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 J21-01—2015(EN)

Specifications for Load Test of Highway Bridges

公路桥梁荷载试验规程

(英文版)

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中华人民共和国交通运输部

公　　告

第 11 号

交通运输部关于发布《公路桥梁荷载试验规程》英文版的公告

为促进公路工程行业标准的对外交流，现发布《公路桥梁荷载试验规程》英文版［JTG/T J21-01—2015(EN)］。

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特此公告。

中华人民共和国交通运输部

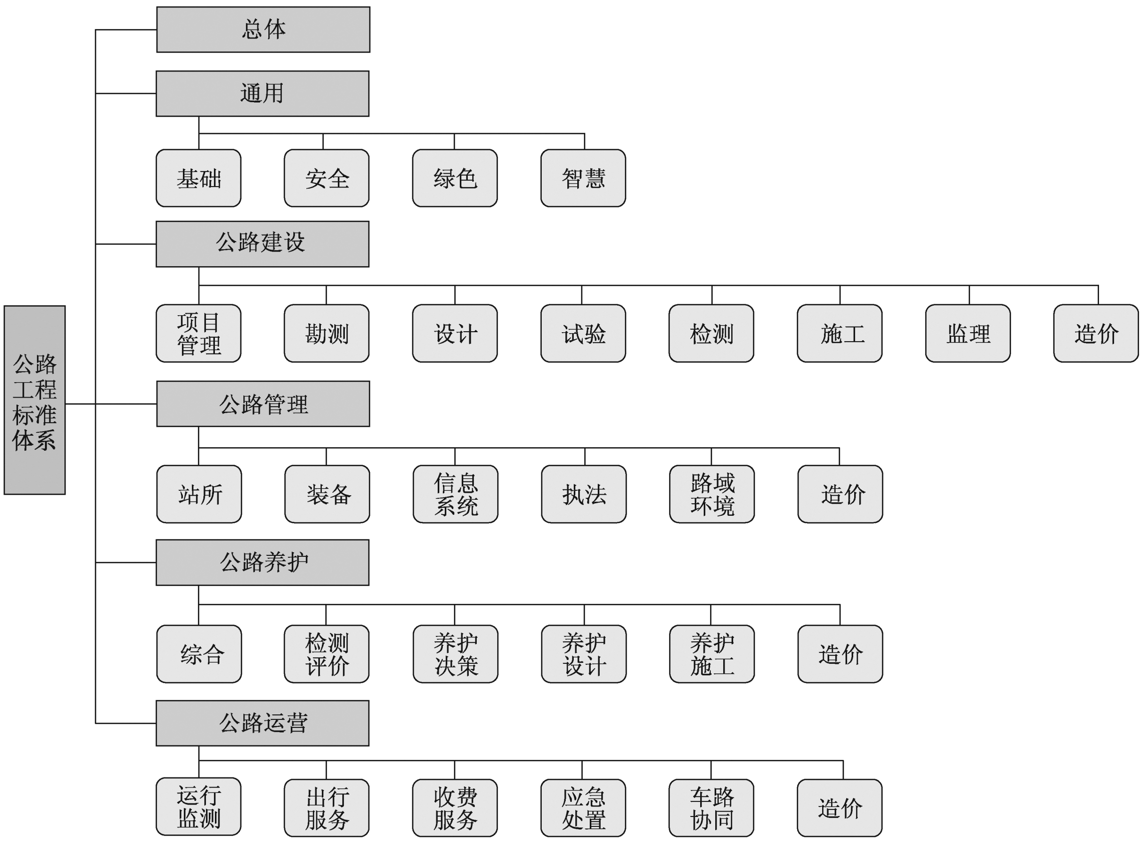
2022 年 1 月 19 日

交通运输部办公厅　　2022 年 1 月 20 日印发

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、开放的共同发展。在丝绸之路经济带与21世纪海上丝绸之路，即“一带一路”倡议的指引下，为适应日益增长的全球交通运输发展的需求，增进世界连接，促进知识传播与经验分享，中华人民共和国交通运输部组织编译并发布了一系列中国公路行业标准外文版。

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



截至2020年底，中国公路通车总里程已近520万公里，其中高速公路通车总里程超过16万公里，公路桥梁已达91万座，且每年仍快速增长。面对规模如此庞大的新建和在役桥梁，如何保证其施工质量与运营安全至关重要，而荷载试验是检验桥梁承载安全的技术手段之一。荷载试验在桥梁交(竣)工验收、日常养护、定期检查、旧桥评定中都具有非常重要的作用，对于实现桥梁的科学管养、确保桥梁安全运营、推动公路桥梁事业发展有着重要现实意义。中国的专家团队在充分总结成熟经验的基础上吸纳借鉴国内外的相关科研成果，编制了《公路桥梁荷载试验规程》(JTG/T J21—01)，其中文版于2015年发布并于2016年4月1日实施。本次编译英文版便是希望将中国的工程经验和技术成果与各国同行进行交流分享。

本英文版的编译工作由中华人民共和国交通运输部委托长安大学主持完成，并由中华人民共和国交通运输部公路局组织审定。

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The People's Republic of China

Ministry of Transport

Public Notice

No. 11

Public Notice on Issuing the English Version of *Specifications for Load Test of Highway Bridges*

The English version of JTG/T J21-01—2015(EN) *Specifications for Load Test of Highway Bridges* is issued hereby for international cooperation and standardization of highway transportation industry.

The general administration and final interpretation of the English version of the *Specifications* belong to Ministry of Transport, while particular interpretation for application and routine administration of the English version of the *Specifications* shall be provided by Chang'an University.

In event of any ambiguity or discrepancies between the English version and Chinese version of the *Specifications*, the Chinese version should be referred and accepted.

Comments, suggestions and inquiries are welcome and should be addressed to Chang'an University (Address: Middle section, South 2nd Ring Road, Xi'an, P. R. China; Postal Code: 710064; E-mail: heshai@chd.edu.cn). The feedbacks will be considered in future revisions.

It is hereby announced.

Ministry of Transport of the People's Republic of China

January 19, 2022

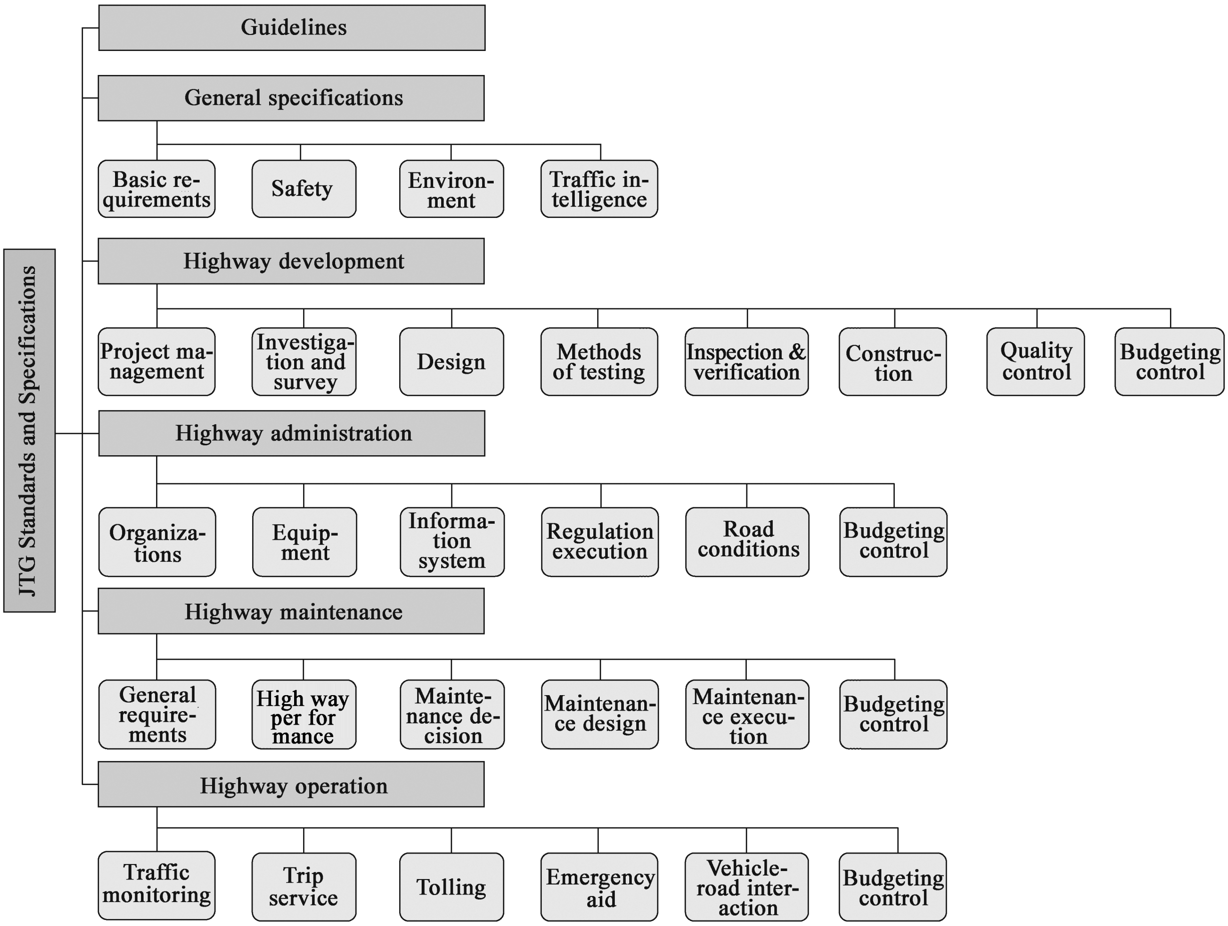
General Office of Ministry of Transport   Printed on January 20, 2022

Introduction to English Version

Standards reflect the achievement of civilization, provide common languages for technical communications and improve global connectivity. In recent years, Chinese government has been proactively implementing the standardization to stimulate innovation, coordination, greening and opening up for shared development in China and worldwide. In light of mutual development along the Silk Road Economic Belt and the 21st-Century Maritime Silk Road (so called 'the Belt and Road Initiative'), the Ministry of Transport of the People's Republic of China organized translation and published international version of Chinese transportation industry standards and specifications to cope with the increasing demands for international cooperation in world transportation, achieve interconnected development and promote knowledge dispersion and experience sharing.

