surface water, the side ditches or drainage ditches on both sides shall be deepened.

7.11 Subgrade in permafrost region

7.11.1 Subgrade construction in a permafrost region shall comply with the following requirements:

- 1 The construction organization design shall be based on the following characteristics: oxygen-deficit at high altitude, alpine cold, permafrost and environmental protection.
- 2 The excavation in a permafrost section with high ice content should be carried out during the cold season, and the construction of the foundation, slope replacement and insulation layer should be completed before the end of June. If constructing an embankment in the cold season, effective insulation measures shall be made with the fill materials.
- 3 Before subgrade construction, an effective temporary drainage system shall be in place, and no long-term accumulated surface water shall be within 100 m on either side of the subgrade.
- 4 If spoils from tunnelling and cutting are frozen soils with little ice or with frozen ice, they may be used to fill the subgrade or for thermal insulation berm if after melting, they meet the requirements for fill.
- 5 Peat soil, turf, clay soil, organic soil and frozen soil blocks shall not be used for embankment fill.
- 6 The turf and humus from topsoil clearing should be stockpiled at selected sites, and covered and watered as maintenance. This turf shall be used in future for protecting the subgrade slope or greening a backfilled borrow pit.

Commentary

The infiltration of high temperature surface water will lead to thawing of frozen soil. This clause ensures that the drainage system is prepared before the construction of subgrade to prevent subgrade construction from changing the original water system and causing the frozen soil near the subgrade thawing, thus affecting the stability of the subgrade.

7.11.2 Embankment construction in permafrost areas shall comply with the following requirements:

- 1 Embankment construction should be carried out during the warm season. Sections with thick ground ice should be constructed during the cold season, but there shall be no accumulated snow during construction.
- 2 Embankment fill shall be borrowed centrally, and the soil shall not be borrowed randomly from both sides of the subgrade. In sections with thaw settlement and severe thaw settlement, the distance between the borrow pit and the slope toe of the embankment shall not be less than 200 m.
- 3 The berm shall be rolled at the same time. The degree of compaction shall be more than 80%. The berm shall be constructed at the same pace as the main embankment.

Commentary

After soil is taken from the borrow pit, the pit often becomes a water pond, which has a great impact on the nearby permafrost. In order to avoid the impact of thawing settlement of the frozen soil affecting the subgrade, this clause stipulates the distance between the borrow pit and the subgrade in the section distributed with thaw settlement and severe thaw settlement permafrost spots.

7.11.3 A cut in a permafrost region shall comply with the following requirements:

- 1 Measures such as water isolation, drainage, soil replacement and protective layer shall be adopted in the construction of a cut section.
- 2 When the soil of the roadbed in the cut section is replaced with coarse grained soil, it should be constructed during the cold season. When replaced with other fill materials, construction should be carried out during the warm season.
- 3 When a cut is made to the depth from which the replacement is made, the exposed ice shall be covered during the day time and opened at night. During the warm season, after the subgrade cut residue is cleared and formed into the required shape, the part to be replaced shall be backfilled immediately.

- 4 During the construction of a deep cutting, the thawing of frozen soil on the cutting surface shall be monitored and necessary cooling measures shall be taken.

7.11.4 The laying of the thermal insulation layer shall comply with the following requirements:

- 1 The laying of the thermal insulation layer shall be carried out after the level and degree of compaction of the underlying layer meet the design requirements. The insulation layer shall be spliced according to the designed splicing method.
- 2 Construction machinery shall not travel directly on the completed thermal insulation layer. After the upper fill layer is placed with a compacted thickness of more than 200 mm, the roller may then compact the layer.

7.11.5 The installation of ventilation ducts shall comply with the following requirements:

- 1 The cross-sectional dimensions and material strength of the ventilation ducts shall comply with the design requirements.
- 2 The longitudinal spacing between ventilation ducts along the road shall meet the design requirements, and the bottom should be 0.5-0.7 m higher than the original ground.
- 3 The ventilation duct shall be installed by the fill-then-cut method, and the embankment shall be filled to more than 200 mm above the upper design elevation of the ventilation pipe. The trench for the duct is then excavated.
- 4 The trench for installing the ventilation duct may be backfilled with medium/coarse sand and compacted with a small roller or plate compactor.
- 5 After the subgrade is completed, the ventilation duct shall be manually cleaned to ensure that no debris such as gravel is left in the duct.

Commentary

The main function of the ventilation duct is to remove heat absorbed by the road through airflow inside the ventilation duct to prevent heat from transmitting into the ground. This prevents affecting the stability of the frozen soil. Therefore, the ventilation ducts do not need to be too much higher than the ground surface. The ventilation effect is related to the transverse slope of the duct and its intersection angle with the prevailing wind direction.

7.11.6 The thermosyphon installation shall comply with the following requirements:

- 1 When the thermosyphon is temporarily stored, it shall be away from the fire source. When stored in the open, it should be covered.
- 2 The thermosyphon shall be installed by an engineering driller after the subgrade construction is completed and the slopes on both sides of the road are leveled.
- 3 Thermosyphon installation shall be carried out immediately after the completion of drilling.
- 4 After the thermosyphon is placed into the hole, it shall be backfilled immediately with sand.

7.11.7 The construction of a retaining wall in permafrost with a high ice content should be carried out during the cold season and shall be executed continuously. The foundation shall be backfilled immediately after its completion. If, after the foundation pit is excavated it is found that the foundation is fully or partially buried in an ice layer or ice with enclosed soil layer, special treatment shall be carried out. The foundation shall be backfilled and compacted immediately after its completion.

7.11.8 Ground temperature and subgrade deformation monitoring shall be carried out according to design requirements for Class 2 and above highways in permafrost areas.

7.12 Subgrade in an area with aeolian sand

7.12.1 Construction preparation shall comply with the following requirements:

- 1 The maximum dry density of aeolian sand fill shall be determined by the heavy compaction test.
- 2 The vegetation and surface crust outside the right of way shall not be damaged when clearing the topsoil. The turf and humus produced from the topsoil clearing shall be stockpiled centrally.
- 3 Control stakes for surveying and right of way stakes shall be protected and clearly marked.
- 4 Construction machinery that is efficient, high temperature resistant and wind and sand proof shall be used.

Commentary

- 2 *Turf and humus may be used to rehabilitate borrow pits or dumping sites.*

- 4 *The particle size of aeolian sand is very fine, which can easily cause mechanical wear. Consequently, high sealing requirements are placed on construction machinery.*

7.12.2 The establishment of borrow pits and dumping sites shall be in accordance with the following requirements:

- 1 Suitable material from a cut shall be used as fill, and the earthwork allocation plan shall be economical and reasonable.
- 2 Sand dunes and sand hillocks on the upwind side of the prevailing wind direction shall be selected as borrow sites. When borrowing from the side of the road, the borrow pit shall be located more than 5 m away from the toe of the leeward slope.
- 3 It is not advisable to borrow soil from a depressed area between hills just for its proximity. It is not advisable to borrow soil from a flat area with coarse sand. Borrow pits and waste dumps shall not be established where there is vegetation or hard surface crust.
- 4 The waste dump shall be located in a low place on the leeward side of the prevailing wind direction.
- 5 After borrowing and spoiling is finished, the borrow pits and waste dumps shall be roughly leveled and their surfaces shall be protected.

7.12.3 Subgrade construction shall comply with the following requirements:

- 1 Construction should be carried during days with low wind speed, and excavation and filling operations shall be stopped if there is a strong wind.
- 2 Aeolian sand fill shall not contain detrimental substances such as weeds, organic matter and clay lumps, and the foundation shall be treated and compacted before filling commences.
- 3 When the foundation of the embankment or the bottom of the subgrade in a cut section is silty soil that needs to be replaced, the thickness of the replacement aeolian sand shall not be less than 500 mm. The content of particles smaller than 0.075 mm shall be less than 10% in the aeolian sand.
- 4 Before the embankment fill is placed, trial sections of various construction schemes shall be evaluated. The length of trial sections of various schemes shall not be less than 100 m, and actual construction shall be carried out according to the scheme selected from the trial

sections.

- 5 The embankment shall be filled from low to the high. Layers are horizontally divided, with each layer being filled, leveled and compacted, layer by layer. The fill and excavation interface shall also be compacted. For the subgrade with covering soil edge, the soil edge on both sides shall be first constructed layer by layer.
- 6 Before the construction of the cut section, the earthwork allocation plan shall be verified and confirmed. The excavation shall be carried out according to the design shape and size of subgrade, and the excavated material shall be transferred to the designated fill section or the waste dump.
- 7 When the upper subgrade is lime-stabilized soil, road mixing or plant-mixing methods may be used.
- 8 After the subgrade is completed, the side slope shall be trimmed, and protection works and sand control works shall be implemented.

7.12.4 Subgrade compaction shall comply with the following requirements:

- 1 When the natural moisture content of aeolian sand is less than 2%, the method of vibratory compaction on the dry fill is advised to be used as the initial and final compaction, layer by layer.
- 2 When the water supply is plentiful and the natural moisture content of aeolian sand is greater than 2%, it is advisable to compact the sand after sprinkling with water or to settle the sand by flooding, layer by layer.
- 3 The final compaction on the top layer of the subgrade should be applied after the geotextile and sealing layer are laid or the subbase course is paved. Compaction shall be done by heavy duty vibratory roller with its vibrating function turning on.
- 4 The degree of compaction of the subgrade shall comply with the requirements in Table 4.4.3. Where the requirements are not met, additional compaction shall be applied. When it is difficult to test the degree of compaction of the current layer, it may be tested just before the upper layer is placed.
- 5 The cutting-ring method should be used to determine the compaction. When a density meter method is used for testing, the density meter shall be calibrated and compared with the

cutting-ring method.

Commentary

The compaction method shall be selected according to the condition of the local water source and the natural moisture content of the aeolian sand. For vibratory compaction of dry sand, the layer thickness is generally controlled to 400-500 mm.

For compaction of dry sand, the initial compaction of each layer may be made by a bulldozer passing over the sand layer 2 times.

The final vibratory compaction of each layer of dry sand: When the roller can travel directly on the desert subgrade, the final compaction of each layer can be directly carried out by heavy vibratory roller, but the edge is generally carried out by non-vibration compaction; When the roller cannot travel directly on the desert subgrade, the final compaction of each layer is still carried out by bulldozer, and generally it can be made by passing 3 times over the sand layer.

7.12.5 The laying of geosynthetic materials shall comply with the following requirements:

- 1 If the geotextile is placed on top of the subgrade, it shall be laid by spreading it out after the subgrade reaches the design level and is loosened and re-compacted. The geotextile shall be stretched to be flat and is compacted statically by a roller. A section being constructed shall have a length not be greater than 500 m. Non-operational equipment shall not travel on the geotextile after it is spread.
- 2 The lap length of the geotextile shall not be less than 400 mm laterally and not less than 500 mm longitudinally. The lap shall be correctly connected.
- 3 The geotextile shall be covered with a sealing material or subbase material immediately after being laid. Vehicles shall not drive or turn around directly on the geotextile when unloading the covering material.
- 4 When laying geogrids or geocells on top of the subgrade or in a high embankment, they shall be laid according to the design, type, location and scope.
- 5 The quality of geotextiles and geosynthetic materials shall meet the requirements of design and relevant current standards.
- 6 Geosynthetics shall be stored under covering, and the laid synthetics should be covered on the same day.

Commentary

Laying geosynthetic materials on a sand base may reinforce the sand base, effectively preventing the sand base from deforming under load, and can also facilitate construction

7.12.6 The construction of protective and sand control works shall comply with the following requirements:

- 1 The protection works and sand control works in the section with completed subgrade should be constructed with maximum effort in a period with little wind, low wind speed or in the rainy season, and shall be completed before the season with strong winds.
- 2 The sand control works on the windward side should precede the construction of the subgrade. The sand control works on both sides may be constructed at the same time after the subgrade is completed.
- 3 The construction of sand containment works should precede the construction of sand fixation works, or both may also be carried out simultaneously.
- 4 The type, form, shape, size, material and quality of sand control work shall meet the requirements.

Commentary

Sand control works include: sand containment works (set at the outer edge of the protected zone), sand fixation works (set at the inner side of the protected zone to prevent side slope from wind erosion), sand transport works (making a road surface with reasonable cross-section and smooth so that the drifting sand can travel without obstruction).

7.12.7 A sand fence shall be set along the main ridge or subsidiary ridge of the dune, and shall be located at the windward slope 1.0-1.5 m away from the ridge line. The spacing between the fence posts shall be increased in sections with large terrain undulations, and the bottom of the fence shall be in close contact with the ground without any gaps.

Commentary

Measures that keep aeolian sand being contained from a certain distance away from the road are called sand containment works. Sand containment is generally achieved by using various sand barriers. Sand barriers have many forms, like fence, wall, dyke and band. The most common barrier is a fence, including reed fence, nylon mesh fence and sprig fence.