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

By the end of 2020, there exist nearly 5.2 million kilometers of highways in China, including more than 160,000 kilometers of expressway and 910,000 bridges, which are still in growth dramatically each year. In the face of such a large scale of newly-built and in-service bridges, how to ensure its construction quality and operation safety is of great importance. Load test is one of the technical means to test the load carrying safety of bridge, which plays an essential role in bridge acceptance for hand-over & complete construction, daily maintenance, regular inspection and aged bridge evaluation. It has practical significance for realizing the scientific management and maintenance of bridges, ensuring the safe operation and promoting the development of highway bridges. On the basis of fully summarizing mature experience and absorbing relevant scientific research achievements at home and abroad, the Chinese experts compiled the JTG/T J21-01—2015 (E) *Specifications for Load Test of Highway Bridges*. The purpose of compiling this English version is to exchange and share Chinese engineering experience and technical achievements with counterparts from other countries.



The compiling work is entrusted by the Ministry of Transport of the People's Republic of China to Chang'an University and approved by the Highway Department of Ministry of Transport of the People's Republic of China.

The contents and numbering of the chapters, sections, clauses and sub-clauses in the English version are exactly the same as those in Chinese version. In event of any ambiguity or discrepancies, the Chinese version should be referred and accepted.

Comments, suggestions and inquiries are welcome and should be addressed to editing organization in charge of English version (Address: Middle section, South 2nd Ring Road, Xi'an, P. R. China; Postal Code: 710064, Fax: 029-82334871;

E-mail: heshai@chd.edu.cn). The feedbacks shall be taken into account in next editions.

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Foreword to Chinese Version

In accordance with the requirements of the[2011] No.115 document "The Circular of the Ministry of Transport of the People's Republic of China on Issuing the Plan of Revising and Revising the Highway Engineering Standards in 2011", Chang'an University, as the chief editor, is responsible for the production of JTG/T J21-01—2015 (E) *Specifications for Load Test of Highway Bridges*.

During the compilation of the *Specifications*, the mature experience in load test of highway bridges have been reviewed and summarized. Based on the principle of coordinating with the current technical standards and specifications of highway engineering, this *Specifications* is prepared in view of the problems and requirements existing in the load test of highway bridges.

The *Specifications* comprises 8 chapters and 5 appendixes. The main contents include: 1. General; 2. Terms and Symbols; 3. Basic Requirements; 4. Instrument and measurement requirements; 5. Static Load Test; 6. Dynamic Load Test; 7. Field Implementation; 8. Reporting; Appendix A. Technical Requirements for Test Instruments of Bridge Static Parameters; Appendix B. Vibration-based Cable Force Measure method; Appendix C. Technical Requirements for Test Instruments of Bridge Dynamic Parameters; Appendix D. Test Record of Crack in Concrete During Load Test; Appendix E. Test Report Format.

Concerning the compiling work, chief editor He Shuanhai is in charge of Chapter 1, Chapter 2 & Chapter 3, Zhang Jinquan Chapter 4, Appendix A & Appendix C, Zhao Yu, Huang Qiao and Xu Hongyuan Chapter 5, Appendix B & Appendix D, Tang Guangwu, Zhou Zhixiang and Song Yifan Chapter 6, Li Chuanxi and Chen Airong Chapter 7, Yan Lei and Qiao Huaiyu Chapter 8 & Appendix E.

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Contents

1 General provisions

1.0.1 The Specifications is to develop load test and to provide the guidelines for the service conditions and load carrying capacity assessments for highway bridges.

***Background*:**
The bridge load test is to record the structural responses under load conditions, to provide a reasonable evaluation for the technical condition and load-carrying capacity, and to better support the maintenance, rehabilitation, or reinforcement in the future.

1.0.2 The *Specification*s is applicable for load test of newly-built, reinforcement or reconstructed highway bridges.

1.0.3 Load test of highway bridges shall follow the scientific, objective, precise, reasonable and safe principles.

1.0.4 The highway bridge load test shall comply with not only the *Specification*s but also the provisions in the current relevant national and industrial standards.

2 Terms and Symbols

2.1 Terms

2.1.1 Bridge load test

The field tests for the static and dynamic characteristics of a bridge structure or components by means of load, including applying static load testand dynamic load test.

2.1.2 Static load test

Static external load, equivalent to the control load, is applied to the bridge structure to test the mechanical responses of critical section.

2.1.3 Dynamic load test

A field test to measure the ambient vibration characteristics and natural vibration characteristics of bridge structures or components under dynamic excitation and environmental load.

2.1.4 Control load

A load, design load or target load, used to determine the load test efficiency. and the initial load used for the multi-step load level.

2.1.5 Target load

A load, the bridge is expected to withstand, needs to be verified through the load test.

2.1.6 Support settlement

The sum of the deformation due to bearing compression and the vertical displacement of the pier.

2.1.7 Load test efficiency

The ratio of the structural responses due to the test load and the control load. Test load refers to the vehicle load applied to bridges in the load test.

2.1.8 Structural verification coefficient

The ratio of themeasurement value of the structural strain (stress) or deformation under the test load to the corresponding theoretically calculated value.

2.2 Symbols

S—Calculated value of the most unfavorable effect on the internal force or deformation at the critical section under the control load;

S_s—Maximum calculated effect of the critical section's internal force or deformation under the static load test load;

S_t—Total deformation (or total strain) of the structure measured under the test load;

S_e—Elastic deformation (or strain) of the structure measured under the test load;

S_p—Residual deformation (or residual strain) of the structure measured under the test load;

S_i—Measurement value before applying the load;

S_l—Measurement value when the load is stable;

S_u—Measurement value when stability is reached after unload;

S_d—Maximum internal force or deformation of the critical section under the dynamic load test;

ΔS—Change of measurement value under load at the gauging point before the correction due to temperature effect;

ΔS_t—Change of measurement value under load at the gauging point after the correction due to temperature effect;

ΔS_p—Relative residual deformation (or strain);

S_e—Average of the measured deformation (or strain) for the transverse measurement points;

S_{emax}—Maximum value of the measured deformation (or strain);

$S_{l\max}$—Maximum internal force or deformation of the critical section under the control load (excludingimpacteffect);

f—Measured natural frequency with additional mass effect;

f_n—N^{th}-order natural frequency of the cable;

f_{dmax}—Maximum dynamic deflection amplitude;

F_{jmax}—Vertex value of the trajectory of the waveform amplitude center;

f_{dmin}—Trough value corresponding tof_{dmax};

f_0—Natural frequency of the structure;

C—Correction amount of the supporting settlement at the measured position;

D—Damping ratio;

M—Additional mass;

M_0—Equivalent mass of the structure at the exciting position;

T—Cable force;

EI—Bending stiffness of cable;

ρ—Linear density of cable;

μ—Impact factor;

ξ—Lateral amplification factor;

η—Verification coefficient

η_q—Load efficiency of static load test;

η_d—Load efficiency of dynamic load test.

3 Basic requirements

3.1 General

3.1.1 The newly-built bridge and the strengthened or reconstructed bridge may be evaluated by load test to check whether the service conditions and load-carrying capacity of the bridge structure meet the design requirements.

3.1.2 In addition to Clause 3.2.4① in the *Specifications for Inspection and Evaluation of Load-bearing Capacity of Highway Bridge* (JTG/T J21-2011), the load test for bridges in service, may be carried out when one of the following conditions is applicable:

1 when the working condition is level 4 ~ 5②;

2 when the load level needs to be upgraded;

3 when a special heavy vehicle needs to pass over the bridge;

4 when the bridge was damaged by a major natural disaster or accident;

5 when it is impossible to accurately determine whether or not the bridge can withstand a pre-determined load by other methods.

3.1.3 For bridges built with new technologies, new construction methods, new types of structures or new materials, a load test should be carried out connection by connection③ or bridge

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① The ratio of load effective to resistance is 1.0 ~ 1.2.

② level 4: there are great defects in key components, which seriously affect the function or the carrying capacity. level 5: There are critical defects in the key components which cannot perform normally, endangering the safety of the bridge.

③ Connection is the girder between two adjacent expension joints for continous girder bridges, which consists of two or more spans.

by bridge.

3.1.4 The load test should be carried out after the bridge deck pavement is completed and reaches its design strength.

***Background*:**
The completion of bridge deck pavement construction (the concrete reached design strength) can ensure that the bridge deck mechanical behavior and moving vihicle test are similar to the design state.

3.1.5 The load test shall ensure the safety of the overall structure and local components.

3.1.6 Bridge load measurement data shall be documented into a highway bridge maintenance file and bridge management system.

3.2 Test Procedures

3.2.1 The load test shall be carried out in three stages, i.e., test preparation, field implementation, and measurement data analysis.

3.2.2 The preparation phase shall include:

1 Information collection. The following document shall be collected:
  1) Design document: design drawings, modification drawings and other original data of design basis.
  2) Construction and supervision documents: material performance test report, acceptance report for each part of construction project, and so on.
  3) Construction monitoring and control data: construction monitoring and control report, bridge linear profile, internal force (stress), cable force (suspender force), etc.
  4) Information about as-built: as-built drawings, acceptance reports.

2 Field investigation. This investigation is mainly to gather information on the overall dimensions of the bridge structure, the cross-section dimension of the main components, the elevation of the main parts, the roughness of the bridge deck, the conditions of the supports, the physical and mechanical properties of the material, cracks in the structure, defects, and the damage and corrosion condition of the rebar.

3 Testing span selection. Based on on-site survey and inspection of the proposed bridge span (connection), a representative bridge span is selected as the test span. It should be convenience for bracket erection, inspection vehicle operation, convenient load and ease of connecting instruments.

4 Programming. The internal force, deflection and structure fundamental frequency shall be calculated in advance. Accordingly, the load vehicle (or load block) shall be determined according to the equivalence principle combined with the measurement contents. Meanwhile, other items shall be prepared, including the multi-step load case, load position, measurement points layout and measurement scheme, etc.

Background:

1 *Technical details related to load test may be collected by visiting the project construction unit, administrative unit and engineering design company, etc.*

2 *The test span is usually determined due to the representative performance of the test bridge (or connection). The test span has the most unfavorable mechanical condition, poor technical condition, and severe damage or defects.*

3.2.3 The site implementation phase shall include:

1 Site preparation. This includes the test point setting and layout, load organization, on-site traffic organization and test system installation and commissioning, etc.

2 Pre-load step. The pre-load step shall be finished before the load test, and the working condition of the whole test system shall be tested and debugged.

3 Load test. The load test is carried out following the predetermined load test scheme, and the measurement values and related information are recorded.

4 Process monitoring. The measurement value of the maximum effect in the main critical section[①] shall be monitored and compared with the corresponding theoretical calculated value. Attention shall be paid to the mechanical index changes of the structural weak parts and the development of existing damage or defects. It shall then be determined whether the bridge structure is normal, whether reload is safe, and whether the next step of load may be carried out.

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① Critical section means the maximum force, or deformation, section subjected to load. As for simply supported girder, it includes the mid-span section.

3.2.4 The test results analysis phase shall include:

1 Theoretical calculation. According to the actual application of the load on the bridge structure, the theoretical internal force, stress (strain) and deformation of the bridge structure shall be calculated. The crack width and dynamic response shall be analyzed if necessary.

2 Data analysis. The original measurement records are analyzed and processed to extract valuable information.

3 Report preparation. Based on the comparison and analysis of theoretical calculation and measurement data, the results are judged and evaluated. Accordingly, the report is formed.

Background:
The originalmeasurement records include large quantities of observation data, written records, pictures, etc. Due to the influence of many factors during the test, the collected data needs to be carefully analyzed to obtain reasonable information. If necessary, some data or signals shall be analysized, accepted & rejected in accordance with statistical methods. Specialized analytical instruments and analysis software may be used for data analysis and processing, or calculations may be conducted according to relevant standards.

3.3 Test Environments

3.3.1 The load test shall be carried out in closed traffic conditions.

3.3.2 Load test should not be carried out under strong winds. For suspension bridges, cable-stayed bridges, long-span truss arch bridges and extra-high pier bridges, the load shall be implemented under the condition of less than wind level 3. For long-span bridges in strong wind areas, the wind velocity shall be monitored when the load test is carried out. And the load test shall be suspended if necessary.

3.3.3 The load test shall be carried out when the enviromental temperature is stable. The load test should not be performed with the temperature lower than 5°C or higher than 35°C. In case of temperatures out of this range, whether the load test is implemented shall be determined based on the temperature requirement of instruments.

***Background*:**
The load testshall be carried out during a period of stable temperature so as to reduce the influence of environmental temperature variations on the test results.

3.3.4 Load test should not be carried out in moderate-heavy rain or foggy weather. For a light rain weather, the instrument transmission lines shall be well protected.

3.3.5 Load test should not be carried out under circumstances of impact, vibration, strong magnetic field or other factors interfering test results.

3.3.6 The load test should not be carried out under strong waves, high humidity or other harsh environments.

***Background*:**
As high temperature, strong light, strong wind, strong waves, or high humidity will affect the implementation of the load test, the load test shall be carried out in a period when the weather is stable.

3.4 Calculation Rules

3.4.1 Numerical models shall be established according to the as-built drawings and before the hand-over & complete construction bridge load test. The control load shall be determined by the design load level. The dynamic parameters of the structure, the internal forces in the critical section, the stress (strain) and the deflection are calculated based on the corresponding design specifications. For the hand-over & complete construction load test of a strengthened or reconstructed bridge, the interaction & influence of the newly-built and aged structures shall be considered in the calculation.

3.4.2 For a bridge specified in Clause 3.1.2 and a bridge whose target load is the control load, a calculation model shall be established based on measured parameters, which include the geometrical dimensions, the material properties and the actual condition. The calculation shall be conducted step by step after the multi-step load cases are determined. Based on the control load, the dynamic parameters, the internal force of the critical section, the stress (strain) and the deformation are calculated according to the corresponding design specifications. For the aged bridges without the design and construction details, the complete construction documents of bridges with the same type or the same age may be referred to. Meanwhile, the checking calculation shall be conducted step by step.

3.4.3 For the calculation and analysis of an irregular bridge, the spatial effects should be considered.

3.4.4 A 3-dimensional model should be adopted to calculate the dynamic characteristics of a bridge. For the dynamic analysis of a strengthened or reconstructed bridge, the differences in mechanical properties between old vs new materials and structures shall be considered.

3.4.5 For the test load determination based on equivalent principle, the internal force, stress (strain), displacement, crack of the critical section under the target load shall be compared with the corresponding value of the test load. The load level shall be determined according to Clause5.4.2. However, the relevant structural responses of other sections shall be within the prescribed limit.

4 Instruments and Measurement Requirements

4.1 General

4.1.1 The technical performance of the test instruments shall conform to the relevant standards. Test instruments shall be regularly calibrated according to the regulations. Advanced instruments should be adopted.

***Background*:**
All instrument used for inspection, including auxiliary measurement instrument, shall be calibrated before being put into use. For some important tests, the main parameters of the instrument shall be specially calibrated beforehand.

4.1.2 Test instrument shall be checked before load test.

4.1.3 The accuracy of the test insturment shall not be greater than 5% of the estimated measurement value.

4.1.4 The measurement range of the test instrument shall meet the test requirements.

***Background*:**
The measurement value shall be in the 15% ~85% of the test instrument range.

4.1.5 In the same load test, the same type of test instrument should be used.

***Background*:**
The choicefor the same type of test instrument is to improve the efficiency and reliability of the testing.

4.2 Static Parameter Test

4.2.1 The static parameter of the bridge static test should include strain (stress), deflection, crack, inclination angle and cable (suspender) force. During the test, the structural response shall be monitored.

4.2.2 Strain (stress) measurement shall meet the following requirements:

1 Tensile and compressive strain (stress) and principal strain (stress) shall be measured.

2 Strain (stress) measuremen tinstruments shall meet the technical requirements of Table A. 0.1 in Appendix A.

Background:
Strain (stress) measurements may be carried out by mechanical, optical, or electrical devices. Sensors include extensometers, electrical resistance strain gauges, vibrating string strain gauges or optical fiber sensors.

The extensometer is a mechanical strain testing device. Whenmeasuring strain with an extensometer, it may be calibrated with an accuracy of 0.001*mm in the dial gauge, and it is assembled into a dial gauge extensometer. When measuring strain with a electrical resistance strain gauge, the electrical resistance strain gauge is usually attached to the structural component. When measuring strain with a vibrating string strain gauge, the "force-frequency" relationship curve is usually pre-calibrated and the strain value is measured by the natural frequency of the steel string. When measuring strain with optical fiber sensors, it is usually necessary to calibrate the relationship between the fiber grating period (or the refractive index of the core) and the force or strain. Accordingly, the strain value may be obtained by the change of the fiber grating period or the core refractive index.*

Electrical resistance strain gauge layout is generally based onfield temperature, humidity and other conditions. Patching with moisture-proofing methods are necessary. Compensation gauge shall be chosen to match the material of the structure. When a dial gauge is used to measure the surface strain, it shall be located as close as possible to the surface of the structure to reduce measurement error. When a vibrating string strain gauge is installed, the initial readings of the instrument shall be recorded with the number of the instrument & measurement point. Fiber grating strain gauge needs to be used with special base. The base is fixed on the surface of the structure by special *fastening screws, which may be disassembled and reused after the load test.*

4.2.3 The deflection measurement shall comply with the following requirements:

1 Vertical deflection and horizontal displacement shall be measured. Horizontal displacement includes longitudinal displacement and transverse displacement.

2 Deformation measurement may be performed with mechanical or electrical (acoustic or optic) or GPS instruments. The instruments shall meet the technical requirements of Table A.0.2 in Appendix A.

Background:
Mechanicaltest instruments include dial gauges, dial indicator, liquid level meters and deflection gauges. Electrical (acoustic or optic) test instruments include electrical measurement deformation meters, levels, theodolites, total station, laser distance measurement devices and electromechanical dial gauges.

Mechanical testinstrument refers to various non-electrical principle instruments, apparatus or equipment, which need manual reading. Electric (acoustic, optic) test instrument can record the measurement value automatically. It has high accuracy, high refresh rate, and large measurement range. When the bridge spans is over 50m, the communicating pipe is usually used to measure deflection. In order to improve the measurement accuracy with GPS, the real-time difference technique based on carrier phase observation is usually performed.

4.2.4 Cracks shall be measured in accordance with the following requirements:

1 Crack measurement shall be focused on regions with higher tension or longer & wider portions.

2 The existing cracks should be measured. And the new cracks shall be identified and measured in the load test process.

3 Crack length, distribution and shape may be directly observed. The crack width may be measured with microscope, crack gauge, crack width detector, or fixed device installed over the crack. If necessary, the depth of the crack may be measured by drilling cores or other nondestructive methods. Crack measurement instruments shall comply with the requirements of Table A.0.3 in appendix A.

4.2.5 Inclination angle measurement shall comply with the following provisions:

1 Both the horizontal and vertical inclination angles should be measured.

2 Inclination angle measurement may be carried out with horizontal inclinometer, fiber optical inclinometer, digital inclinometer or biaxial inclinometer etc. The inclination angle measurement instrument shall comply with the technical requirements of Table A.0.4 in Appendix A.

4.2.6 Cable (suspender) force measurement should comply with the following requirements:

1 The vibration measurement method mentioned in Appendix B may be used to determine the forces of stay cables, cable (suspender), tie bars and main cables. The instruments shall comply with the requirements in Appendix C.

2 For measurement of the vibration signals of cables, the sensors shall be arranged far away from the anchorage. Spectral analysis needs to be conducted. When there is a damper in the cable, the calculation formula of the cable force shall be modified.

3 The measurement of the cable force shall be performed at a similar temperature to that during the span closure. The temperature difference between the two cases shall be controlled within the range of ±5℃, otherwise the cable force shall be revised.

***Background*:**
Cable (suspender) force includes the cable tension forces in cable-stayed bridges, suspender force in the through (or half through) arch bridges, tie bar forces, main cable forces in suspension bridges and suspender cable forces. When testing cable forces, the vibration frequency of the cable is estimated beforehand. The appropriate sensors for the vibration response are selected. The cable is vibrated by means of ambient random vibration or artificial excitation. The transverse vibration frequency of the cable is measured, and the cable force is calculated and analyzed correspondingly. The cable force is measured at the same temperature as that of the main girder closure, and it is convenient to compare the measurement cable force with that of the closure.

4.3 Test for Dynamic Parameters

4.3.1 During the dynamic load test, the natural vibration parameters and dynamic responses of the bridge shall be tested. Meanwhile, the reaction of the structure shall be monitored.

Background:

Thenatural vibration parameters include the natural frequency (natural vibration period), damping ratio and vibration mode shape. The dynamic responses refer to the dynamic stress, dynamic deflection, acceleration, dynamic amplification factor and impact factor under the specific dynamic load.