7.12.8 The construction of sand fixation works shall comply with the following requirements:

- 1 The sand surface shall be leveled before the construction of sand fixation works.
- 2 When using natural gravel, salt cap rocks and clay to cover the sand surface, their particle sizes should not be more than 60 mm, and the thickness should be between 20 and 100 mm.
- 3 When covering the sand surface with sprigs or thatch, all kinds of thatch and sprig shall be cut into short pieces with the length of 300-500 mm. The short pieces shall be filled with sand and compacted after being laid flat. The sprigs or thatch can also be tied into bundles and laid flat and fixed.
- 4 During fixing sand by adopting the grid made of sprigs or thatch, the short sprigs or thatch shall be inserted into the sand and fixed, and the inserted depth and exposed height shall meet the requirements. For fixing sand by a grid made of earth, the height of the earth bank shall meet the requirements. Grids shall be straight both horizontally and vertically with clear lines.
- 5 For fixing sand by adopting the planting method, the types of saplings or shrubs, their planting spacing and layout shall meet the requirements.

Commentary

The measures to prevent the drift of aeolian sand are called sand fixation works. There are several kinds of sand fixation methods as follows:

- (1) Covering sand surface method: Including sprigs or thatch covering sand surface and soil (clay, salt crust rock, gravel) covering sand surface for sand fixation.*
- (2) Sand barrier method: Including sprig or thatch sand fixing grid, soil sand fixing grid.*
- (3) Chemical sand fixation method: Including asphalt (asphaltic sand) to fix sand, sand fixation agent to consolidate the sand surface.*
- (4) Geotechnical sandbag fixation method: Finned sandbag or finless sandbag.*
- (5) Geocell sand fixation method: Geocell sand barrier.*
- (6) Biological sand fixation method: Using drip irrigation and other measures to build artificial ecological forests.*

7.12.9 For sections of road where sand transport is controlled, bumps and other obstacles within 20 to 30 m on both sides of the subgrade shall be removed, and the site shall be leveled. Inflammable materials within the fire isolation zone shall be removed.

7.13 Subgrade in an area with snow hazards

7.13.1 Before construction, the snow hazards shall be investigated and checked for their types, ranges, scales, positions and local control experiences along the highway. The changes in engineering geology and hydrogeology shall also be checked and a practical construction plan shall be formulated.

7.13.2 Borrow pits shall not be established within 20 m on both sides of the road. nor waste soil or debris dump shall be made. The vegetation and natural landscape on both sides of the road shall be protected to reduce snow hazards that may occur as a result of the changed landform caused by construction.

7.13.3 Gravel soil with good water stability should be used as fill for the subgrade in the sections covered with snow.

7.13.4 Before the thaw period, the drainage system of the road shall be cleaned to ensure that thaw water is discharged smoothly.

7.13.5 Subgrade drainage facilities and slope protection shall be constructed in advance, and the stability of the subgrade and side slope which can be affected by frost heave or infiltration of thaw water in the spring season shall be fully considered.

7.13.6 The subgrade protection masonry works in snow areas shall meet the design requirements, and the rubble, blocks and mortar for the masonry shall meet the frost resistance requirements. The mortar strength shall not be less than M10, and mortar shall be dense and full, and shall not be frozen before reaching 70% of the design strength. When using dry masonry, large blocks of stone shall be used.

7.13.7 The subgrade construction in avalanche areas shall comply with the following requirements:

- 1 Special observation instruments and personnel shall be equipped for monitoring and providing advance warning of a landslide, rock fall, rain and snow, and large amount of flowing groundwater.

- 2 The collapse, falling debris and a landslide caused by the operation of construction machinery shall be monitored and prevented.
 - 3 In the same avalanche area, the construction of a snow prevention project shall start from the source of the avalanche, and a work item may begin only after the completion of the preceding work item.
 - 4 During the construction in a cut, the benches shall be excavated along the contour line, and shall be excavated from top to bottom, and the spoil shall be placed under the benches.
 - 5 A snow stabilization fence shall be placed along the contour line. A snow stabilization fence should have multiple rows, the highest row of fences shall be near the avalanche starting point and below the snow cornice. The stability of fence foundation and the anchoring requirements for the bars shall be secured. The degree of compaction of the backfill shall not be less than 96% , and the angle between fence and slope shall meet the design requirements.
 - 6 The layout of the snow prevention forest shall start from the avalanche source zone to the avalanche movement area. Fast-growing tree species suitable for the local environment shall be planted in stages from top to bottom.
 - 7 When constructing an avalanche prevention dam from reinforced concrete or mortar masonry, the degree of compaction of the original ground foundation and backfill shall not be less than 96% . The backfill behind the wall shall be connected integrally with the hillside. The structure shall be waterproof, drained and freeze-thaw resistant.
- 7.13.8 Subgrade construction in wind-blown snow areas shall comply with the following requirements:
- 1 Obstacles on both sides of the subgrade within a range of not less than 30 m from the toe of the slope on both sides shall be removed, and the ground surface shall be leveled. Snow prevention facilities shall be installed if necessary.
 - 2 The location of a borrow pit shall be selected according to the local prevailing wind direction and wind speed. In a road section where the wind blows from a constant direction, the borrow pit should be located on the leeward side of the embankment, and the distance from the slope toe of the embankment should be not be less than 50 m. In a section with variable wind from two directions, it is advised to set up a centralized borrow pit. The distance from the slope toe of the road should not be less than 100 m, and its slope shall be evened after the

completion of the construction. The cross-section parallel to the main wind direction shall be smooth. Borrow pits may also be used as a snow storage facility if necessary.

- 3 The spoil from subgrade construction in the snow blowing section shall be discarded to the leeward side, and the distance from the slope toe of the subgrade or the top edge of the cut slope shall not be less than 100 m, and shall be levelled.
- 4 Extra excavation in a rock cut section for a snow catching platform shall be dealt with in the following ways:
 - 1) Materials with good water stability and freeze-thaw resistance shall be selected as backfill material for the extra excavation part, and the degree of compaction shall comply with the requirements in Table 4.4.3 of the *Specifications*.
 - 2) A snow catching platform shall have a 2% slope along the direction away from the subgrade and shall be compacted.
- 5 The degree of compaction of the roadbed and snow catching platform in a soil cutting or in a section with a weathered mud shale which would disintegrate and soften by water shall comply with the requirements in Table 4.4.3. The subgrade slope shall be constructed according to the design requirements for snow damage prevention, and the obstacles within the designated range shall be cleared away.
- 6 The side slope of the subgrade in a cutting should not be steeper than 1:4. If the amount of excavation work left outside of the cut slope is not large, it is better to excavate it all.

7.14 Subgrade in an area with frozen overflowed groundwater

7.14.1 Before construction, the local topography, geology, meteorology, the source for frozen overflowed groundwater, its type and scale, harmful situations, local prevention and control experience shall be investigated and checked, and a practical construction plan shall be developed.

7.14.2 Subgrade shall be constructed in a way of reducing the impact on the original natural drainage system. When building structures such as for drainage, retention and interception, the existing naturally formed drainage system shall be kept unimpeded.

7.14.3 In the frozen or alpine cold area where groundwater may turn into ice, the subgrade fill

shall consist of sand gravel soil with good water stability.

7.14.4 For frozen overflowed groundwater on the hillside, an ice catching ditch may be placed outside the subgrade side slope to channel the water into a nearby river or culvert. The cross section of the ice catching ditch shall be determined according to the terrain, geology, amount of seepage water and ice catching capacity, and proper drainage facilities shall be connected.

7.14.5 For frozen overflowed groundwater in valleys, ice accumulation pits may be placed in the natural flat areas to accumulate ice. The size of an ice pit shall be determined according to the terrain, geology, amount of seepage water and ice accumulation capacity, and proper drainage facilities shall be connected.

7.14.6 An ice retaining wall shall be placed on the outer side of the side ditch to prevent the ice from flowing to the road surface. The height and width of the ice retaining wall shall be determined according to its capacity to accumulate ice.

7.14.7 Block stone, rubble and mortar for masonry for an ice retaining wall shall meet the requirements of frost resistance. The strength of the mortar shall not be less than M10, and it shall not be frozen before reaching 70% of the design strength. Masonry mortar shall be dense and without voids. When masonry is laid dry it is advisable to use block stones.

7.14.8 An ice catching ditch and ice catching pit in the soil section shall meet the design requirements. If the design did not specify them, the ice catching ditch and its side ditch shall be protected by mortar masonry. For an ice catching pit in the soil section, based on the conditions of water seepage and soil quality of the slope, a dry masonry short wall shall be set up at the toe of the side slope, and its side ditch shall be protected by mortar masonry.

7.14.9 If there is underground water seepage, drainage facilities such as underdrain and blind ditch shall be used to divert the underground water away from the subgrade.

7.14.10 The construction of underground drainage shall comply with the following requirements:

- 1 Underground drainage facilities shall be below the freezing depth, and should not be less than 2 m below the road surface. A filter layer, waterproof layer and water outlet shall be well constructed.
- 2 Underground drainage facilities shall be completed before the subgrade is completed.
- 3 The underground drainage structure shall be excavated in layers and any seepage water or

surface water shall be discharged at the same time. The upper opening shall be connected with the aquifer through a closed infiltration tank, the lower opening shall discharge water to a place beyond the slope toe of the subgrade, and the water outlet shall be sealed.

7.15 Subgrade over abandoned underground mines

7.15.1 Preparation for construction shall comply with the following requirements:

- 1 The buried depth of the underground mine, the lithology, thickness and integrity of its cap rock, the development degree of the caving zone and fracture zone, and the connectivity between fractures and other conditions shall be checked. The type of underground mine, and proposed treatment method, as well as the boundary of treatment range or support positions shall be confirmed and marked, and the special construction plan shall be designed.
- 2 Survey control points shall be set outside the influence area of the abandoned underground mine and protected.
- 3 When there is seepage water on the surface, a blind ditch or an interception underdrain shall be constructed to divert the water away from the subgrade.

Commentary

The types of underground mine are divided into long wall, irregular column, single tunnel, strip, short walling and fill.

7.15.2 The treatment method, length, width and depth of the area to be treated for an underground mine shall meet the design requirements, and the strength and stability of the subgrade foundation after treatment shall meet the design requirements.

7.15.3 When treating an underground mine by grouting, the construction shall comply with the following requirements:

- 1 Before construction, a trial road section shall be built on a representative section. The number of bored holes for trial grouting shall not be less than 3% of the total number of holes. The drilling rig, grouting equipment, test or inspection equipment, drilling and grouting technology, and various parameters of the grout shall be determined and selected from the trial section.

- 2 When the grouting area is near a mine tunnel, the grouting stop wall shall be built in the tunnel according to the design requirements.
- 3 When an underground mine is generally flat, the hole boring and grouting in the same road section shall be carried out in the order of the holes for making a curtain first and holes for grout injection later. When the underground mine is inclined, the construction shall be carried out in the order of the deepest part first and then the shallowest part. Curtain grouting shall be carried out in separate batches with intervals.
- 4 The drill diameter, depth, verticality and position deviation of the drilled hole shall meet the requirements. Clean water drilling shall be adopted when drilling into the fracture zone and caving zone. It is advised to drill with a casing in areas prone to collapse. After the hole is drilled, the hole shall be flushed. For the voids and cracks in a rock formation which does not easily soften, water pressure shall be used to clean the area before grouting. Before grouting, the hole shall be covered for protection.
- 5 The treatment area should be divided into 2 to 3 separate batches for drilling and grouting. If the hole wall is stable, holes should be bored and grouted in batches. If the hole wall is unstable, holes should be grouted one by one.
- 6 Grout should be made by mixing cement, fly ash, clay and other materials with water, and the grout shall be mixed mechanically in a central mixing station. The ratio of water to solid material in the grout, the type and amount of admixture shall be determined by field testing.
- 7 For a single-layer underground mine, or for a multi-layer underground mine whose partitions are thin, or already collapsed with no obvious boundary between layers, drill a hole in one sitting. Drilling shall take place from deepest to shallowest. For a multi-layer underground mine with distinct and widely spaced layers, it is advisable to adopt the method of dividing the tasks by depth. Holes shall be formed in divided groups, from less deep to deepest, and grout is also applied in divided groups. When an underground mine has a large cavity, or cracks have developed, or the underground mine is filled with water at a high flow rate, it is advisable to fill the mine with aggregate such as sand and stone chips first, and then to grout it intermittently. The grout should be mixed with additives such as water glass.
- 8 Measures to block grout shall be taken during grouting. If during the process of grouting, when the grout is spilled, or leaks to the adjacent holes, it shall be handled. Grouting may be terminated and the hole be sealed only after the grouting reaches the terminal condition.

- 9 After treatment, the grout filling condition of the original voids and cracks in the rock body, the integrity degree of the rock mass after grouting, and the compressive strength of the solidified grout shall be tested. It is advisable to use a coring drill for inspection, and the bore hole diameter shall not be less than 91 mm. When the depth of the underground mine is less than 30 m, it is advisable to excavate inspection wells or pits for testing. Inspection drilling and geotechnical testing shall be carried out after a period of treatment.

Commentary

The applicable conditions for the grouting method is that the overburden has collapsed or slide severely after mining, or the mined-out collapsed area is judged to be less stable or unstable.

The parameters of the grout include density, viscosity, grout solidifying rate, initial and final setting time and unconfined compressive strength of the solidified grout.

The grout stopping method from deepest to less deep and one-time grouting includes flange stopper (when the hole wall is stable), stopping plug or casing stopper (when the hole wall is not stable), and grouted from less deep to deepest is stopped by a casing stopper.