4.3.2 The natural vibration parameters test shall comply with the following requirements:

1 The natural frequency (vibration period), damping ratio and vibration mode shape shall be measured.

2 Test instruments to measure thethe natural vibration parameters include a vibration sensor, signal amplifier and data recorder etc. The vibration sensor shall be laid in the peak (trough) point of the theoretical vibration mode shape, reference point and dividing points. The selected reference points and the various mode nodes are used to simultaneously measure the vibration response signals of each measurement point. The test instrument of bridge vibration characteristics shall comply with the technical requirements in Appendix C.

Background:

Whenmeasuring the vibration mode shape of a bridge, the theoretical vibration mode shape is usually analyzed beforehand. The number of the measured points shall be great enough to describe the vibration mode shape curves, and the measurement points shall be distributed on the critical section as much as possible. When the number of vibration sensor is limited, a vibration sensor is usually arranged on the reference point and other vibration sensors are moved in batches to obtain all measurement data. The vibration measurement instrument system is calibrated at the reference point before the vibration mode shape measurement. With the help of the system sensitivity of each channel, the measurement amplitude relationship is obtained and normalized, with the maximum coordinate value set to 1.

4.3.3 The dynamic response measurement shall comply with the following requirements:

1 Dynamic displacement, dynamic strain, dynamic amplification factor and impact factor shall be measured.

2 Dynamic displacement may be measured by a dynamic displacement sensor & signal amplifier, photoelectric deformation measurement instruments. The dynamic strain may be measured by electric resistance strain gauges, dynamic strain acquisition or optical fiber strain gauges and modems. The dynamic amplification factor and impact factor shall be calculated from the measurement data. The bridge dynamic response test instrument shall

comply with the requirements in Appendix C.

3 The measurement points of dynamic responses shall be arranged in the locations with larger deflection or strains.

4 The validity of data acquisition shall be ensured.

4.4 Testing Requirements

4.4.1 After the test instrument is set up, the measurement system shall be adjusted with no less than 15 minutes of stable observation.

Background:

Afterthe test instrument is set up, the test instrumentation is usually checked with passing vehicles or preload to observe whether the test instrumentation is working properly. The measurement data needs to be stabilized for a period of time before load testing.

4.4.2 Necessary measures shall be taken to safeguard the test instrument at the test site.

Background:

The parts of the testinstrument that are susceptible to collision disturbance shall usually be set for protective instrument, a security rope, or an eye-catching sign. In the field, the effect of temperature and humidity shall not be neglected, and moisture-proof measures are adopted to ensure the normal working conditions of the instrument.

4.4.3 The measurement data shall be analyzed in real time. If abnormal phenomena are found, the cause shall be identified and corrective measures shall be taken.

4.4.4 The test results may be recorded manually or automatically. Manual recordings shall be timely and accurate with a special form. For automatical measurement system, the measurement values of some critical points shall be monitored.

Background:

Therecord forms generally include the number of the test instrument, the number of the multi-steps load, the corresponding readings, the record of any abnormal conditions, and the names of the recording persons and the checkers.

5 Static Load Test

5.1 General

5.1.1 The scheme for the bridge static load test shall be set up on the basis of the inspection and analysis of the bridge.

***Background*:**
The staticload test scheme includes measurement sections, test cases, measurement contents, test loads, measurement point arrangement, test process control and data analysis.

5.1.2 The static load test should be carried out on the critical sections for internal force, stress, displacement and crack of the bridge.

5.1.3 The static load test includes symmetrical load cases and the off-center load cases. For skewed bridges, curved bridges, irregular bridges and straight bridges that have transverse support asymmetry. The load position and the off-center direction of the test cases shall be determined through calculation.

***Background*:**
Bridge design is controlled by the most unfavorable case. The most unfavorable case tends to be off-center load cases, which can reflect the differences between actual state and design state concerning internal force & deformation of the bridge. Regarding the randomness of the bridge operation load, the symmetrical load cases shall be considered to indicate the mechanical characteristics of bridges under normal circumstances.

5.2 Test case and measurement section

5.2.1 The load cases and measurement sections for the static load test shall be determined in accordance with most unfavorable condition principle and representative principle of the bridge.

***Background*:**
Measurement sections are selected according to the most unfavorable principle based on the force envelope diagram and stress distribution. Correspondingly, the test cases are determined.

5.2.2 Static load cases and measurement sections for regular bridges should be determined as shown in Table 5.2.2, from which the basic load case must be conducted, and additional load cases may be conducted according to the specific situation. When the strain on the section with maximum bending moment is measured, the displacement of the section should be recorded simultaneously.

Table 5.2.2 Static load cases and measurement sections for regular bridges

<table>
<tr><th>Bridge type</th><th colspan="2">Test cases</th><th>Measurement sections</th></tr>
<tr><td rowspan="2">Simply supportedgirder bridge</td><td>Basic load case</td><td>Max. Bending moment of main girder at mid-span</td><td>Mid-spansection</td></tr>
<tr><td>Additional load cases</td><td>①Max. bending moment of maingirder at L/4 section;
②Max. shear force of main girder near the support;</td><td>①L/4 section
②Intersection of cross-section centroid lineand oblique line about h/2 from support point (Table 5.5.1-2)</td></tr>
<tr><td rowspan="2">Continuous girder bridge</td><td>Basic load case</td><td>①Max. negative bending moment of main span at support
②Max. positive bending moment of mainspanat mid-span section
③Max. positive bending moment of maingirder side spans</td><td>①Support section of main span(s)
②Max. bending moment sectionofmain span(s)
③Max. bending moment section of side spans</td></tr>
<tr><td>Additional loadcases</td><td>Max. shear of maingirder near main span (middle) support</td><td>Sections to be decided by calculation</td></tr>
<tr><td>Cantilevered girder bridge</td><td>Basic load case</td><td>①Max. negative bending moment in cross section at support
② Max. positive bending moment in anchorage span</td><td>①Pier support section
②Max. positive bending moment section of anchorage span</td></tr>
</table>

continued

Bridge type	Test cases		Measurement sections
Cantilevered girder bridge	Additional load cases	①Max. shear in cross section at pier support ②Max. positive bending moment at mid-span of suspended span ③Max. shear at support of suspended span ④Max. deflection at cantilever arm	①Calculate the location of thespecif · ic section ②Mid-span section of suspended span ③The h/2 of the bottom of thegirder, the 45 degree and the intersection of the cross-section centroid(Table 5.5.1-2) ④End section of cantilever span
Three hinged arch bridge	Basic load case	①Max. shear of arch crown ②Max. horizontal thrust of haunch	① Both cross-sections about 1/2h from arch crown ②arch springing section
	Additional load cases	①Max. positive and max. negative bending moment at$L/4$ section ②Max. sum of absolute value of positive and negative deflections of$L/4$ section	①$L/4$ section of the main arch ②$L/4$ section and $3L/4$ section of main arch
Two hinged arch bridge	Basic load case	① Max. positive bending moment of arch crown ②Max. horizontal thrust in haunch	①Arch crown section ②Haunch section
	Additional load cases	①Max. positive and max. negative bending moment at$L/4$ section ②Max. sum of absolute value of positive and negative deflections at$L/4$ section	①$L/4$ section of main arch ②$L/4$ section and $3L/4$ section of main arch
Hingeless arch bridge	Basic load case	① Max. positive bending moment and deflection of arch crown ② Max. negative bending moment in haunch ③Max. tension force of suspender (cable) near mid-span of tied arch bridge	①Arch crown section ②Haunch section ③Typical suspender (cable)
	Additional load cases	①Max. horizontal thrust in haunch ②Max. positive and max. negative bending momentcaseat $L/4$ section ③Max. sum of absolute value of positive and negative deflections at$L/4$ section	①Haunch section ②$L/4$ section of main arch ③$L/4$ section and $3L/4$ section of main arch
Vierendeel bridge	Basic load case	①Max. positive bending moment of girder at mid-span section ② Max. or min. bending moment at anchorage end	①Mid-span section ② Anchorage end girder or vertical wall section
	Additional load cases	Max. shear force at anchorage end	Anchorage end section of girder

continued

Bridge type	Test cases		Measurement sections
Batter post rigid frame bridge	Basic load case	①Max. positive bending moment of girder at mid-span ②Max. negative bending moment of maingirder at inclined leg top	① Max. positive bending moment section of mid-span ② Rigid point middlegirder or side girder sections of inclined leg
	Additional load cases	① Max. positive bending moment of maingirder side span ②Max. shear at top of inclined leg ③ Max. or min. bending moment at inclined leg foot	① Max. positive bending moment section of side span ②Middle or side girder sections of inclined leg top or inclined leg top section ③Inclined leg foot section
T-shaped frame bridge	Basic load case	① Max. negative bending moment of maingirder at support ② Max. positive bending moment of maingirder in suspended span	①Pier top section ③ Mid-span section of suspended span
	Additional load cases	①Max. shear of maingirder near pier ②Max. shear at support of suspended span	① Calculate the location of the specific section ② The $h/2$ of the bottom of the girder, the 45 degree and the intersection of the cross-section centroid (Table 5.5.1-2)
Continuous rigid frame bridge	Basic load case	① Max. negative bending moment of maingirder at main span pier ② Max. positive bending moment and deflection of main girder at mid-span section ③Max. bending moment and deflection of maingirder side span	①Pier section of main span ② Max. positive bending moment section of main span ③ Max. position bending moment section of side span
	Additional load cases	①Max. shear at pier ② Max. horizontal (longitudinal) displacement at pier	① Calculate the position of specific section ②Pier top section
Cable-stayed bridge	Basic load case	① Max. positive bending moment and deflection at mid-span of maingirder ②Max. negative bending moment in maingirder at pier ③Max. horizontal (longitudinal) displacement atpylon top and max. bending moment at pylon base	①Max. positive bending moment of mid-span ②Pier top section ③Pylon top section (displacement) and max. bending moment section of pylon foot
	Additional load cases	①Max. cable tension near middle span ②Max. horizontal displacement of maingirder	①Typical guy ② Stiffeninggirder at both ends (horizontal displacement)

continued

Bridge type	Test cases		Measurement sections
Suspension bridge	Basic load case	①Max. positive moment and deflection of stiffeninggirder at mid-span ②Max. positive moment of stiffeninggirder in 3L/8 section ③ Max. horizontal (longitudinal) displacement atpylon top and max. bending moment at pylon base	①Max. bending moment section at mid-span ②Mid-span3L/8 section ③Section ofpylon top (displacement) and max. bending moment section of pylon foot
	Additional load cases	①Max. tension main cable strand in anchor span ② Max. longitudinal displacement at end of stiffeninggirder ③Max. increment of live load of suspender (cable) ④Max. suspender (cable) tension	①Typical cable strand in anchorage zone of main cable ② Stiffeninggirder at both ends (horizontal displacement) ③Typical suspender (cable) ④ Most unfavorable suspender (cable)

Note: L-calculated bridge span; h-maingirder depth.