The treatment method for spillage or grout leaking is to adjust the grouting pressure or change the grouting stopping measures.

When grout leaking to an adjacent hole occurs, the two holes may be grouted simultaneously if the grouting conditions are satisfied. When the grouting conditions are not satisfied, the hole which receives leakage can be blocked. After the grouting hole is filled completely with grout, the receiving leakage hole can be cleaned and washed, and then grouting can be carried out. The termination condition for grouting is that under the specified termination pressure, the grouting volume is less than 70 L/min and may be maintained for more than 15 min.

Other test methods include geophysical prospecting, drilling with in-hole television, and drilling and then grouting. The qualitative or quantitative evaluation may be made by taking photos, visual inspection, measurement calculation and laboratory testing.

7.15.4 The following requirements shall be fulfilled when an underground mine is treated by supporting with dry masonry or mortar masonry:

- 1 Ventilation measures shall be taken during construction, and the construction order is from inside to outside.
- 2 The minimum size of the rubble shall not be less than 100 mm, the compressive strength of

the mother rock shall not be less than 30 MPa, and the strength grade of the mortar used in the masonry shall meet the design requirements.

- 3 The masonry shall be built in sections and in layers, with a stepped pattern in the laying process, and the top surface of the masonry shall be filled tightly.

Commentary

The applicable condition for this supporting method is that the underground passage or mine tunnel in and out of the mine is in good condition and passable, the mine space is stable and large with good ventilation, conveying material is convenient, and the manual operation conditions are satisfied.

7.15.5 The following requirements shall be met when dynamic compaction is used to treat an underground mine:

- 1 Before construction, the trial dynamic compaction shall be carried out in representative areas, and the formal construction can only be started after the trial meets the requirements. Construction shall be controlled according to the required spacing for compacting points, compacting energy, number of compacting blows on one point and number of overall compacting applications. The detailed construction process may be controlled by referring to the dynamic compaction part of Section 7.6 of the *Specifications*.
- 2 The test results in the construction process shall meet the requirements, otherwise it shall be complemented by more compaction or other effective measures shall be taken to deal with it.
- 3 After the treatment is completed and placed for a period of time, the degree of compaction of the loose body in the deep part of the ground foundation and the treatment effect shall be checked.

Commentary

The applicable conditions of dynamic compaction are that the underground mine is at depth less than 10 m, its overburden layer is weak with low strength. The Technical Code for Ground Treatment of Building (JGJ 79) has detailed specifications on various foundation treatments by dynamic compaction, which can be used as reference.

7.15.6 When the mine is treated by excavating and backfilling, the foundation pit shall be excavated at the required slope, and the backfill shall be compacted in layers.

7.15.7 When the lining reinforcement method is used to treat the mine tunnel, it shall comply with the relevant provisions of the current *Technical Specifications for Construction of Highway Tunnel* (JTG/T 3660).

7.15.8 The treatment effect shall be tested as required. If the test indicators do not meet the specified requirements, the reasons shall be analyzed. Information shall be provided as feedback and dealt with.

7.15.9 During construction and after construction is completed, the treated section should be monitored for horizontal displacement and subsidence. The arrangement of the monitoring points and monitoring accuracy shall comply with the design requirements and the relevant requirements of the current *Standard for engineering surveying* (GB 50026).

Commentary

Under normal circumstances, during the period of treating an underground mine and the normal construction of the subgrade, monitoring shall be made once a week for the first half year. Monitoring shall be continued once a month after half a year till the project is handed over and is accepted. Monitoring shall be made every two months for two years after opening to traffic. When the deformation is significant, the monitoring frequency shall be increased.

7.15.10 When the subgrade foundation over an underground mine is backfilled with sand gravel, crushed stone or rubble, the quality of the fill and the degree of compaction shall meet the design requirements. The normal filling of the subgrade shall comply with the relevant requirements in Chapter 4 of the *Specifications*.

7.16 Subgrade in coastal area

7.16.1 For subgrade construction in coastal areas, a detailed construction scheme shall be formulated based on design requirements and hydrological conditions such as tide level, waves and current.

7.16.2 The subgrade in coastal areas shall be filled with materials with good water stability.

7.16.3 The construction of sloped embankments shall comply with the following requirements:

- 1 Provisions shall be taken to ensure that the embankment fill is not washed away and eroded by the current.

- 2 When the slope is protected by dressed stone, block stone or concrete blocks, or geosynthetic material, the quality of these materials shall meet the relevant requirements. The slope shall be even and the contact surface of the blocks shall be tilted inward, and the blocks shall be attached firmly to the slope.
- 3 The parapet shall be constructed after the settlement of the embankment is mostly completed.

7.16.4 The construction of a vertical wall embankment shall comply with the following requirements:

- 1 A vertical wall embankment shall be filled with stone blocks. The stone blocks shall be embedded and stacked in a staggered manner.
- 2 The rock foundation bed or concealed rock foundation bed formed by the riprap method shall meet the design requirements. The thickness of the foundation bed on the rock or non-rock base shall meet the design requirements.

7.17 Subgrade in reservoir area

7.17.1 A detailed construction scheme shall be made based on the geological and hydrological conditions, and the positional relationship between the design route line and the reservoir bank.

7.17.2 In the construction of a subgrade in a reservoir area, measures shall be taken to reduce pollution in the reservoir water body and the surrounding environment.

7.17.3 When the subgrade is built along the edge of a reservoir or near its bank, the stability of the reservoir bank shall be fully considered and necessary protective measures shall be taken.

7.17.4 The embankment fill material should be made of material with high water permeability.

7.17.5 The slope protection material shall be hard stone with a high strength which does not weather readily. Stone with good frost resistance shall be selected to protect the slope in frozen areas. In the upper reaches of a reservoir, the buried depth of foundation for slope protection works shall meet the design requirements.

7.17.6 The construction of a flooded embankment in the reservoir area shall comply with the following requirements:

- 1 The fill material shall be hard rock which is not easily weathered.
- 2 The masonry thickness of the outer slope of the embankment shall meet the design requirements. The stone block size should not be less than 300 mm. Blocks shall be laid staggered, and with a stepped pattern in the laying process. The blocks shall attach firmly to the side slope. The contact surface of the blocks shall tilt inward.
- 3 For a road section with a high subgrade and deep water, a packed stone protection may be built at the toe of the protected slope which faces the water.

7.18 Subgrade in seasonally frozen region

7.18.1 Constructing a subgrade in a seasonally frozen region shall comply with the following requirements:

- 1 Parameters such as frost heave ratio and natural moisture content of the subgrade fill shall be reconfirmed.
- 2 The subgrade in a seasonally frozen region should be constructed during the non-frozen season. The subgrade built from frost heave susceptible and weak materials shall not be constructed during the freezing season, and the specific index and requirements shall be determined by tests for the construction of the subgrade from non-frost susceptible materials in the freezing season.
- 3 The soil embankment of a motorway and Class 1 highway shall not be constructed during the frozen period. The half-fill and half-cut section and the connecting part between fill and cut shall not be constructed during the frozen period.
- 4 Temporary drainage works shall be built in combination with permanent drainage works.
- 5 The completed subgrade shall be covered with soil and compacted to overwinter. Protective measures such as drainage works for the upper surface and ground surface shall be built.
- 6 The degree of compaction of the overwintering subgrade shall meet the design requirements.
- 7 The subgrade should be constructed after the soil thawed completely during the spring thaw period.

7.18.2 Foundation treatment shall meet the following requirements:

- 1 Before filling, the snow and ice within the foundation range shall be cleared and the foundation shall be compacted. The compaction criteria shall comply with the requirements in Table 4.4.3.
- 2 The section where soil needs to be replaced shall be excavated to the design depth, and an appropriate fill shall be selected. The fill is placed, leveled and compacted at the same time.

7.18.3 Embankment fill material shall meet the following requirements:

- 1 Seasonally frozen soil shall be divided into five categories based on frost heave: non-frost heave, weak frost heave, frost heave, severe frost heave and extreme frost heave, as shown in Table 7.18.3-1.

Table 7.18.3-1 Frost heave severity classification of seasonally freezing and thawing soil

Soil type	Natural water content before frozen $W(\%)$	The minimum distance between the pre-freezing water table and the design frost depth h_w (m)	Average frost heave $\eta(\%)$	Frost heave classification	Frost heave severity classification
Pebble, gravel, coarse or medium sand (the content of particles with size less than 0.075 mm not more than 15%), fine sand (the content of particles with size less than 0.075 mm not more than 10%)	Unsaturated	N/a	$\eta \leq 1$	I	Non-frost heave
	Saturated	Without water separation layer	$1 < \eta \leq 3.5$	II	Weak frost heave
	Saturated	With water separation layer	$3.5 < \eta$	III	Frost heave
	$W \leq 12$	> 1.0	$\eta \leq 1$	I	Non-frost heave
		≤ 1.0	$1 < \eta \leq 3.5$	II	Weak frost heave
	$12 < W \leq 18$	> 1.0	$3.5 < \eta \leq 6$	III	Frost heave
		≤ 1.0	$6 < \eta \leq 12$	IV	Severe frost heave
	$W > 18$	> 0.5	$\eta > 12$	V	Extreme frost heave
		≤ 0.5			
Silty sand	$W \leq 14$	> 1.0	$\eta \leq 1$	I	Non-frost heave
		≤ 1.0	$1 < \eta \leq 3.5$	II	Weak frost heave
	$14 < W \leq 19$	> 1.0	$3.5 < \eta \leq 6$	III	Frost heave
		≤ 1.0	$6 < \eta \leq 12$	IV	Severe frost heave
	$19 < W \leq 23$	> 1.0			
		≤ 1.0			
	$W > 23$	N/a			

continued

Soil type	Natural water content before frozen $W(\%)$	The minimum distance between the pre-freezing water table and the design frost depth $h_w(\text{m})$	Average frost heave $\eta(\%)$	Frost heave classification	Frost heave severity classification
Silty soil	$W \leq 19$	> 1.5	$\eta \leq 1$	I	Non-frost heave
		≤ 1.5	$1 < \eta \leq 3.5$	II	Weak frost heave
	$19 < W \leq 22$	> 1.5			
		≤ 1.5	$3.5 < \eta \leq 6$	III	Frost heave
	$22 < W \leq 26$	> 1.5			
		≤ 1.5	$6 < \eta \leq 12$	IV	Severe frost heave
	$26 < W \leq 30$	> 1.5			
		≤ 1.5	$\eta > 12$	V	Extreme frost heave
Clayey soil	$W \leq W_p + 2$	> 2.0	$\eta \leq 1$	I	Non-frost heave
		≤ 2.0	$1 < \eta \leq 3.5$	II	Weak frost heave
	$W_p + 2 < W \leq W_p + 5$	> 2.0			
		≤ 2.0	$3.5 < \eta \leq 6$	III	Frost heave
	$W_p + 5 < W \leq W_p + 9$	> 2.0			
		≤ 2.0	$6 < \eta \leq 12$	IV	Severe frost heave
	$W_p + 9 < W \leq W_p + 15$	> 2.0			
		≤ 2.0	$\eta > 12$	V	Extreme frost heave

Note: 1. W_p is water content of soil at its plastic limit ($\%$); W -average water content before frozen.

2. Salinized frozen soil is not listed.

3. When the plasticity index is greater than 22, the frost heave severity is reduced by one level.

4. Particles with size less than 0.005 mm being more than 60% is non-frost soil.

5. When the fill material contains more than 40% of gravel soil to its total mass, the frost heave severity is determined according to the type of fill soil.

6. Water separation layer refers to the separation layer at or above the bottom of the seasonally frozen layer.

- 2 The soil fill within the frozen depth of subgrade shall meet the requirements in Table 7.18.3-2 in addition to the requirements in Clause 4.1.2 of the *Specifications*.

Table 7.18.3-2 Subgrade soil fill in seasonally frozen area

Subgrade type	Frozen severity zone	The distance between the water table or ground water level and the road surface (m)	Selected subgrade fill			
			Upper roadbed	Lower roadbed	Upper embankment	Lower embankment
Filled subgrade	Severe frost zone	$h_w > 3$	I	I - III	—	—
		$h_w \leq 3$	I	I - II	I - III	—

continued

Subgrade type	Frozen severity zone	The distance between the water table or ground water level and the road surface (m)	Selected subgrade fill			
			Upper roadbed	Lower roadbed	Upper embankment	Lower embankment
Filled subgrade	Medium frost zone	$h_w > 3$	I - II	I - III	—	—
		$h_w \leq 3$	I	I - II	—	—
Zero fill or cut subgrade	Severe frost zone	$h_w > 3$	I	I	—	—
		$h_w \leq 3$	I	I	—	—
	Medium frost zone	$h_w > 3$	I	I - II	—	—
		$h_w \leq 3$	I	I	—	—

Note: 1. The type and the frost heave class of soil are shown in Table 7. 18. 3-1.

2. When type I soil is used for the upper roadbed in severe frost heave and medium frost heave areas, the content of fine-grained soil (particle size less than 0.075 mm content) should be less than 5%.

3. In areas where sand and gravel are scarce, then lime, cement, fly ash, slag and curing agent are used for improvement, the fill is not restricted by this table.

- When borrowing soil from a borrow pit, the unmelted interlayer of permafrost shall be removed, and the subgrade fill containing frozen blocks shall be fully melted in the open air before being used.

7. 18. 4 Embankment fill shall meet the following requirements:

- Before filling, drainage ditches or side ditches shall be excavated on both sides of the subgrade, and in combination with permanent drainage, underground drainage facilities such as underdrain and seepage well shall be constructed first.
- The fill within the freezing depth range shall not be mixed. Soils with different frost heave properties shall be filled in separate layers, and the soil with severe frost resistance should be used in the upper layer.
- The top surface of each filled subgrade layer shall have a 2%-4% transverse slope.

7. 18. 5 Constructing subgrade in a cutting shall meet the following requirements:

- A water retaining barrier shall be built in advance in a cut section and the drainage ditches shall be cleared in advance.
- When coarse-grained soil such as sandy gravel is used to replace the soil in part of the subgrade, the particle size less than 0.075 mm content should be less than 5%.

- 3 In a rock section the cutting should not be over-excavated. Overcut areas and the uneven area caused by clearing soft rock layer should be backfilled and levelled with sandy gravel with good water stability or with concrete.

7.18.6 Slope protection shall meet the following requirements:

- 1 During freezing period, the soil slope in a cutting shall not be excavated to the design level in one operation. A covering layer of 100-400 mm shall be kept in reserve according to the soil strength of the slope, and then the slope can be trimmed to the design level in the normal construction season. When the subgrade is cut to the position of 1 m above the top surface of the subgrade, the cutting shall be stopped, and a temporary drainage ditch shall be made, and the construction will be resumed after the winter.
- 2 For slope protection with plants, the grass species and shrubs which are cold-resistant, drought-resistant, endure infertile soil and with developed roots shall be selected.
- 3 The foundation of the facing wall shall be buried at least 0.25 m below the freezing line, and the foundation shall be treated with a layer of gravel or crushed stone, with a thickness not less than 0.15 m.
- 4 The minimum buried depth of retaining wall foundations shall not be less than 1 m and shall be built not less than 0.25 m below the freezing line. The subsoil from the base to a depth of 0.25 m below the freeze line shall be replaced with non-frost heave material.
- 5 The backfill against the retaining wall shall consist of sandy soil or other permeable materials, and it is strictly prohibited to use silt or humus soil.
- 6 Masonry and stone laid side ditches shall be completed before the freezing season starts.

7.18.7 Waterproofing and drainage works shall comply with the following requirements:

- 1 In the construction process, the underground seepage water and surface water shall be drained away in advance.
- 2 The construction quality of temporary drainage facilities shall meet the requirements for freeze-thaw damage resistance.
- 3 Internal drainage facilities that are not completed before freezing starts shall be insulated to avoid freezing.

- 4 Before the freezing season starts the surface drainage system of the subgrade and its affected area shall be completed to drain the subgrade water away to prevent frost heave.

7.19 Subgrade along a river

7.19.1 Before construction of the subgrade along a river, a detailed construction plan shall be prepared based on the design requirements, and by checking the on-site topography, material composition, water level, water depth, flow rate and scour depth.

7.19.2 Subgrade construction shall not reduce the cross-section of the river channel. The spoil shall be properly disposed. It is strictly prohibited to dump spoil into the river.

7.19.3 An embankment affected by variable water level or below normal water level, shall be constructed with permeable materials with good water stability and weathering resistance. The particle size should not be greater than 300 mm. The slope toe below normal water level should be protected by rock-filled steel gabion.

Commentary

The main form of water damage along a river subgrade is that one side of the subgrade can be eroded and collapse. This is manifested as water scour and an eroded highway slope toe. Therefore, the design and construction of slope protection works along the river subgrade are key points.

7.19.4 Measures shall be taken to ensure the stability of the subgrade along the river according to the design requirements. It could be a high fill, or half-cut and half-fill, or the connection between the new and old subgrade in a widened section. For the subgrade along a valley, rock aggregate should be adopted as fill.

7.19.5 When the subgrade slope has a phreatic water level or permeable layer, measures shall be taken to drain the water from the subgrade.

8 Winter and Rainy Season Subgrade Construction

8.1 General

8.1.1 During winter and the rainy season, a detailed construction plan shall be prepared considering the seasonal characteristics and geological and topographic conditions of the construction section.

8.1.2 Temporary drainage shall be provided for construction in winter and the rainy season, and shall be connected integrally with the permanent drainage facilities.

8.1.3 Meteorological information shall be collected continuously during winter and the rainy season to avoid disasters and accidents.

8.1.4 All preparation shall be made before construction in winter and the rainy season.

8.2 Construction in winter

8.2.1 In a seasonal frozen area, when the diurnal mean temperature is below $-3\text{ }^{\circ}\text{C}$ and it lasts more than 10 consecutive days, or the diurnal mean temperature is above $-3\text{ }^{\circ}\text{C}$ but the frozen soil is not completely melted, the construction shall be considered as winter season construction.

8.2.2 The construction of a soil embankment for a motorway or Class 1 highway as well as an embankment in an adverse geological area should not be constructed in winter. Winter construction shall not be carried out for soil embankment in the range of 1 m below roadbed. A half-fill and half-cut section and the interface between fill and cut shall not be constructed in winter.

Commentary

The embankment of soil with fill thickness less than 1 m and the interface between fill and cut often have groundwater penetration. Because the fill is thin, it will freeze easily, and the strength and degree of compaction of the soil after thawing will be reduced, which has a great impact on the pavement and thus it shall not be constructed in winter.

8.2.3 Measures shall be taken for subgrade construction in winter to promptly drain away the rainwater or thawed snow water, and groundwater produced during cutting excavation.

8.2.4 The subgrade foundation treatment in winter shall comply with the following requirements:

- 1 Before freezing starts, the topsoil shall be removed, the benches shall be excavated, and insulation measures shall be taken to prevent freezing.
- 2 The snow and ice on the foundation shall be cleared before filling.
- 3 For areas which need to be replaced or for a depressed area that needs to be filled, suitable fill shall be used for backfill, and the area shall be levelled and compacted quickly.
- 4 Insulation measures shall be taken immediately after the foundation has been treated to prevent freezing.

8.2.5 Winter embankment construction shall comply with the following requirements:

- 1 The embankment fill shall be unfrozen sand, soil, crushed stone, gravel, alluvial gravel or stone chippings and other materials with good water permeability. No clay with a high moisture content shall be used.
- 2 The embankment shall be filled to the same level over the full width of the cross section, and the loose thickness of each layer shall be reduced by 20% to 30% compared with normal conditions, and shall not exceed 300 mm. The material being filled shall be compacted on the same day.
- 3 When the fill construction is suspended, the filled layer and slope shall be leveled and covered to prevent freezing. When the work is resumed, the surface ice and snow shall be cleared and additional fill shall be placed and compacted.
- 4 When there is only 1 m left from the fill elevation to the bottom of the roadbed, the filling shall be stopped after compaction, and the upper surface shall be covered with an anti-

freezing insulation layer. After the winter the embankment shall be treated and re-compacted, and then filled in layers to the design elevation.

- 5 After the winter the embankment shall be compacted again, and the degree of compaction shall comply with the requirements in Table 4.4.3.

Commentary

In winter the construction method is generally thin layer, fast filling, fast compaction and continuous operation. By filling each layer quickly, the result is to prevent the soil from freezing or reduce freezing.

8.2.6 Subgrade construction in cut in winter shall comply with the following requirements:

- 1 The slope shall not be excavated to the design line in one operation. A certain thickness of the covering layer shall be reserved and then trimmed to the design slope line after the winter is over.
- 2 When the subgrade is cut to 1 m above the top surface of the roadbed, the excavation shall be stopped while a temporary drainage ditch is being made, and the construction shall continue after the winter.

Commentary

This clause specifies the requirements for excavating in frozen soil, such as a reserved thickness for slope or bottom of cut and drainage, in order to prevent subgrade instability caused by freeze-thaw. This part of the work is executed during normal construction to ensure quality.

There are many construction methods for excavating the surface frozen soil in a road cut in winter, such as blasting frozen soil, mechanical breaking and artificial defrost. During construction, different regions will select appropriate and effective construction methods and construction techniques depending on the thickness of frozen soil and different geological conditions.

8.2.7 As the water level along a river is low in winter, the foundation pit may be excavated to build the protection project, but measures shall be taken to ensure the quality of the project.

8.2.8 Before the thawing period starts, the side ditches and drainage ditches along the whole road line shall be cleaned and unblocked.

8.3 Construction during the rainy season

8.3.1 Drainage of the subgrade shall comply with the following requirements:

- 1 Construction during the rainy season shall be planned in detail, and the on-site drainage system shall be effective in draining the surface water away quickly.
- 2 The surface of each layer of embankment fill shall have a 2% to 4% cross slope to drain water.
- 3 At the shoulder of the embankment that has been filled, measures shall be taken to drain rainwater to the drainage system, such as building a longitudinal temporary soil barrier to control water, and setting up water outlets and drainage channels at certain intervals.
- 4 During the rainy season excavating, a cutting should be carried out in layers. Longitudinal and transverse drainage slopes and temporary drainage ditches shall be built for each layer to ensure even water discharge.

Commentary

For a road section being constructed during the rainy season, detailed field investigation and research shall be conducted to develop a practical construction organization design. The focus shall be on solving drainage problems. Temporary drainage, and permanent drainage shall be well connected, and water shall be directed into the water courses of bridges and culverts along the road line and drainage ditches to form a complete drainage system to ensure that the construction site will not be flooded during the rainy season.

8.3.2 The treatment of the subgrade foundation shall comply with the following requirements:

- 1 The foundation shall be constructed well before the rainy season. Holes and depressed areas shall be filled and fully compacted, the foundation shall be leveled, and the longitudinal and transverse drainage slope shall be constructed.
- 2 In a low-lying road section, the original ground shall be finished well before the rainy season, and the embankment shall be filled to at least 0.5 m higher than the highest water level that accumulated water is expected to reach.

8.3.3 Embankment construction shall comply with the following requirements:

- 1 The fill material shall have good water permeability, such as gravel soil, alluvial gravel, sandy gravel, stone chippings and sandy soil. When soil from a cut is used as fill material, and its water content meets the requirements, it shall be filled and compacted immediately after being excavated. Soil with high water content that is difficult to dry shall not be used as fill material during the rainy season.
 - 2 The surface of each filled layer shall be made with a 2% to 4% crown slope to facilitate drainage. Low-lying areas or parts below the design flood level plus 0.5 m shall use fill material with good water permeability and high saturated strength. Protection works such as slope protection and slope toe wall shall be constructed early.
 - 3 When it is necessary to borrow soil to fill an embankment during the rainy season, borrow pits shall be designed to meet the requirements of subgrade stability.
 - 4 The embankment shall be filled in layers and compacted immediately.
- 8.3.4 Subgrade construction in a cut shall comply with the following requirements:
- 1 The slope should not be cut to the design slope in one operation, and a certain thickness of the covering layer shall be kept to be trimmed to the design slope after the rainy season.
 - 2 In the rainy season, when the cutting reaches the level of 300-500 mm above the top surface of the subgrade, the cutting construction shall be stopped and temporary drainage ditches shall be made on both sides. Construction shall be resumed after the rainy season.
 - 3 When the subgrade is cut from rock in the rainy season, the blasting hole should be drilled horizontally.

Commentary

The purpose of keeping a small quantity of loose material on the cutting slope and as well as keeping a layer with the same thickness for the subgrade is to prevent the running water on the surface to erode the formed slope or damage the subgrade. The excess material will be cut after the rainy season, which will allow the slope and subgrade to meet the design requirements.

If the subgrade has insufficient strength, and was not treated properly, the pavement at the cut section will develop road surface defects, so it shall be treated by overcutting, then backfilling and compaction. If the soil quality is poor, it shall be replaced or improved by mixing with lime. The thickness of the backfilling or replacement and the fill material shall meet the design requirements. If there are special conditions such as karst caves, weak interlayers and poor soil quality in the

subgrade foundation in the cut section, special treatment shall be applied.

8.3.5 If the foundation of a structure cannot be constructed after the foundation pit is excavated in the rainy season, measures to prevent it from being flooded shall be taken. The bearing capacity of the foundation shall be tested again after the rainy season if necessary.

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9 Subgrade Construction Safety

9.1 General

9.1.1 The construction team shall establish a sound production safety management system and safety management units, provide full-time persons for the control of work safety, share production safety rules and regulations, implement the responsibility system to direct and control the whole process and every aspect of construction safety management, construction safety technology execution and construction safety operations.

9.1.2 All staff shall be familiar with the relevant production safety laws and regulations and technical norms. Persons may take their job positions only after having passed the training course. Personnel engaged in special operations shall undergo professional training and obtain corresponding qualifications before occupying a job position. Construction operators must abide by the safety technical operating rules of their professions.

9.1.3 The construction team shall carry out site investigation before starting a project. Safety and security measures shall be developed at the beginning based on the terrain, geology, hydrology, meteorology and environmental conditions of the construction area, combined with the design documents and construction plans. During construction, relevant information such as temperature, rainfall and snow, storm, flood and geological disaster shall be obtained promptly, and prevention and emergency works shall be done according to the surrounding environmental conditions which change from time to time.