5.2.3 For irregular bridges and hybrid bridges, the load cases and the measurement sections shall be determined by calculation in accordance with the load cases and the main mechanical characteristics of the bridge.

***Background*:**

For various forms of irregular bridges andhybrid bridges, the measurement sections and corresponding load cases are determined by calculation results and structural features of the bridges. When calculated, the cases for torque moment &bending-torsion coupling and the support reactions shall be taken into account besides the most unfavorable cases of bending moment, shear force, axial force, etc.

5.2.4 The measurement sections and corresponding load cases shall be selected and determined based on the mechanical characteristics of the ultimate structural system for strengthened or reconstructed bridges. Meanwhile, the most unfavorable principle, strengthened scope and original damaged structure situation shall be taken into account.

5.2.5 For strengthened or reconstructed bridges, other than those specified in Clause 5.2.2, additional load cases and measurement sections shall be performed in the case of any of the following situations:

1 For multi-girder (plate) bridges strengthened by enlarging cross sections of side girders, the off-center load case should be added according to the structural symmetry.

2 For bridgesstrengthened by concrete replacement, the measurement sections should be added in the concrete replacement area and the corresponding load cases should be determined.

3 For repaired structuralcomponents with stress crack width exceeding the design code limit, measurement section should be added at a typical crack location and the corresponding load cases should be determined.

***Background*:**
For bridges retrofitted by concrete replacement or crack repair, measurement sections shall be selected and load cases shall be added for the repair area. The retrofit effect could be verified on the deformation behaviour of the interface between the old and new concrete and the structural performance.

5.2.6 Load cases and measurement sections of widened bridges shall comply with the Clause 5.2.2 in the *Specifications*. Load cases and measurement sections shall also be respectively set for the newly-built and aged structures, and load cases may be added for transverse connection.

***Background*:**
For widened bridges, if there arebig differences in the structural stiffness or the boundary support stiffness between the newly-built and aged parts, the load transverse distribution of the bridge and internal forces in transverse girders maybe change significantly. Therefore, special tests shall be focused on this aspect.

5.2.7 For the static load test of in-service bridges, other than the rules specified in Table 5.2.2, additional load cases and measurement sections shall be performed according to the calculation results, damage degree and location, and other features of the structure.

5.3 Measurement items

5.3.1 The static load test shall illustrate the mechanical characteristics on the most unfavorable critical section in terms of the internal force, stress (strain), displacement and crack of the bridge. Abnormal phenomena shall be carefully noted, when observed.

***Background*:**
Stress (strain) measurement is mainly focused on the tensile and compression zones of themeasurement sections. Measurement points are aligned along the section depth or transverse

position of the section so as to obtain the stress distribution features of the structure. The displacement measurement includes deflection, and longitudinal or lateral displacement of the critical sections of the girders, and the three-dimensional coordinates of the pylon, etc. It can illustrate the global or local stiffness of the bridge. When it is difficult to directly measure the displacement of the pylon, its displacement and verticality can also be worked out by measuring its inclination angle. The increment and distribution of cable (suspender) force under the test load illustrate the mechanical characteristics of the structure. The observation of test phenomena, such as crack development, abnormal vibration and noise of the structure, can help the engineers to understand the working performance of the structure or components in the test process.

5.3.2 The measurement contents of static load test for regular bridge may be determined according to Table 5.3.2.

Table 5.3.2 Measurement contents of static load test for regular bridge

Type	Measurement contents	
Simply supported girder bridge	Basic contents	①Deflection and stress (strain) of mid-span section ②Settlement of support ③Cracks in concretegirders
	Additional contents	①*L*/4 section deflection ②Stress (strain) at inclined section near support
Continuous girder bridge	Basic contents	①Max. negative bending moment section stress (strain) of the main span support ②Max. positive bending moment section stress (strain) and deflection of the main span ③Max. positive bending moment section stress (strain) and deflection of the side span ④Settlement of support ⑤Cracks in concretegirders
	Additional contents	Stress (strain) of inclined section near main span (middle)
Cantileveredgirder bridge	Basic contents	①Stress (strain) on the section at the pier ②Max. positive bending moment section stress (strain) and deflection of anchorage span ③Settlement of pier top ④Cracks in concretegirders
	Additional contents	①Stress (strain) of inclined section near pier ②Stress (strain) and deflection of mid-span section of anchor span ③Stress (strain) of inclined section near anchor span support ④Max. deflection of the cantilever span ⑤Partial stress (strain) of corbel

continued

Type	Measurement contents	
Three-hinged arch bridge	Basic contents	①Deflection and stress (strain) on$L/4$ section ②Stress (strain) at inclined section atgirder mid-height on both sides of arch crown ③Horizontal displacement at pier and/or abutment top ④Concrete cracks in main arch
	Additional contents	①Deflection and stress (strain) on$L/4$ section ②The displacement and stress (strain) of thecritical section on the arch
Two hinged arch bridge	Basic contents	①Stress (strain) and deflection of arch top section ②Deflection and stress (strain) on$L/4$ section ③Horizontal displacement at pier and/or abutment top ④Concrete cracks in main arch
	Additional contents	①Deflection and stress (strain) on$L/4$ section ②The displacement and stress (strain) of thecritical section on the arch
Hingless arch bridge	Basic contents	①The stress (strain) and deflection of the arch section ②The stress (strain) of the haunch section ③Concrete cracks in main arch
	Additional contents	①Deflection andstress (strain) of the $L/4$ section ②Horizontal displacement at pier and/or abutment top ③The deformation and stress (strain) of critical section on arch
Vierendeel bridge	Basic contents	①Stress (strain) and deflection of the max. positive bending moment of the main girder ②The max. or min. bending moment stress (strain) at anchorage end ③Settlement of support(settlement of bearing) ④Cracks in concrete girders
	Additional contents	Inclined section stress (strain) near anchorage end
Batter post rigid frame bridge	Basic contents	①Stress (strain) and deflection of the max. positive bending moment section of the mid-span maingirder ②Max. negative bending moment section stress (strain) of maingirder ③Settlement of support(settlement of bearing) ④Cracks in concretegirders
	Additional contents	①Stress (strain) and deflection of max. positive bending moment section of side span on maingirder ②Inclined section stress (strain) of the maingirder or inclined leg near the top of the inclined leg ③Max. or min. bending moment section stress (strain) of inclined leg

continued

Type	Measurement contents	
T-shaped frame bridge	Basic contents	①Stress (strain) of section over pier support ②Stress (strain) of the anchor span section ③Deflection of cantilever end ④Stress(strain) of T-shape piercritical section ⑤Cracks in concretegirders
	Additional contents	①Stress (strain) at inclined section near pier support ② Inclined section stress (strain) near cantilever end or near hanginggirder support
Continuous rigid frame bridge	Basic contents	①Main girder stress (strain) of main span section over pier ② Stress (strain) and deflection of the max. positive bending moment section of main span ③ Stress (strain) and deflection of the max. positive moment section at side span ④Cracks in concretegirders
	Additional contents	①Stress (strain) at inclined section near pier support ②Critical section stress (strain) in pier ③Horizontal (longitudinal) displacement of pier top
Cable-stayed bridge	Basic contents	①Stress (strain) and deflection of max. positive bending moment section of the middle span of the main girder ②Inclined section stress (strain) of maingirder over pier support ③Horizontal (longitudinal) displacement of the mainpylon top and the stress (strain) of pylon foot section ④Stress (strain) atpylon bottom section ⑤Cracks in concretegirders ⑥Typical cable tension
	Additional contents	①Max. increment of live load tension of stay cable ②Longitudinal drift of stiffening girder
Suspension bridge	Basic contents	① Max. positive bending moment section stress (strain) and deflection of the stiffening girder ②Max. horizontal (longitudinal) displacement of mainpylon top and the stress (strain) at the pylon foot section ③Concrete cracks inpylon and girder body ④The most unfavorable increment of suspender (sling)
	Additional contents	①Max. tension increment of main cable span of anchor cable ②Max. longitudinal drift at the stiffeninggirder end ③Max. increment of live load tension of suspender(sling)

Note: L-calculated bridge span.

5.3.3 For suspension bridges, cable-stayed bridges and high-pier bridges, the longitudinal displacement of piers or pylons shall be monitored. If necessary, the three-dimensional coordinates of the pylon top shall also be measured. The vertical deflection and the horizontal displacement of stiffening girders shall be measured for suspension bridges and cable-stayed bridges, where the horizontal displacement measurement points should be arranged in the end of the stiffening girders. The three-dimensional coordinates of critical sections of the main cable shall be measured on suspension bridges.

5.3.4 For irregular bridges and hybrid bridges, the measurement contents shall be determined according to the mechanical characteristics, calculation results and the requirements in Clause 5.2.2 and Clause 5.3.2.

5.3.5 For strengthened or reconstructed bridges, other than that specified in Clause 5.3.2, additional measurements contents should be added as follows:

1 The respective stress/strain of newly-built and aged structures at the typical interface for bridges strengthened with bonded plates/sheets, and the maximum stress/strain of bonded plates/sheets.

2 The maximum stress/strain on the typical interface for bridges strengthened with newly added components and replacement components.

3 The eccentricity of the external prestressing tendons for bending components strengthened by external prestressing method.

4 Crack or debonding on the typical interface .

***Background*:**

For the bridges strengthened with bonding steel plates/carbon fiber plate or sheet, enlarging cross section, newly-addedcomponents, or rearranged components, the reliable bond between the newly-built and aged structures is important to ensure their co-working performance. Because of the differences of age and materials between the newly-built and aged structure, crack or debonding may be generated and developed with external load. The coordinate deformation and co-working of the newly-built and aged component may be checked through stress/strain in the same location during the static load test.

For bridges strengthened with external prestress, the eccentricity of external prestressing force will exert great influence on the component stress and its ultimate load-carrying capacity. Therefore, it is important to control the eccentricity and its variation range of external prestressing tendons to ensure the strengthened bridge performance in operation process.