9.1.4 Before starting a project, the construction team shall know the existing roads, structures, facilities, underground and overhead pipelines within the range of the construction, develop safety measures to ensure the safety of existing structures and facilities. If the highway under construction crosses or runs alongside existing roads, waterways, utility lines and other facilities, it is necessary in the construction organization design to take corresponding measures to ensure the non-stop services

of the existing projects and demolition, protection or reinforcement schemes for them based on the structural characteristics and required functions of the existing projects.

9.1.5 When multiple teams work at the same job site at the same time or when different professions operate crossing each other, technical site safety measures shall be made by all participants with safety management agreements being signed.

9.1.6 Before constructing the subgrade, hazard identification shall be carried out according to engineering characteristics and construction environment. For major hazards, emergency plans shall be made, emergency organizations shall be established, emergency supplies shall be prepared, and training and exercises shall be organized and held as required.

9.1.7 For high-risk activities such as high slopes, construction safety risk assessment shall be carried out as required, risk assessment reports shall be prepared, and on-site monitoring shall be carried out.

9.1.8 In highway construction, the national laws and regulations on labor protection must be abided, construction conditions shall be improved, employees shall be equipped with necessary safety protective articles and appliances which shall be renewed regularly.

9.1.9 Employees in the construction area shall correctly use safety protective equipment and appliances.

9.1.10 Before constructing the subgrade, safety technology shall be informed to top staff down. The information shall include safety technical requirements, risk status and emergency response measures.

9.1.11 Before constructing the subgrade, the construction site, machinery and safety protection facilities shall be fully inspected, and the construction conditions shall meet the safety requirements. Repetitive materials used for structural load-bearing elements and temporary facilities shall be inspected for their condition before use.

Commentary

The tasks of inspecting the conditions of the repetitive used load-bearing elements mainly include checking their appearances, diameters, wall thicknesses and mechanical properties.

9.1.12 The construction team shall set up safety protection facilities at the construction site or within its management scope based on the characteristics of its operating targets and environmental conditions. Safety protection facilities shall be placed firmly, safety warning signs shall be well

noticeable. If necessary, night warning lights or reflective signs shall be installed. The safety protection facilities on the construction site must be managed by dedicated personnel and inspected at any time to maintain their integrity and effectiveness.

Commentary

The construction team shall set up safety warning signs and safety protection facilities at the following high risk places related to subgrade construction:

- (1) *The access to the construction site and intersections along the roadway;*
- (2) *Dangerous sections such as sharp turns, steep slopes and winding road sections;*
- (3) *Construction lifting machinery, temporary electrical facilities and scaffolding and other temporary facilities;*
- (4) *Civil explosives and stores for flammable and explosive or dangerous materials;*
- (5) *The edges of the fill slope, excavation slope, the trench and foundation pit, the mouths of the boring hole, cave, the edge of the high earth platform formed in the construction;*
- (6) *Operation area for slope protection works;*
- (7) *Operation area for dynamic compaction;*
- (8) *Potential landslide area;*
- (9) *The hill slope to be cleared to prevent rock fall;*
- (10) *Area with potential collapse over abandoned underground mine;*
- (11) *Other dangerous areas involved in subgrade construction.*

9.1.13 For dangerous places such as with blasting operations, works for slope protection, retaining wall, prestress-tensioning of anchor rods or anchor cables, hand-dug hole and demolition, warning zone shall be set up by following regulations and necessary safety measures shall be made.

Commentary

The operational area of the workplace where no one is allowed to enter without permission is called the warning zone.

9.1.14 If the construction is temporarily suspended, the construction team shall manage to protect the site.

9.2 Fire prevention, electricity, lighting and ventilation

9.2.1 Fire separation distances between temporary construction buildings, temporary facilities, production areas and office areas shall comply with the relevant requirements of the current *Technical Code for Fire Safety on Construction Sites* (GB 50720). Construction sites and living areas shall be equipped with fire control facilities and equipment and fire safety signs shall be set up in accordance with the relevant state regulations.

9.2.2 The temporary use of electricity at the construction site shall comply with the relevant provisions of the current *Safety technical specifications for highway engineering construction* (JTG F90).

9.2.3 The construction site shall be provided with the required lighting facilities to ensure construction safety.

9.2.4 When hand digging anti-slide pile holes, seepage wells and drainage tunnels, and working on reinforcing masonry inside abandoned underground mines or karst caves, the following requirements shall be met:

- 1 For working in an underground confined space, the site shall be equipped with gas concentration detection equipment, and the relevant requirements of the current *Safety regulation for working under hazardous condition of the oxygen deficiency* (GB 8958) shall be met.
- 2 Before the operators enter into an underground confined space, it shall be ventilated for 15 minutes, and the air in the space shall be tested to confirm it is within the limited value of level 3 normal concentration specified in the *Ambient Air Quality Standards* (GB 3095). Ventilation shall be maintained during manual digging or masonry operations. There shall be at least one spare set of ventilation equipment on site.
- 3 In areas containing toxic and harmful gases, the underground space shall be tested for toxic and harmful gases and oxygen content at least every 2 h, be ventilated constantly, and be equipped with no less than 5 sets of compressed oxygen self-rescuer and other rescue equipment. Any potential rescue needs shall be satisfied.

- 4 After blasting in an underground space, only after the smoke and dust in the space has settled, or after ventilation has removed all the smoke and dust, workers can enter the space.

Commentary

The limiting concentration of ambient air pollutants specified in the Ambient Air Quality Standards (GB 3095) are described in Section 10.5.1 of the Specifications.

9.3 Drainage during construction

9.3.1 The drainage scheme must meet the safety requirements for subgrade construction, existing structures near the road and underground pipelines.

9.3.2 When developing the dewatering plan and soft soil foundation treatment plan, be aware that as the water content of the foundation or pore water pressure will be changed, their impact on the safety of existing structures or facilities in adjacent areas shall be fully considered, and the dewatering shall not endanger the safety of nearby existing roads and structures.

9.3.3 During the construction process, the settlement, displacement and inclination of traffic facilities, pipelines and structures in an area affected by dewatering shall be watched, and measurements shall be taken as soon as problems are found.

9.3.4 After the completion of the construction, the site shall be cleared and the landform restored, and the holes left on the ground surface shall be backfilled with sand and gravel materials and compacted.

9.4 Construction access road

9.4.1 Before constructing the subgrade, the transport routes, temporary traffic diversion and schemes for building construction access roads shall be determined according to project demands, transport vehicles, traffic volume and site conditions.

9.4.2 Construction access roads shall be built according to project characteristics, service purposes, traffic loads and environmental conditions, and shall comply with the following requirements:

- 1 A construction access road shall be even, sound and able to meet the requirements for

transportation safety. It shall not damage the original water system and reduce the flood discharge capacity of the original river.

- 2 The width of a two-lane construction access road should not be less than 6.5 m. The width of the single-lane construction access road should not be less than 4.5 m, with a passing bay being provided. A passing bay shall be located in an area with good visibility, and the spacing between passing bays should not be greater than 300 m. Where a passing bay is provided on a construction access road, the road here should not be less than 6.5 m in width, and the effective length of the passing bay should not be less than 20 m.
- 3 Necessary warning signs shall be provided.
- 4 When a construction access road crosses an overhead power line, the safe distance between the construction access road and the overhead line shall comply with the relevant requirements of the current *Technical Code for Safety of Temporary Electrification on a Construction Site* (JGJ/T 46).
- 5 In case that the construction access road passes under various overhead pipe lines, the clearance shall meet the requirements on transportation safety, and height limit signs shall be set ahead of the pipeline in both directions.
- 6 If the construction access road passes through a structure, the clearance shall meet the requirements on transportation safety, and height limit signs and width limit signs shall be positioned ahead of the structure.

Commentary

The warning signs to be provided for the construction access road include speed limit signs located in obvious positions on the road, with the speed being determined based on the traffic volume, road conditions and surrounding situations. Warning signs shall be located at dangerous sections such as sharp turns, steep slopes and consecutive curves. Warning signs shall also be positioned at dangerous sections of the access road with potential rockfalls, landslides. Safety signs and additional night warning lights shall be located at the side towards steep gullies or river banks. Crossing warning signs shall be located ahead of an at-grade intersection of the construction access road with the existing road.

9.4.3 Signs for load limit, width limit and speed limit shall be located for temporary bridges which can be used only after being checked and accepted.

9.4.4 Before using existing roads, the bearing capacities of bridges and culverts, underground

pipelines and structures on existing roads shall be investigated, tested and checked to confirm that they can meet the transportation requirements and are safe, and meet the requirements of Clauses 9.4.2 and 9.4.3 of the *Specifications*.

9.4.5 When highway reconstruction and expansion works are carried out without closing to traffic, operation control zones shall be set up according to relevant regulations and traffic organization program. Temporary traffic safety facilities shall be located visibly at both ends of the construction section and at the accesses along the road, and regular inspection and maintenance shall be carried out.

9.4.6 In case construction work is performed in half width of the road, separation facilities must be set up between the work area and the normal traffic. Special personnel and communication equipment shall be used to direct and control traffic.

9.4.7 Before blasting operation, traffic in the blasting warning area must be temporarily closed. After blasting, the soil and rock on the road shall be cleared immediately and the facilities shall be checked and repaired. Traffic shall be opened after the driving conditions are satisfied.

9.5 Use of mechanical construction equipment

9.5.1 The construction team shall establish the safe operation procedures and safe practice files for mechanical construction equipment.

9.5.2 Before mechanical equipment enters the site, their certificates, performance and condition shall be checked. After the mechanical equipment enters the site, the safe practice details shall be shared with the operators.

9.5.3 All kinds of safety protection devices, protection limit devices and safety data devices on mechanical equipment must be complete and effective.

9.5.4 The mechanical equipment must be operated and used in accordance with their technical function, load capacity and operating conditions stipulated in the safe operating rules and the operating instructions. Over-loading, over-speeding or extending the applicable range are strictly prohibited.

9.5.5 Mechanical equipment should not be operated on areas with steep slopes or on unstable rock and soil. Reliable safety measures shall be taken when mechanical equipment is operated at the side of a subgrade slope, foundation pit or near edges of gullies and on unstable ground.

9.5.6 When multiple machines are working in the same area, a safe distance between them shall be maintained.

9.5.7 Hand labor work shall not be carried out within an area where machines work. When laborers are required to help mechanical equipment in their operations, operators shall pay continuous close attention.

9.5.8 When a drilling rig and other tall equipment on the construction site are outside the protection range of the lightning protection devices at adjacent structures, lightning protection devices shall be equipped in accordance with the relevant regulations.

9.5.9 The safe distance between tall equipment and an overhead line shall comply with the relevant provisions of the current *Safety technical specifications for highway engineering construction* (JTG F90). When it is necessary to operate a distance to the overhead line which is less than the specified safe distance, strict safety protection measures shall be taken after approved by relevant departments in accordance with relevant regulations.

9.5.10 The hoisting work shall comply with the relevant provisions of the current *Safety technical specifications for highway engineering construction* (JTG F90).

9.5.11 Hauling vehicles on the construction site shall be equipped with reflective warning signs. The hauling vehicles shall comply with the road traffic laws and regulations, and shall only run along prescribed routes and at prescribed speeds. Overloading the vehicles is not allowed. Vehicles carrying people mixed with cargoes are strictly prohibited.

9.5.12 Before cleaning, maintaining, or repairing mechanical equipment or electrical devices, the electrical power must first be switched off, and the mechanical equipment shall be stopped completely before being attended. Working on a live line is strictly prohibited, and maintenance work based on an agreed time that electricity will be delivered is strictly prohibited.

9.6 Demolition of existing structures

9.6.1 The section layers to be demolished, the sequence and methods of demolition shall be determined according to the structural characteristics of the structures to be demolished and the requirements of the construction environment. Demolition work shall be carried out from top to bottom, layer by layer and section by section, and working above other workers shall not be allowed.

9.6.2 When demolition work may pose a threat to the safety of adjacent buildings, appropriate protective measures shall be taken.

9.6.3 Demolition work shall comply with the relevant provisions of the current *Safety technical specifications for highway engineering construction* (JTG F90). A warning zone shall be established at the demolition site.

9.6.4 Blasting operations in demolition work shall comply with the relevant provisions of Clause 9.7.12 of the *Specifications*.

9.6.5 Personnel and tools for demolition shall be kept in a stable position. Suspension ropes and safety ropes shall be tied when temporary suspension operations are necessary. The suspension rope and safety rope shall be anchored separately and securely.

9.6.6 When dismantling existing retaining structures and protection facilities for the subgrade, the stability of the existing cut slope shall be ensured. If necessary, temporary supports shall be provided for reinforcement or protection, and demolition shall be made in layers from top to bottom and in sections. Demolition in great haste is strictly prohibited.

9.6.7 Materials from the demolition shall be cleaned up immediately and placed in a classified way.

9.7 Cutting, excavation for foundation pit and/or trench

9.7.1 Before excavation, existing structures, pipelines and drainage facilities shall be relocated or reinforced according to the construction organization design. During construction, the reinforced parts or elements shall be inspected and maintained frequently to maintain the safe operation of facilities. For underground facilities such as an underground pipeline that may not be necessarily having to be moved out of the construction site, their underground locations and distribution shall be determined, warning signs shall be positioned, and protective measures shall be taken.

9.7.2 During the excavation of a road cutting, a dedicated person shall be assigned to monitor and inspect the stability of the working face and slope body within the impact area of construction. If any abnormality is found, construction shall be suspended immediately, equipment and personnel shall be evacuated and safety measures shall be taken.

Commentary

The so-called " find any abnormality" in the clause means that through direct observation or through observation and assessment, the slope body has been confirmed to have signs of sliding or

collapse which will endanger the construction safety. Taking urgent measures include activating the emergency plans.

9.7.3 When widening a road in a cut section during road reconstruction, it shall be carried out from the top of the related cross-section to bottom. During the excavation process, the slope stability shall be monitored at all times. Measures shall be taken if there are signs of dangerous rocks, cracks or landslides.

9.7.4 When excavating a structural foundation pit, a safe slopegrade or support protection shall be determined according to the site soil quality, hydrology and excavation depth. When the foundation pit is deep or the slope stability is poor, the excavation shall be made in an interval jump sequence of segment then after next segment. During the construction, the stability of the ground around job site shall be observed or monitored according to regulations, and corresponding treatment measures shall be applied when problems are found. When excavated soil or materials is temporarily placed near the edge of the pit, the distance between the soil or materials and the edge of the pit, and the stockpiling height shall be controlled, so as not to affect the stability of the pit slope. Mechanical equipment being operated or driven around the foundation pit shall not affect the construction safety.

Commentary

Supporting structure and protection are crucial to construction safety during the excavation of subgrade drainage facilities and for the foundations of the protective structures. This includes the support design, construction, maintenance and removal of the support. Careful design and execution of these elements may avoid the instability of the pit wall, collapse and personal injury accidents.

9.7.5 Retaining structures such as a concrete cast-in-place pile and underground diaphragm wall are made for the slope of foundation pit. Excavation can be carried out only after the strength of the retaining structure reaches the design requirements.

9.7.6 When performing mechanical excavation, existing structures and pipelines shall be avoided, and colliding with them is strictly prohibited. It is strictly prohibited to use a heavy machine to excavate within 2 m from the existing directly buried cables and 1 m from various pipelines. When working near existing structures and pipelines, dedicated personnel shall be on-site for supervision.

9.7.7 During excavation, in case of cultural relics, explosives, unidentified objects and underground pipelines and structures (not marked by the original design drawings or the administrative body) are met, the construction must be suspended immediately to protect the site. The information shall be reported to the supervisor and the relevant administrative body shall be contacted in order to get instructions of how to treat this information. Only after proper handling and safety is confirmed, and

the treatment task is finished and documented, that construction can be resumed.

9.7.8 Blasting operations shall meet the following requirements:

- 1 Blaster, safety officer and storekeeper engaged in blasting work shall be trained by the professional institutions in accordance with the relevant regulations and obtain the corresponding qualifications.
- 2 Blasting operations and the procurement, transportation, storage and use of explosive materials shall be carried out in accordance with the relevant provisions of the current *Regulations on the Safety Management of Civil Explosives*, the *Safety Regulations for Blasting* (GB 6722) and the *Safety code for miniature civil explosives magazine* (GA 838).
- 3 Smooth blasting must be adopted for a road cutting rock slope with a gradient of 1:0.1 to 1:0.75. Controlled blasting technology shall be used near cities, tourist attractions and important engineering facilities.

Commentary

The harmful effects of blasting and the permissible safe distance are determined according to the calculation method in the Safety Regulations for Blasting (GB 6722).

9.7.9 When a trench depth exceeds 2 m, operations at the edge of the trench shall have safety protection measures the same as required for working at height, and warning signs shall be posted. When a trench is near the site internal roads or residential area, safety guardrails shall be installed and warning lights shall be displayed at night.

9.8 Embankment and roadbed filling

9.8.1 Temporary waterproofing and drainage systems shall be established before embankment construction. Water must not accumulate in the subgrade foundation, toe of the slope and the area which can affect the subgrade stability. When building an embankment in mountainous areas, the surface and groundwater shall be prevented from penetrating into any part of the embankment structure.

9.8.2 Before using a vibratory roller to compact the subgrade, possible vibration effects on nearby ground and underground structures and pipelines shall be analyzed to be sure they are safe.

9.8.3 The safe distance between the filling section and the overhead line shall comply with the

relevant provisions of the current *Technical Code for Safety of Temporary Electrification on a Construction Site* (JGJ/T 46).

9.8.4 When there is a pipeline under the subgrade, a roller shall not be used to compact less than 0.5 m above the top of the pipeline. When heavy compacting machinery is used for compaction or heavy vehicles are driven on backfill, a calculated thickness of compacted soil shall be laid over the top of the pipeline. The minimum thickness of soil shall be determined by calculation according to the weight of machinery and vehicles and the design loading capacity of the pipeline.

9.8.5 Clearly visible warning signs shall be set up at the edge of the filling operation area.

9.9 Construction of retaining structures and drainage facilities

9.9.1 Before working on a side slope or inside a foundation pit, the stability of the slope or pit wall shall be checked. Dangerous rocks or stones and loose earth or stone blocks that affect the safety of construction shall be removed, or necessary protective measures shall be taken.

9.9.2 When constructing on a slope or inside the foundation pit, climbing ladders shall be installed. During construction, designated personnel shall conduct regular inspections and monitor slope stability to confirm safety. If any deviation is detected, work shall be suspended immediately, personnel shall be evacuated, and safety measures shall be taken before work may be resumed.

9.9.3 When working at a height above 1.2 m, scaffolding shall be positioned. Scaffolding shall be designed by professionals, and its strength, stiffness and stability must be checked and has to comply with the relevant provisions of the current *Safety technical specifications for highway engineering construction* (JTG F90). On high scaffolding its platform shall be anchored on the rock body with anchor rods. The scaffolding may be used only after it has passed inspection. During the construction, the scaffolding shall be checked frequently, and it shall be strengthened if during use it becomes loose, deformed or subsides.

9.9.4 When the height of a retaining wall exceeds 2 m, safety protection shall be provided in accordance with the requirements for high elevation operations in the *Safety technical specifications for highway engineering construction* (JTG F90).

9.9.5 For masonry work, no one shall work or be below the scaffolding. A worker working above another worker is forbidden, and material shall not be transported by rolling down the slope or by throwing.

9.9.6 When lifting stones by hoisting frames, they shall be operated by designated persons who must be in charge and designated persons for directing. Overloading is strictly prohibited. It is strictly forbidden to use the hoisting frame to carry passengers. The production and installation of temporary lifting equipment must comply with the relevant national regulations.

9.9.7 When removing the formwork from the back face of a concrete gravity retaining wall which is inclined inwardly, the necessary temporary supports shall be placed on the rear side of the wall.

9.9.8 Before installing prefabricated components, a detailed lifting plan shall be made based on site conditions, and all lifting equipment must comply with the national safety management regulations for special equipment.

9.9.9 Shotcrete operations shall be carried out in a top-down order. When spraying, close attention shall be paid to the pressure changes indicated on the gauge. If there is an abnormality all equipment for the shotcrete works shall be stopped, power shall be switched off, the air compressor shall not supply air, and the malfunction shall be solved promptly. No one is allowed to stand in front of the nozzle in the working area. When dealing with a blocked pipe, the operator shall hold the nozzle tightly to prevent the pipe from swinging and hurting people. Do not dismantle pipe joints when pipes are under pressure.

Commentary

When dealing with equipment malfunctions in the construction process, it is necessary to stop the machine, switch off the power and air pressure to prevent accidents caused by uncontrolled actions of the machine. After the malfunction is cleared, the relevant operators shall be notified that work will be resumed before supplying power and air pressure to prevent anyone from standing in a dangerous position and possibly being injured by a sudden startup.

9.9.10 During the drilling of anchor rods and anchor cable construction, operators shall stand on the side of the hole when cleaning the hole by blowing air to prevent the mud, water and soil to injure operators.

9.9.11 The cable tensioning operation area shall be defined as a warning area. The tensioning bed shall be stable, and tensioning equipment must be securely installed. During the tensioning process, the operator shall not leave his post, and no one is allowed to stand near the jack.

Commentary

When tensioning prestressed anchor rods or cables, the cable wires may break and anchor wedges can slip off and fly out axially and injure people. Furthermore, an entire anchor rod (cable) may be ejected together with the tensioning equipment due to unreliable anchoring. Therefore, it is

strictly prohibited for people to stand next to the jack when tensioning is underway to prevent injury accidents.

9.9.12 A special construction scheme shall be prepared for the construction of a hand-dug anti-slide pile, which shall comply with the following requirements in addition to the requirements of Clause 6.7 of the *Specifications*:

- 1 The construction of piles in the same row shall be dug in an interval jump sequence.
- 2 A guard ring shall be installed at the hole mouth, and the ring shall be 0.3 m above the ground. A guardrail and temporary drainage ditch shall be constructed around the hole mouth, and warning red lights shall be installed for use at night. Spoils, irrelevant equipment or tools and other sundries shall not be placed near the hole mouth.
- 3 During the rainy season, when hand-dug piles are constructed without blasting, the hole mouth shall be equipped with an awning. No work shall be carried out inside the hole on rainy days.
- 4 In-hole blasting operations shall be specially designed, using the method of “shallow hole blasting for loosening”, and the quantity of explosives shall be strictly controlled. The safety management for blasting shall be carried out in accordance with the relevant provisions of current *Blasting Safety Regulations* (GB 6722). Personnel in the adjacent pile holes must be evacuated before blasting.
- 5 Concrete protective walls shall be cast as excavation progresses. The excavation depth of each section shall meet the requirements of the construction scheme and shall not exceed 1 m. The formwork for the wall shall be removed after the concrete strength reaches 5 MPa.
- 6 Workers in the hole shall wear safety hats, safety belts, anti-slip shoes and safety ropes shall be tied at the hole mouth. Workers shall get into the hole through a ladder with a cage. No tools or materials are allowed to be carried by workers going down or up. Workers shall not use the hoist to lift them going up and down the hole.
- 7 The winch, rope, bucket, hoist and other equipment shall be in good condition; The lifting equipment shall be equipped with a limit switch and a hook lock.
- 8 A protective cover shall be provided above the head of workers digging the hole. The waste bucket shall not be filled to capacity. When discharging waste the workers in the hole shall be positioned under the protective cover.

- 9 The voltage for hole lighting must be safe. Use waterproof lighting bulb with cover. The electric cable shall be waterproof and insulated.
 - 10 Ventilation requirements and air quality in holes shall comply with the requirements of Clause 9.2.4 of the *Specifications*.
 - 11 Pile holes deeper than 15 m shall be equipped with effective communication equipment. The workers shall not continuously work in the hole for more than 2 hours at a time. The protective wall shall be reinforced concrete. The ladder against the wall shall be provided with a rest platform every 8 m. If the depth exceeds 30 m, there shall be lifting equipment for workers going up and down.
 - 12 Landslide monitoring shall be carried out simultaneously with the pile construction. When the landslide risk appears and the safety of the workers is in danger, the workers shall be notified to evacuate immediately.
 - 13 The hole mouth shall be guarded by dedicated personnel. The workers inside the hole shall check the protective wall for deformation, cracks, water seepage and other conditions, and keep in touch with the personnel on the surface. Evacuate immediately if any abnormality is found.
- 9.9.13 The construction of a mechanically bored seepage well shall meet the following safety requirements:
- 1 The construction site and access road shall be flat and solid as required for the normal operation and movement of the boring machine.
 - 2 The boring machine shall be stable and firm.
 - 3 Personnel are strictly prohibited from entering the hole during boring.
 - 4 It is strictly prohibited to use the boring machine to bore or lift under an overhead power line. When operating near the overhead line, the minimum distance between the edge of the machine and the power line shall comply with the provisions of the current *Technical Code for Safety of Temporary Electrification on Construction Site* (JGJ/T 46).
 - 5 The installation of well pipes should be carried out by a crane. The lifting point shall be correct, and the bolts shall be secure. It is forbidden to place hands or feet on the well mouth when lowering the well pipes down to the well. The well pipe mouth shall be at least

0.5 m above the ground. The well mouth must be closed with safety signs.

9.9.14 A special construction plan shall be prepared for the construction of manually dug seepage wells, and the following safety requirements shall be met:

- 1 When a seepage well is built in an unstable soil layer, proper support measures shall be taken for the well wall and well mouth according to the soil conditions.
- 2 Materials, equipment and earthworks shall not be piled up within 1 m around the seepage well. Anti-fall and anti-slip measures shall be taken at the well mouth.
- 3 When the operating conditions inside the well is harsh, manual excavation shall be rotated, and each worker shall not work inside the well for more than 2 h. Workers shall take the escape ladder up and down the well. Ventilation requirements and air quality in the well shall comply with the requirements of Clause 9.2.4.
- 4 When excavating in the well, the stability of the well wall and support shall be observed at all times. When the soil wall shows signs of collapsing, well circular wall becomes skewed or the support is displaced or deformed severely, the operation must be stopped immediately and workers shall be evacuated to a safe place. The operation may be resumed after safety technical measures are taken and safety is confirmed.
- 5 When the well depth is greater than 1.5 m, dedicated personnel shall be posted above ground to monitor the digging operation. No one shall be inside the well during installation of a prefabricated well pipe. When conveying the spoil out of the well by a hanging bucket, collision or hooking failure shall be prevented and the workers in the well shall be notified to temporarily clear the area.
- 6 When using the intervals between draining water operations to dig the seepage well, the digging workers shall cooperate closely with the pump operator and wear insulating rubber boots.
- 7 When lifting and transportation equipment is working near the edge of the seepage well, the stability of the foundation shall be checked closely to prevent ground collapse or equipment tipping accidents.