5.3.6 For the static load test of in-service bridges, other than the rules specified in Clause 5.3.2, additional measurement contents shall be performed according to the extent, location and features of the structural damage as well as the test purposes.

5.3.7 For girder deflection measurement, the vertical displacement of the supports shall be measured at the same time, and the corresponding modification of the supports shall be considered according to Clause 5.7.3.

5.4 Test load

5.4.1 For static load test, control load shall be determined according to the test purposes. The design load shall be taken as the control load for hand-over & complete construction bridge load test. For other bridges (aged bridges, damaged bridge, etc.), the target load shall be taken as control load.

5.4.2 The load test efficiency η_q should be 0.85 ~ 1.05 for hand-over & complete construction bridge load test. Otherwise, η_q should be 0.95 ~ 1.05, where it shall be worked out according to the following equation:

$$\eta_q = \frac{S_s}{S \cdot (1+\mu)} \tag{5.4.2}$$

where:

S_s—The maximum calculated effect value for the internal force or displacement of the critical section corresponding to a static load case;

S—The most unfavorable effect value for the internal force or displacement of the critical section under the control load;

μ—The impact factor.

Background:

In view of the differences between the actual test load and the control load, thestatic load test efficiency of the critical section is usually adopted. The critical sections for an integral structure are the overall sections of the structure. The critical sections for a multi-girder structure are the critical sections of the most favorable girder. Medium and small span bridges are mostly multi-girder (rib) type structure, which are designed on the basis of individual girders (ribs) in accordance with the transverse distribution theory. The girder (rib) that has the biggest internal force effect is usually set as the test load control target, and the load efficiency of other girders are within the limit simultanously.

The analysis shows that for themulti-girder structure with three or more design lanes, the load efficiency of the individual girder (rib) is far less than 0.85 if the load is applied in accordance with the lanes and with an efficiency of 0.85 on the overall section. If the central girder (rib) is loaded with an efficiency range of 0.85 to 1.05, the load efficiency of the other girders (ribs) will not be more than 1.05. If the side girder (rib) is loaded with efficiency range from 0.85 to 1.05, the load efficiency of other girders (ribs) may exceed 1.05.

When the temperaturevariation has a great influence on the internal force of the bridge, the load test shall usually be conducted in the season when the temperature internal force is unfavorable. Another method of increasing the test load efficiency may be used to compensate for the internal force result from the temperature on the critical section.

5.4.3 Static load test may be carried out with load vehicles or weights. In the case of vehicle load, three-axle load-carrying vehicles should be selected, and the carrying stowage shall be arranged safely.

***Background*:**

For the weights (or water tanks, sandbags, etc.) load, there exist long duration for preparation, load, unload and traffic interruption. Accordingly, vehicle load is usually adopted in the test.

When the vehicleload is adopted, the carried loads shall be safely arranged so as to avoid position change during vehicle movement, which could result in axle (wheel) load changes. When load weights are used, the bearing frame shall be firstly built according to the ground wheel mark of the control load, and the weights or water tanks are then arranged on the bearing frames. Considering only internal forces requirement of the critical sections, the stack of weights or water tanks may be directly loaded on the bridge deck.

The investigation for thedimension and axle load distribution of the trucks in China market after 1990 has been achieved. The results show that there are few vehicles with four or more axles, which is, therefore, not recommended as an option for load vehicles. However, there are many trucks with three or less axles for local transportation. These vehicles are common in all the provinces and their wheelbase and wheelspan are similar to bridge design load. Although the wheelbase and axle weight distribution vary from brand to brand, their deviation influence on the load efficiency may be controlled within 10%, which has little impact on the load efficiency. Therefore, three-axle vehicles are recommended as the test load vehicles.

Forthe design load of Truck-S20 class or Highway – I, it is a common practice in China to adopt two three-axis vehicles to simulate the 55t heavy vehicle. The distance between the two vehicles may be appropriately adjusted according to the vehicular difference and load efficiency.

5.4.4 For the load test with a oversized special vehicle, the simulated load or equivalent load should be adopted according to the actual wheel position and axle weight.

5.4.5 The test load shall be labeled and weighed before conducting the test. For the method of vehicle load, the numbering, vehicular weight, axle weight, wheelbase and wheel weight of each vehicle shall be recorded in detail. For the method of weights load, it is supposed to number, weigh and record all the loads of different levels respectively according to the load classification.

***Background*:**

For the vehicle load method, the carrying weights shall be neatly stacked or uniformly spread on the truck floor (crushed stones, sands, etc.). The vehicle shall be weighted axle by axle correspondingly.

For water tanks or containers piled up on bridge deck, the weight is normally worked out with the measured volume multiplied by the unit weight. For weightsarranged on the deck as load, the weight units are usually weighed, batched and arranged in heaps according to the demands of each load level. Either weighting method or volume method may be used for the weighing of loads, depending on the actual load methods and the specific field conditions.

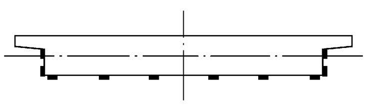
5.4.6 The single axle weight of the load vehicle shall not exceed the limits in relevant standards and specifications. If necessary, the load-carrying capacity and crack width of components (such as bridge decks) shall be checked.

***Background*:**

The purpose of thiscluase is to ensure the local bearing safety of bridge deck, i. e., it is to prevent the bridge deck from local damage or serious crack by load.

5.5 Measurement point arrangement

Table 5.5.1-1 Layout ofstrain measurement points on main sections

Name	Types of main section		Layout of strain measurement points	Background
Concrete maingirder	Slab	Integral solid slab		①Notless than 5 measurement points on the slab bottom, symmetrical arrangement ②Notless than 2 measurement points on the slab side

continued

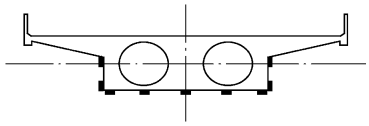
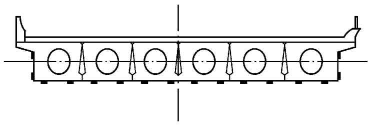
Name	Types of main section		Layout of strain measurement points	Background
Concrete maingirder	Slab	Integral hollow core		①No less than 5 measurement points on theslab bottom, symmetrical arrangement ②Nolessthan 2 measurement points on the slab side ③Measurement pointsshall be arranged on the location corresponding to the web
		Precast hollow slab		①No less than 2 measurement points on eachslab bottom ②No fewer than 2 measurement points on the slab side

Table 5.5.1-1 (Continued)

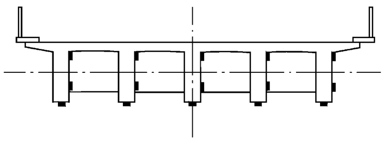
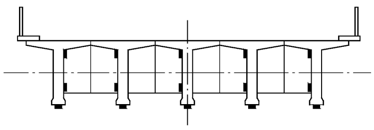
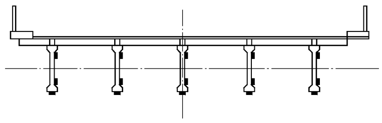
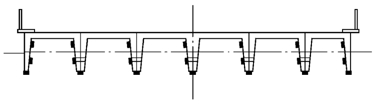
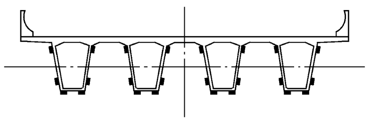
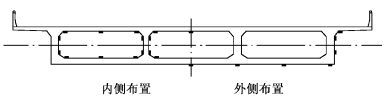
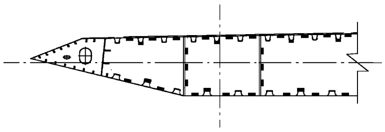
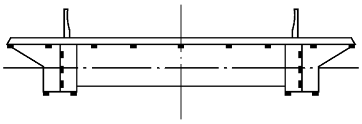
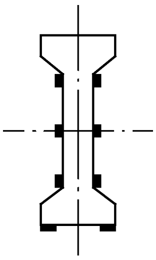
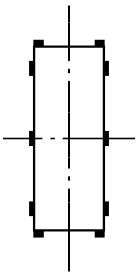
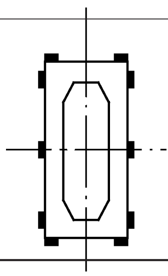
Name		main section	Layout of strain measurement points	Background
Concrete maingirder	Girder section	Reinforced concrete Tgirder		①1 ~ 2 measure- ②ment points on each girder bottom ③No less than 2 measurement points on eachgirder side
		Prestressed concrete T girder		① 1 ~ 2 measurement points on eachgirder bottom ②No less than 2 measurement points on eachgirder side
		I-girder		① 1 ~ 2 measurement points on eachgirder bottom ②No less than 2 measurement points on eachgirder side
		π-girder		① 1 ~ 2 measurement points on eachgirder bottom ②No less than 2 measurement points on eachgirder side
		Separated boxgirder		①No less than 2 measurement points on eachgirder bottom ②No less than 2 measurement points on each web side
		Integral box girder		①No less than 3 measurement points on the top and bottom of each box inside. ②No less than 2 measurement points on each rib side ③When the box girder is not provided with access hole, measurement pointsshall be arranged externally

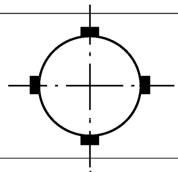
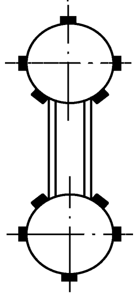
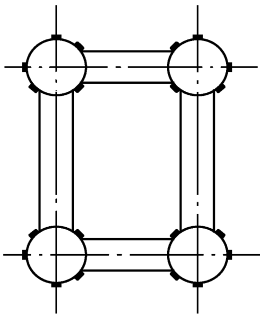
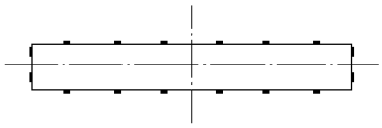
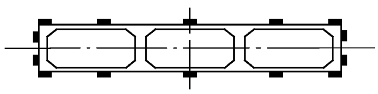
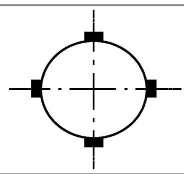
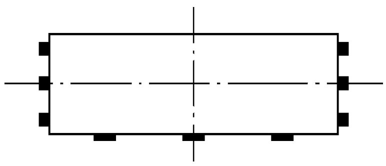
Table 5.5.1-1 (Continued)