9.9.15 The construction of drainage tunnels shall meet the following safety requirements:

- 1 Emergency plans such as for drainage tunnel collapse, sudden water/mud burst, electric

shock, fire, explosion, suffocation and harmful gases shall be prepared according to the identified hazards, and corresponding emergency resources shall be allocated.

- 2 When the ground formation is sound and the geological conditions are good, the three processes for constructing (which are drainage tunnel excavation, lining and grouting) may be carried out in sequence. The tunnel will be excavated first, and then the lining and grouting will be carried out later. When the rock layer is broken and the geological conditions are poor, the excavation and lining shall be carried out simultaneously.
 - 3 According to the specific geological conditions of a landslide to be treated, drainage tunnel excavation may be carried out by the manual method or drilling and blasting method. When the drilling and blasting method is used, based on the integrity of the rock formation, the method of full section excavation or excavating a pilot tunnel first can be determined. In an area rich in groundwater, it is advisable to excavate with a lower pilot tunnel.
 - 4 For unstable ground formation, temporary support by wood, steel or shotcrete with anchor bolt shall be adopted after blasting and before a permanent lining is made. Support or special support shall be provided in the section between the part having been permanently supported and the excavation face when tunneling in a soft or quicksand stratum.
 - 5 When excavating a tunnel in a formation which is particularly weak or with a flow of water, protective advance grouting or pipe umbrella reinforcement method shall be adopted to strengthen the formation, and then the excavation may be carried out.
 - 6 Ventilation and air quality in tunnels shall comply with the requirements of Clause 9.2.4 of the *Specifications*. If the excavation is in a stratum with methane, the safety requirements for constructing a tunnel with methane in the current *Safety technical specifications for highway engineering construction* (JTG F90) shall be met.
 - 7 Safety equipment such as ventilators and pumps shall be equipped with backup equipment.
 - 8 In water leakage areas, waterproof lamps shall be used; in areas with methane, explosion-proof lamps shall be used.
- 9.9.16 When constructing interception ditches on high slopes, protective facilities shall be installed to prevent operators from falling.
- 9.9.17 The excavation of an underdrain trench shall be carried out from the lower levels to the upper levels. Support shall be provided as excavation progresses and trenches shall be promptly

backfilled to prevent collapse. When the construction is suspended or completed, it shall be promptly covered and sealed.

9.9.18 Supporting underdrain shall be excavated in the interval jump order. When the excavation depth of the supporting underdrain exceeds 1.5 m, additional supports shall be provided.

9.9.19 Warning areas shall be identified around the construction of slope protection, retaining structure and drainage facilities, and clear warning signs shall be posted. Guard rails and clear warning signs shall also be installed around the holes of anti-slide piles, seepage wells and other drainage facilities where construction is suspended, and warning lights shall be lit at night.

9.10 Borrowing and spoiling of soil

9.10.1 The side slope and depth of the borrow pit shall be designed to meet the stability requirements. The borrow site should be far away from activities and production facilities such as structures, facilities and pipelines, and shall not affect their safety.

9.10.2 Safety protection facilities and warning signs shall be located around the borrow pit, and night warning or reflective signs shall be positioned if necessary.

9.10.3 If there is an overhead power line in the borrow site, protective measures shall be taken, such as to protect earth tables (round areas surrounding the poles) not to be borrowed for the safety of poles and their guy wires. The radius of an earth table shall be determined according to the structure of the pole and its guy wires, the embedded depth of the pole and the soil quality. Safety signs shall be placed around the earth tables.

9.10.4 When it is necessary to borrow soil near a structure, safety and technical measures shall be in place before borrowing is allowed to be sure that the structure will be safe.

9.10.5 The spoil site shall be away from buildings, walls and overhead power lines, and shall not impede the normal use and maintenance of various underground pipelines and structures.

10 Environment Protection during Subgrade Construction

10.1 General

10.1.1 Subgrade construction shall comply with the relevant national laws and regulations on land management, soil and water conservation, environmental protection, ecological protection, resource utilization, energy utilization and circular economy, and shall rationally utilize resources and energy, control pollution and protect the environment.

10.1.2 Before starting the project, the topography, geology, hydrology, meteorology, ecology and environmental conditions of the construction site as well as the conditions of existing structures shall be investigated. In accordance with relevant national regulations on managing the environmental protection for construction projects, as well as relevant laws and technical standards on resource conservation, energy conservation and emission reduction, combined with project characteristics, design requirements and construction environment, construction environmental protection programs, energy saving and emission reduction plans shall be made and implemented.

10.1.3 Highway subgrade construction organization design shall relate to the actual project situations, and based on the requirements of the environmental protection design. Since the construction may cause environmental damage and adverse effects, specific preventive measures and plans shall be formulated and implemented. The highway subgrade construction organization design shall include the following contents related to environment protection:

- 1 Land use and water and soil conservation measures;
- 2 Ecological protection and restoration measures;
- 3 Water resources protection and waste pollution control measures;

- 4 Air pollution control measures;
- 5 Noise and vibration control measures;
- 6 Energy conservation and emission reduction measures;
- 7 Protective measures for existing structures;
- 8 Cultural relics protection measures.

Commentary

The selection of construction methods and processes need to fully consider the possible impact on environment in the process of slope excavation, preloading on soft foundation, or by vibration, noise, dust and sewage.

10.1.4 In the construction of the subgrade, attention shall be paid to the protection of farmland water conservancy and environment, occupy less arable land, especially farmland. Temporary land use shall be promptly reclaimed. In planning the temporary facilities such as construction access roads and construction work yards, the best use of existing roads and wastelands shall be made to reduce the impact on the environment.

10.1.5 The subgrade construction plan for construction in nature reserves, forests, grasslands, wetlands and scenic spots shall be beneficial to ecological protection and restoration.

10.1.6 The selection of construction machinery and equipment shall comply with environmental protection regulations, with energy-saving and environmentally friendly machinery and equipment featuring low noise, low vibration and low emission are preferred. During construction regular maintenance shall be executed to reduce the impact of oil leakage on the environment.

10.2 Land resource utilization and soil and water conservation

10.2.1 In constructing the subgrade, the use of temporary land shall be strictly controlled.

10.2.2 In subgrade construction there shall be control and reduction of the disturbance and damage to the original landform, surface vegetation and water system, and protection of the original surface vegetation, topsoil and soil crust.

10.2.3 Earthwork balance in subgrade construction should use cut material to fill, make full use

of excavated materials and conserving land. Spoils that cannot be used shall be piled up and disposed in a centralized way. The construction organization design shall comply with the relevant requirements of current laws and regulations.

10.2.4 Soil and water conservation in subgrade construction shall meet the following requirements:

- 1 Construction access roads shall be controlled within the prescribed range to reduce the construction disturbance. Temporary roads shall be restored after completion of construction.
- 2 Before the main project starts, the cultivated soil layer shall be stripped and piled up in a centralized manner. After the construction is completed, the soil should be used as the mulch for the reclaimed land, forest and grassland.
- 3 Reduce the time the ground surface is exposed. In case of heavy rain or strong winds temporary protection shall be strengthened. During the rainy season, earthworks shall be excavated, transported, filled and compacted in rapid sequence to avoid soil erosion.
- 4 Temporary soil stockpiles and finished processed materials in the storage yard shall be piled together in a centralized manner. Measures such as sand sediment traps and blocks for preventing washing-away shall be provided.
- 5 Measures such as water interception and drainage, sand sediment traps and blocks for preventing washing-away shall be built before excavating the soil and rock from the borrow sites. Excavation outside the designated borrow site is prohibited.
- 6 Protective measures shall be taken for hauling materials such as soil, sand, stone and slag, to prevent spillage along the way resulting in soil erosion.

10.2.5 Selecting sites for borrowing and spoiling shall be in accordance with the requirements of the design documents and shall also comply with the following requirements:

- 1 Selecting sites for borrowing and spoiling shall conform to the regional environmental planning and local land use planning, and shall also conform to the planning requirements by city or town and scenic area, and be coordinated with the surrounding landscape.
- 2 Borrow sites and spoil sites shall occupy no or little woodland, farmland or garden land; and shall be away from rivers, lakes and reservoirs or other ecological control areas, away

from wildlife migration paths. should use barren mountains, sloping wastelands or other wastelands.

- 3 It is strictly prohibited to establish a borrow pit in a dangerous area with potential collapse, landslide and debris flow.
- 4 The possibility of induced collapse, landslide and debris flow shall be analyzed when the borrow site is selected in mountainous and hilly areas
- 5 The extraction of sand and gravel from the river shall meet the relevant requirements on river management.
- 6 A selected spoil site shall not affect the safety of surrounding public facilities, industrial enterprises and residential areas.
- 7 If the spoil site involves a river course, it shall meet the requirements for river regulation planning, and for flood control and discharge planning. A spoil site shall not be located in the range of the regulated river courses and lakes.
- 8 It is strictly prohibited to set up a spoil site in an area where it may seriously affect the important infrastructure, the safety of people's lives and properties, and safety of flood discharge.
- 9 A spoil site should not be located in a gully with large flow rates, otherwise the flood control verification studies shall be conducted.
- 10 In a hilly terrain a spoil site should be located in a barren valley, depressed land or secondary stream. In a plain area a spoil site should be located in depressed land or waste land. In a desert region a spoil site should be located away from wind gaps or places prone to wind erosion.

10.2.6 The plan and cross-section of a borrow pit and a spoil site shall be designed to comply with the requirements of Clauses 4.15.1 and 4.15.2 of the *Specifications* and meet the following requirements:

- 1 The layout and cross-section of the borrow pit and the spoil site shall be designed to benefit the slope stability and its re-utilization after construction is completed.
- 2 The spoil from a steep slope embankment and deep cut section shall be placed on the lower side of the slope and piled up intermittently to ensure that the surface water inside the spoil

site may be discharged smoothly.

- 3 The retaining structure of a spoil site shall be specially designed to have a proper structural form by considering the quantity of soil or rock, their location and terrain characteristics, so as to effectively control soil erosion.

10.2.7 Temporary protective measures must be taken during construction. The design of temporary protection works shall comply with the requirements of the current *Technical standard of soil and water conservation for production and construction projects* (GB 50433).

10.2.8 Sites for excavation, filling, disposal must have solutions like blocking to prevent erosion, slope protection, drainage interception and other remediation measures.

10.2.9 The duration of temporary land occupation during highway subgrade construction shall take less time than regular construction. The land of construction sites shall be restored promptly, with water and soil conservation measures implemented to restore the useful function.

10.3 Ecological protection and restoration

10.3.1 Before subgrade construction, the ecological environment along the road shall be investigated to evaluate the possible impact of construction on the ecological environment.

10.3.2 For embankment fill or cut excavation and for borrowing and spoiling of soil, topsoil shall be stripped and preserved in the planned progress according to the subgrade construction schedule. The minimum stripping thickness of topsoil shall be determined according to the relevant provisions of the current national environmental protection standards. The height of a pile of topsoil shall not exceed 2 m, and corresponding protection measures such as drainage ditches shall be built where necessary to prevent soil erosion.

10.3.3 Before construction, appropriate measures shall be taken to protect rare plants within the area of subgrade construction in accordance with relevant provisions of environmental protection standards.

10.3.4 When the road passes through forest land, attention shall be paid to protecting the trees within the area for road construction, and the number of trees to be felled shall be strictly controlled. It is strictly prohibited to cut down trees outside the road area that does not affect driving safety.

10.3.5 When the highway passes through grasslands and meadows, attention shall be paid to protect humus and surface vegetation, and restrict borrowing from the road side. The sites for borrowing and spoiling should be selected from the places where vegetation growth is poor, and shall be centrally located.

Commentary

The surface humus is rich in nutrients, seeds and roots necessary for plant growth, and is the survival condition of plants. Humus is formed through tens of thousands of years of physical, chemical and biological processes, and is a limited natural resource. From engineering practice, it is proven that it is a rapid, economical and effective method to restore the ecological environment by first removing humus soil and protect it before backfilling for greening after construction.

10.3.6 When the highway passes through a wetland, the temporary site for storing construction waste shall be located outside the wetland, and it shall be disposed of after the completion of construction.

10.3.7 When constructing in areas with dense grass and trees, the regulations on forest protection and fire prevention shall be observed.

10.3.8 When the subgrade construction is carried out on a road section where there is frequent presence of wild animal which are under state or local protection, signs such as “warning” and “no hooting” shall be placed. The construction plan shall consider the types, habits, migration seasons or routes and regular activities of wild animals, and necessary passages shall be provided for animals to cross the road.

10.3.9 Ecological restoration shall comply with the following requirements:

- 1 After the borrowing and spoiling activities are completed, the borrowing site and spoiling site shall be backfilled (if necessary), levelled and compacted. The surface slope shall generally be less than 5° , and the stored topsoil shall be used for reclamation. After the construction is completed, vegetation shall be restored on the excavated surface.
- 2 After completion of the highway construction, the temporary land occupation, construction camps, temporary roads, equipment and material storage sites shall be reclaimed in a planned way. After reclamation, the original landform and landscape shall be maintained as far as possible. The original farmland shall be restored.
- 3 The bare land in the project area shall be restored with vegetation if it is suitable for planting trees and grass.

Commentary

Ecological restoration refers to the restoration and re-establishment of a healthy ecosystem (including natural ecosystem, artificial ecosystem and semi-natural and semi-artificial ecosystem) with self-recovery ability over the disturbed ecosystem through artificial design and restoration measures.

Reclamation refers to the activity of taking remediation measures in the process of highway construction, to restore land damaged due to excavation, collapse, compacted by material piles. Measures are taken to restore the land to a usable state.

10.4 Water resource protection and waste pollution control

10.4.1 In the construction and living areas, corresponding sites shall be set up for storage of industrial and domestic waste, and they shall be disposed regularly. The sludge generated from sewage treatment shall be transported to the designated storage site.

10.4.2 Industrial and domestic wastewater shall not be discharged in an uncontrolled manner. During the construction process, water from various drainage facilities shall not be discharged directly into drinking water sources, farmland, and fish ponds.

Commentary

Industrial sewage mainly includes the wastewater or oil from cleaning construction machinery and equipment as well as slurry overflow from foundation treatment. Domestic sewage primarily includes discharge water generated from kitchen, washing and toilet uses. These two types of water, if being discharged directly, will harm water quality or soil quality, pollute drinking water sources and affect the survival of fish or crop growth, so they must be treated with necessary purification measures before being discharged.

10.4.3 In karst areas, the passageway of karst water (underground and surface) shall not be cut off by subgrade construction. Water obstruction, stagnation or farmland water shortage shall not be caused.

10.4.4 It is strictly prohibited to use industrial waste with excessive harmful substances as subgrade fill material.

Commentary

When industrial waste residue is used as fill or additive, the content of harmful substances shall be tested before use to avoid excessive harmful substances and environmental pollution.

10.5 Air pollution control

10.5.1 Measures shall be taken during subgrade construction to control exhaust emissions and dust to comply with relevant national regulations on ambient air quality.

10.5.2 Exhaust emissions of machinery, equipment and transport vehicles shall comply with the relevant regulations of the national and local governments.

10.5.3 Stockyard, mixing station, material processing yard and others for subgrade construction should be located in an open area downwind of a developed area and away from residential areas and schools. When the above requirements cannot be met, environmental protection measures shall be taken.

10.5.4 Dust reduction measures shall be implemented on construction access roads by spaying water. At the intersection of a construction access road with an existing road, dedicated personnel shall be assigned for cleaning spillage and management.

10.5.5 For the transportation, storage and use of powdered materials, the following requirements shall be met:

- 1 When transporting powdered materials, measures shall be taken to prevent spillage or dust pollution. Dry powder materials should be transported in bags or tanks.
- 2 Fly ash, cement and lime shall not be stored outdoors.
- 3 The use of powdered materials as subgrade fill or to improve subgrade fill on site shall not be operated on windy days and effective measures shall be taken to prevent dust pollution.

10.5.6 Domestic and industrial waste shall not be burned. Weeds or trees shall not be burned during site clearance.

10.6 Noise and vibration control

10.6.1 Motorized vehicles and mechanical equipment used in subgrade construction shall be carefully maintained to keep their technical performance stable and prevent environmental noise pollution.

10.6.2 The highway construction organization design shall stipulate the working time and construction method for construction machinery that generates loud noise and works near environmentally sensitive areas. The construction field noise level shall comply with the current *Emission standard of environment noise for boundary of construction site* (GB 12523).

10.6.3 In residential areas or noise sensitive areas, when continuous operation is necessary for a special purpose and the ambient noise in the construction noise field is likely to exceed the emission standard during construction, measures for preventing ambient noise pollution shall be taken.

Commentary

If the noise exceeds the limiting value, measures to prevent and control noise pollution may be taken, such as adjusting the working time, optimizing the combination of construction machinery and equipment, changing the construction method, adding noise reduction devices, and setting up temporary noise barriers.

10.6.4 Mechanical equipment with loud vibration shall be equipped with technical measures for vibration and noise reduction, such as a silencer, sound insulator and shock absorber.

10.6.5 When dynamic compaction and impact compaction are carried out in populated areas or near other vibration-sensitive buildings, the buildings that may be seriously affected shall be monitored and vibration isolation measures shall be taken.

10.6.6 When a blasting operation is close to a sensitive building, the amount of explosives and the excavation progress shall be controlled to reduce the vibration.

10.7 Cultural relics protection

10.7.1 When construction is around cultural relic protection areas, appropriate protection measures shall be applied, and damage to cultural relics and historical sites shall be strictly prohibited.

10.7.2 When cultural relics are found during construction, the construction shall be suspended, the site shall be well protected, and the local cultural relics management department shall be informed immediately to study and handling. Concealing the information or unauthorized disposal of relics is not allowed.

11 Subgrade Correction and Inspection for Approval

11.1 Subgrade correction

11.1.1 Before the subgrade is completed and ready for inspection for approval, the appearance quality shall be checked and the local defects shall be addressed.

Commentary

Subgrade correction includes the correction after self-inspection and the correction after handover inspection for acceptance. The purpose of the correction is to ensure that all the work meets the technical standard and quality criteria specified in the design documents and the Specifications.

11.1.2 The surface of the subgrade shall be repaired using a reasonable scheme and process based on the specific defects. The compacted thickness of the newly repaired soil layer shall not be less than 100 mm, and the surface shall be flat after compaction, and without loose or peeling parts. After the correction, the slope shall be smooth, good-looking and firm, and the slope shall meet the design requirements.

11.1.3 Protection and retaining works shall be checked as to whether there are weepholes being omitted or blocked, whether there are deformation and displacement from the structure, and if there are quality defects, they shall be treated.

11.1.4 The surface of the ditch and channel of the drainage system shall be evenly smooth, their bottoms shall be flat, and the water may be drained away unblocked and without leakage. If there are quality defects, they shall be dealt with.

11.1.5 Temporary works and facilities shall be disposed of in a reasonable way, and the highway shall be in harmony with the natural environment.

11.2 Subgrade inspection for approval

11.2.1 After the completion of itemized works, sub-projects and independent projects, intermediate handover inspection for acceptance shall be carried out in accordance with the relevant provisions.

11.2.2 Before the inspection for subgrade handover, the transverse points, level points, as well as other marking stakes required and possibly needed in the inspection shall be restored within the construction section.

11.2.3 Before the inspection for subgrade handover, self-inspection shall be carried out according to the requirements of the *Specifications* and the current *Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering* (JTG F80/1). After passing the self-inspection, required handover documents shall be prepared and application for inspection for handover shall be submitted.

11.3 Subgrade final inspection and approval

11.3.1 Subgrade completion and handover inspection shall be carried out in accordance with the relevant provisions by the Ministry of Transport and the current *Inspection and Evaluation Quality Standards for Highway Engineering Section 1 Civil Engineering* (JTG F80/1).

11.3.2 Items required to be monitored as specified in the design document and by the *Specifications* shall be tracked and be monitored as required.

Wording Explanation for the *Specifications*

The extent of strictness of the *Specifications* is expressed by using the wording as follows:

- 1) For words denoting a very strict or mandatory requirement: “must” is used for affirmation, “must not” for negation.
- 2) For words denoting a strict requirement under normal conditions: “shall” is used for affirmation, “shall not” for negation.
- 3) For words denoting a permission of a slight degree of choice or an indication of the most suitable choice when conditions permit: “should” is used for affirmation, “should not” for negation.
- 4) “May” is used to express the option available, sometimes with the conditional permit.

Glossary in Chinese and English

序号	中文词汇	英文翻译
B		
1	白云石	Dolomite
2	板岩	Slate
3	崩塌与岩堆地段路基	Subgrade over rockslide area
4	比例误差系数	Coefficient of proportional error
5	边坡锚固	Slope anchorage
6	边数	Number of legs
7	变质岩	Metamorphic rock
C		
8	测回内同向观测高差较差	Difference in height of a replicate set
9	测角中误差(")	RMSE of measurement angle (")
10	测距相对中误差	RMSE of relative length of measured distance
11	测距中误差(mm)	RMSE of measured distance (mm)
12	沉积岩	Sedimentary rock
D		
13	大理岩	Marble
14	单位权中误差(")	RMSE of unit weighting (")
15	导线测量的主要技术要求	The main technical requirements for traverse survey
16	导线全长相对闭合差	Relative closure error of the total traverse length
17	对向观测高差较差	Difference in height in reverse observations
F		
18	方位角闭合差(")	Azimuth closure error (")
19	防止飞石或落石	Prevent flying or falling rocks
20	粉煤灰路堤	Fly ash embankment
21	附(闭)合导线长度(km)	Closed traverse length (km)

continued

序号	中文词汇	英文翻译
22	附和或环线闭合差	Closure error of a closed traverse
23	附和或环线水准路线长度	Length of closed traverse
G		
24	干砌片石护坡	Dry laid stone slope protection
25	高程控制测量等级与技术要求	Survey class and technical requirements of elevation control
26	高路堤与陡坡路堤	High embankment or embankment on steep hill side slope
27	工业废渣路堤	Slag embankment
28	固定误差	Constant error
29	光电测距三角高程的主要技术要求	The main technical requirements for EDM trigonometric leveling
30	硅质砂岩	Siliceous sandstone
H		
31	红黏土与高液限土地区路基	Subgrade in red clay or high liquid limit soil region
32	花岗岩	Granite
33	滑坡地段路基	Subgrade over potential landslide area
34	黄土地区路基	Subgrade in loess region
J		
35	机械开挖	Mechanical excavation
36	加筋土挡土墙	Reinforced soil retaining wall
37	检测已测测段高差之差	Determine the height difference of the measured sections
38	静力爆破	Static expansive rock breaking
K		
39	抗滑桩	Anti-slide pile stabilizing pile
40	客土喷播	External soil-seeding spray
L		
41	砾岩	Conglomerate
M		
42	锚定板挡土墙	Anchor plate retaining wall
43	锚杆挡土墙	Anchor rod retaining wall
44	煤矸石路堤	Waste coal embankment
45	每边测距中误差(mm)	RMSE of the length on each side (mm)
46	每公里高差中数中误差	RMSE of height difference per kilometer
N		
47	泥砾岩	Argillaceous conglomerate
48	泥石流地段路基	Subgrade over debris flow area
49	泥岩	Mudstone

continued

序号	中文词汇	英文翻译
50	泥质砂岩	Argillaceous sandstone
51	泥质页岩	Argillaceous shale
52	凝灰岩	Tuff
O		
53	偶然中误差 $M\Delta$	Accidental RMSE
P		
54	泡沫轻质土路堤	Foamed concrete embankment
55	膨胀土地区路基	Subgrade in expansive soil region
56	片麻岩	Gneiss
57	片岩	Schist
58	平面控制测量等级与技术要求	Level and technical requirements of plane control survey
Q		
59	起始边边长相对中误差	RMSE of the relative length of the starting side
60	千枚岩	Phyllite
61	全中误差	Total RMSE
R		
62	柔性防护网系统	Slope netting (for slope stabilization)
63	软土地区路基	Subgrade in soft soil region
S		
64	三角测量的主要技术要求	Main technical requirements for triangulation
65	三角形闭合差(")	Triangle closure error(")
66	三维植物网	Landscape netting
67	闪长岩	Diorite
68	石灰岩	Limestone
69	石笼式挡土墙	Gabion retaining wall
70	石英岩	Quartzite
71	水泥混凝土骨架防护	Cement concrete skeleton protection
72	水准测量的主要技术要求	Main technical requirements for leveling survey
T		
73	台背与墙背填筑	Backfill against abutment or wall
74	填砂路堤	Sandfill embankment
75	铁质砂岩	Ferruginous sandstone
76	同向测回间高差较差	Difference in interval between two replicate sets
77	土钉支护	Soil nail protection
78	土工膜袋	Geomembrane bags

continued

序号	中文词汇	英文翻译
79	土工泡沫塑料路堤	Expanded Polystyrene (EPS) foam embankment
W		
80	往返较差、附合或环形闭合差	Difference between forward run and backward run of closed traverse closure error
81	卫星定位测量的主要技术要求	Main technical requirements for Satellite positioning survey
X		
82	相邻点间平均边长参照值	Reference value of average side length between adjacent points
83	玄武岩	Basalt
84	悬臂式和扶壁式挡土墙	Cantilever or counterforted retaining wall
Y		
85	岩浆岩	Magmatic rock or volcanic rock
86	岩溶地区路基	Subgrade in karst region
87	云母片岩	Mica-schist
Z		
88	植生袋	Vegetation bag
89	中误差	Root Mean Square Error (RMSE)
90	重力式挡土墙	Gravity retaining wall
91	最弱点点位中误差	RMSE of the points with the highest deviation
92	最弱点高程中误差	RMSE of the elevation of weakest points
93	最弱相邻点边长相对中误差	RMSE of the relative side length of the adjacent points with the highest deviation
94	最弱相邻点相对点位中误差	RMSE of the relative position of the adjacent points with the highest deviation