Name	Types of main section		The arrangement of strain measurement points	Background
Steel box girderSteel-concrete composite girder	Steel box girder			①No less than 3 measurement points on the top and bottom of each box inside ②No less than 3 measurement points on each box side ③ Selective measurement points arrangement for stiffening rib
	steel-concrte composite girder	π-shapegirder		①No less than 2 measurement points on the top and bottom of each longitudinal girder ②No less than 3 measurement points on each longitudinal girder side ③No less than 5 measurement points on lower edge of concrete, symmetrial arrangement
		I-Shape girder		①No less than 2 measurement points on the top and bottom ②No less than 3 measurement points on each side

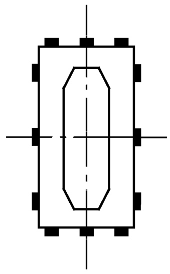
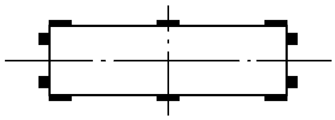
continued table 5.5.1-1

Name	Types of main section		The arrangement of strain measurement points	Background
Arch rib	Steel reinforced concrete	Rectangle		①No less than 2 measurement points on the top and bottom ②No less than 3 measurement pints on each side
		Box		①No less than 2 measurement points on girder top and bottom ②No less than 3 measurement points on each side

continued

Name	Types of main section		The arrangement of strain measurement points	Background
Arch rib	Concrete flled steel tube	Single limb		① No less than 4 measurement points, symmetrical arrangement
		Double limbs		①No less than 5 measurement pointsshall be arranged on the joint between steel tube and batten plate, the geometric center shall be accurately measured
		Four limbs		①No less than 5 measurement pointsshall be arranged on the joint between steel tube and batten plate, the geometric center shall be accurately measured
	Integral slab (box)	Integral slab		①No less than 5 measurement points on the top and bottom, symmetrical arrangement ②No less than 2 measurement points on the single side
		Integral box		①No less than 5 measurement points on the top and bottom, symmetrical arrangement ②No less than 2 measurement points on the side ③Measurement pointsmust be arranged on the position corresponding to the web plate. ④The same as integral box girder when measurement points are aranged in the box
pier	Round			① No less than 4 measurement points, symmetical arrangement
	Rectangular			①No less than 3 measurement points on each side in transverse direction ②No less than 2 measurement points on each side in longitudinal direction

continued

Name	Types of main section	The arrangement of strain measurement points	Background
pier	Box		①No less than 3 measurement points on each side in transverse direction ②No less than 3 measurement points on each side in longitudinal direction
bent cap	Rectangular		①No less than 3 measurement points on the plate bottom ②No less than 3 measurement points on each side

5.5.1 The layout of strain measurement points shall comply with the following principles:

1 The strain measurement points shall be reasonably arranged according to the measurement sections & items. It shall reflect the stress characteristics of the bridge.

2 The arrangement of one-way strain measurement pointsshall follow the principles of horizontal symmetry, vertical layout and highlighting critical strain points. It shall also fully reflect the strain distribution feature along the depth of the sections. The single-point rosette gauge measurement points should not be less than two groups, and the location shall be accurately measured after arrangement.

3 The arrangement of one-way strain measurement points for typical sections is shown in Table 5.5.1-1. For symmetric structures, the number of strain measurement points on the 1/2 sectionmay be reduced, but not less than 2.

4 For curved bridges, skew bridges and irregular bridges, the strain measurement points shall be determined in accordance with the internal force (stress) characteristics and structural features of the bridge under the control load.

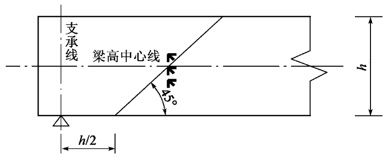
5 The strain measurement points in tensile regions of the reinforced concrete structureshould be arranged on the main rebar of the tensile regions.

6 The principal strain (stress) shall be measured with rosette gauge and the measurement

points arrangement is shown in Table 5.5.1-2.

7 The strainmeasurement shall include compensation gauges, which shall be arranged on the non-stressed parts of the same material as well as the same environment.

Table 5.5.1-2 The arrangement ofstrain gauge rosette measurement points

Name	Test content	The arrangement of strain measurement points	Location
Maingirder	Principal stress near the support		①No less than 3 strain gauge rosette at intersec-tion of girder centerline and 45° line projecting from support ② Theprincipal strain test position for remain-ing components shall be determined by calculation

***Background*:**

Generally, one-way strain gauges are used tomeasure the normal strain, and rosette gauges are used to measure the principal strain (stress). For one-way strain measurement, the arrangements reflect the strain variation features along the transverse and depth directions of the component sections. The strain measurement points of the web (rib) plates reflect the strain distribution along the depth direction of the sections. The top strain measurement points shall be arranged on the top edge of the web (rib) plates.

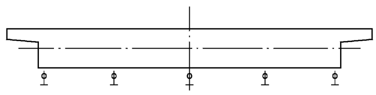
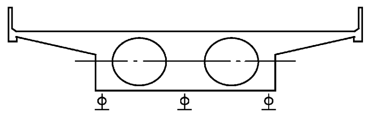
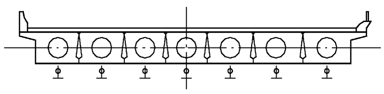
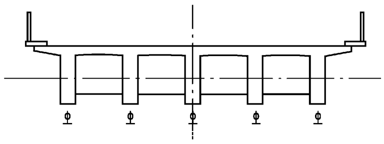
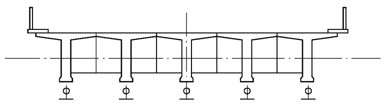
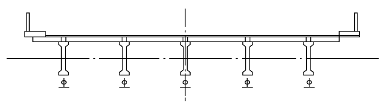
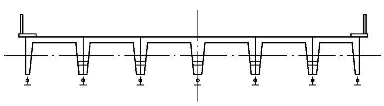
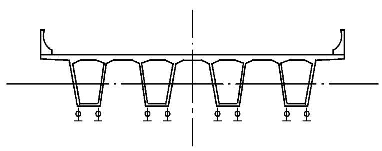
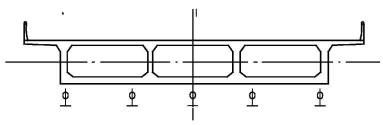
After the measurement sections are determined, the arrangement of strain measurement points is closely related to the section shape. For the bendingcomponents, the maximum compression and tensile stress regions shall be focused. The effectiveness of the strain measurement points on the top and bottom plates shall be ensured for bending components. In order to reflect the variation trend along the depth direction, the strain measurement points are generally arranged along the depth direction of the web plates or the rib plates.

It is difficult to set measurement points for the top of the boundary girders. The strain measurement points shall be located as close as possible to the top plate or upper flange plates, and shall not be arranged adjacent to the neutral axis.

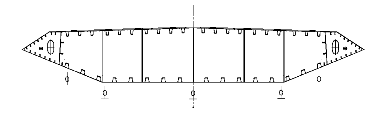
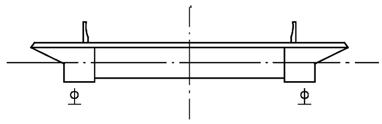
Strain measurement points are usually notarranged on the top edge of arch rib for a filled spandrel arch bridge or the solid mid-span segment for an open-spandrel arch bridge.

For the flexural components of reinforced concrete, the concrete strain measurement results will be distorted with the concrete crack in tensile regions. And the steel strain measurement data are much *more reliable. In the test, the concrete cover in the tensile region is often chiseled away, and the strain gauges shall be set on the exposed steel bar. Accordingly, the concrete cover will be patched soon after the test.*

Table 5.5.2 The transverse arrangement of verticaldeflection measurement points for girders

Name	Type of main section		Thearrangement of deflection measurement points	Background
Concrete maingirder	Platesetion	Integral solidslab		No less than 3 measurement points on the transverse bridge bottom or the deck
		Integral hollowslab		No less than 3 measurement points on the transverse bridge bottom or the deck
		Precast hollow slab		No less than 1 measurement point on each plate bottom or no fewer than 3 measurement points on the deck
Concrete maingirder	Girder section	Reinforced concrete Tgirder		No less than 1 measurement point on eachgirder bottom or no fewer than 3 measurement points on the deck
		Presressed reinforced concrete T girder		No less than 1 measurement point on eachgirder bottom or no fewer than 3 measurement point on the deck
		I shapegirder		No less than 1 measurement point on eachgirder bottom or no fewer than 3 measurement points on the deck
		π shapegirder		less than 1 measurement point on eachgirder bottom or no fewer than 3 measurement points on the deck
		Separated box girder		No less than 1 ~ 2 measurement points on eachgirder bottom or no fewer than 3 measurement points on the deck
		Integral box girder		No less than 3 measurement points on the transverse bridgegirder bottom or the deck

continued

Name	Type of main section	Thearrangement of deflection measurement points	Background
steel box girder steel-concrete composite girder	Steel box girder		No less than 5 measurement points on the transverse bridgegirder bottom or no fewer than 3 measurement points on the deck
	Steel-concrete compositegirder		No less than 1 measurement point on each longitudinalgirder bottom or no fewer than 3 measurement points on the deck

5.5.2 The layout for the deflection measurement points shall comply with the following principles:

1 The value ofdeflection measurement points shall reflect the maximum deflection and its variation law of the structure.

2 The measurement points along the bridge for verticaldeflection on the main girders should be arranged at the peak position of the deflection curve under the different load cases.

3 The transverse locations of verticaldeflection measurement points shall fully reflect the distribution features of transverse deflection. The measurement points for integral sections should not be less than three, and that for the multi-girder (separated type) sections should be arranged girder by girder. The transverse arrangement of vertical deflection measurement points for typical girders is shown in Table 5.5.2

4 The horizontaldisplacement measurement points of the main girders shall be arranged at the location with maximum value.

5 The horizontaldisplacement measurement points of pier & pylons shall be arranged at the top, and the longitudinal and transverse measurement points shall be set if necessary.

6 The measurement points for support settlementshall be arranged close to the bearings.

Background:
The deflection measurement points are usually arranged at the bottom of the girders (chords, ribs or the main arch ring). The points may be arranged on the bridge deck under the condition when the on-site arrangement is difficult.

For the deflection curves measurement of the girders, arches, stiffening girders and main cables, the deflection measurement sections are usually added between the maximum and minimum deflection sections.

5.5.3 In load test, the effective measurement points for bridge construction control should be adopted.

Background:
It is cost-effective to make use of effective measurement points for construction control. And it facilitates to comparation and analysis with the test results of construction control.

5.5.4 The crack measurement points shall be arranged in the locations where obvious crack and wider cracks exist.

5.5.5 The inclination angle measurement points should be arranged in the locations where obvious rotation and larger rotation angles exist.

5.6 Test process control and record

5.6.1 Preloading shall be carried out prior to loading.

Background:
Thepreloading is usually carried out with the first step of load in multi-step load or a single vehicle.

5.6.2 The test loads shall be applied in steps, and the load steps shall be determined according to the total amount of the test load and the load increment in different steps. The test loads may be divided into 3 ~ 5 levels. In the event of insufficient technical data for a bridge, more steps shall be added in the test. If the tests focus on the bridge response behaviour under load, more load steps may be added.

5.6.3 In the process of load and unload, it shall be ensured that the internal force or deflection in non-critical sections does not exceed the most unfavorable values under the control load.

5.6.4 In the case of conditions restricted in test, the most unfavorable load may be conducted merely for the critical sections in the additional load cases.

5.6.5 In the load process, any abnormal phenomena such as abnormal noise, instability, distortion and the structure shaking shall be recorded. Correspondingly, the solution shall be prepared in advance.

5.6.6 The load interval shall meet the time requirements for the structure to reach its stable response. The subsequent load shall not be applied until the structural response under the previous load is relatively stable and the effective recordings have been done. In the load case for the maximum internal force (deflection) on the main critical sections, the stabilization time for multi-step load shall not be less than 5 min. For a newly-built bridge that has not yet been put into operation, the stabilization time for multi-step load of the first load test case should not be less than 15 min.

***Background*:**
The stabilization time ofload and unload depends on the time of structure deformation completion. Within the same load step, when the deformation increment at the maximum deformation measurement point in the last 5 min is less than 15% of the deformation increment in the first 5 min, or is less than the minimum resolution of the measurement instruments, it is generally identified that the structure deformation has achieved.

The stabilization time ofload shall be extended appropriately if long time is needed for stable recording at measurement points. It maybe result from weak connection or slow deformation in structure, for instance, the measured deformation (or strain) value is much less than the calculated value.

5.6.7 According to the load steps of load test cases, the observation and analysis shall be conducted for strain (or deformation) on structural control points and the damage of weak parts in the load and unload process. The measurement value shall be compared with the theoretical calculation values. In the case of any following situations taking place in the test, the loading shall be broken off. The causes shall be investigated and the related solution shall be adopted before the test continue.

1 The strain values of the control measurement points have reached or exceeded the calculated values.

2 The deformation (or deflection) of the control measurement points has exceeded the calculated values.

3 The length, width or number of structural cracks has increased significantly.

4 The distribution of measured deformation is abnormal.

5 Abnormal noise in the bridge or other abnormal conditions appears.

6 Themeasurement values of cable force increment for cables or suspenders have exceeded the calculated values.

5.6.8 Observations and recordings shall comply with the following principles:

1 The observation time for measurement system stability shall be more than 15 min before loading.

2 The recordingsshall be well done for test time, ambient temperature, cases, etc. Automatic recording system and real-time monitoring for key points should be adopted. For manual recording, the data shall be recorded timely and filled into the special forms accurately.

3 Before the test, the existing crack length, width, distribution and trend shall be observed, recorded and marked on the structure. In the test process, the new cracks length, width and the existing cracks development shall be observed. All the cracks distribution and trend on the structure surface shall be marked and recorded specially. Recording charts shall adopt the format specified in Appendix D of the *Specifications*.

Background:

1 The ambient temperature variation has a certain influence on the internal force of the statically indeterminate structure. When the test period is long, the internal forces and deformation caused by temperature variation will have influence on measurement results. Therefore, stabilization observations are required to correct the observed results.

2 Automatic recording systems are benefical for data acquisition efficiency and precision.

3 The priority for crack observation is the locations where the structure undertakes large tensile force and existing long &wide cracks exist. The crack records usually include crack length, width, trend and the corresponding load case.

5.7 Measurement data analysis

5.7.1 The measurement data shall be adjusted according to the effect of temperature variation, support settlement and instrument calibration. No adjustment is required when the effect is less than 1%.

5.7.2 The temperature influence correction may be calulated according to the following formula:

$$\Delta S_t = \Delta S - \Delta t \cdot K_t \quad (5.7.2)$$

where:

ΔS_t—Variation value under load at measurement points after temperature correction;

ΔS—Variation value under load at measurement points before temperature correction;

Δt—The temperature variation (℃) in the observation period. The surface temperature of the components should be adopted for strain and the air temperature shall be adopted for deflection;

K_t—The value variation at the measurement points when the temperature rises 1℃ in the non-load condition. If the measurement value changes significantly with temperature variation, the mean value from several observations shall be used;

ΔS_1—The value variation at the measurement points during a period in the non-load condition;

Δt_1—The temperature variation value during the corresponding period.

***Background*:**

The complexity of the temperature influence is constituted by the temperature differences between the surface and the interior of thecomponents, measurement point location and other location, local and overall, gauge and compensation gauge, etc.

To minimize the temperature impact on test precision, the strategy is usually adopted, such as shortening the load time, or selecting a period with little temperature fluctuation.

Ifnecessary, the measurement data for temperature stability before the load test may be used for temperature correction by means of establishing the relation curve of temperature variation and measurement value variation.

5.7.3 In the case that settlement occurs at a support, the correction to the support settlement may be calcuated according to formula (5.7.3):

$$C = \frac{l - x}{l} \cdot a + \frac{x}{l} \cdot b \quad (5.7.3)$$

where:

C—the corrected value to consider the support settlement influence at the measurement points;

l—The distance between the Supports A and B;

x—The distance from the deflection measurement point to Support A;

a—Settlement of Support A;

b—Settlement of Support B.

5.7.4 The deflection or strain at the measurement points may be calculated according to formula (5.7.4-1) ~ (5.7.4-3):

$$S_t = S_i - S_i \quad (5.7.4\text{-}1)$$

$$S_e = S_i - S_u \quad (5.7.4\text{-}2)$$

$$S_p = S_t - S_e = S_u - S_i \quad (5.7.4\text{-}3)$$

where:

S_t—the total structural deflection (or strain) value measured under the test load;

S_e—The elastic deflection (or strain) measured under the test load;

S_p—The residual deflection (or strain) measured under the test load;

S_i—Measurements value before load;

S_l—Measurements value when load is stable;

S_u—Measurements value when unload is stable.

5.7.5 The relative residual deflection (or strain) of the measurement points may be calcuated according to formula (5.7.5):

$$\Delta S_p = \frac{S_p}{S_t} \times 100\% \quad (5.7.5)$$

where:

S_p—The relative residual deflection (or strain) measured under the test load;

S_t—The total deflection (or strain) value measured under the test load.

5.7.6 The verification coefficient at the measurement points shall comply with the following principles:

1 The verification coefficient at the measurement points shall be calculated according to formula (5.7.6-1):

$$\eta = \frac{S_e}{S_s} \quad (5.7.6\text{-}1)$$

where:

η—Verification coefficient;

S_e—Refer to formula (5.7.4-2);

S_s—Refer to formula (5.4.2).

2 When the structure is in a linear elastic working state, the stress shall be calculated by Hooke's law in accordance with the measurement strain.

3 Thelateral amplification factor may be calculated according to formula (5.7.6-2), based on the maximum value S_{emax} of measurement deflection (or strain) and the average value S_e of the measurement deflection (or strain):

$$\xi = \frac{S_{\mathrm{emax}}}{S_{\mathrm{e}}} \qquad (5.7.6\text{-}2)$$

***Background*:**

Forcomparison of S_e with S_s, the measurement maximum value of S_e and the corresponding maximum value from spatial theory analysis of S_s shall be adopted. For the plane calculation, the calculation value of lateral amplification factor ξ is usually adopted.

For integral sections, themeasurement average value may be compared with the calculated value. The the lateral amplification factor shall be calculated from measurement value. And the theoretical calculation value may be adopted if the measurement value is not available.

The structure is in good condition when theload test efficiency meets the following requirements.

(1) the ratio of S_e to S_s comply with formula (5-1):

$$\beta < \frac{S_e}{S_s} \leqslant \alpha \qquad (5\text{-}1)$$

For α、β in the formula, please refer to Table 5-1.

Table 5-1 table of α_l、α、β valus

Load bearing structure	β	α					α_l
		$\eta_q \leqslant 1.0$	$\eta_q = 1.1$	$\eta_q = 1.2$	$\eta_q = 1.3$	$\eta_q \geqslant 1.4$	
Prestressed concrete and composite structure	0.7	1.05	1.07	1.10	1.12	1.15	0.20
Reinforced concrete and masonry structure	0.6	1.10	112	1.15	1.17	1.20	0.25

Note: Intermediate valuesmay be determined by linear interpolation.

When $S_e/S_t < \beta$, the reasons for the low elastic working efficiency of the structure are usually examined. The structural dimension, the material properties, the static calculation mode, the load test efficiency, the load weighing and measurement instruments, etc. shall be re-examined. And the test shall be conducted again after that.

(2) The ΔS_p shall comply with the rules as following:

First test:

$$\Delta S'_p \leqslant \alpha_l \qquad (5\text{-}2)$$

where:

α_l—refer to Table 5-1.

If the test results are not acceptable, and

$$\alpha_l < \Delta S'_p \leqslant 2\alpha_l \qquad (5\text{-}3)$$

A second test is usually conducted.

Second test:

$$\Delta S_p^n \leqslant 0.5\alpha_l \qquad (5\text{-}4)$$

If the test results are not acceptable, a third test is usuall conducted.

Third test:

$$\Delta S_p^m \leqslant \frac{1}{6}\alpha_l \qquad (5\text{-}5)$$

If the third test results meet the above requirements, adynamic load test is usually conducted further to confirm the reliability of the structure.

If the incremental cyclicload is adopted in the test, the value of α_l specified in Table 5-1 shall be multiplied by 1.33.

The lateral amplification factor ξ at the main measurement points under the control load test case reflects the uniformity degree of the bridge.

The smaller the ξ value is, the more uniform the load transverse distribution and the more reliable the transverse connection of the structure. On the contrary, the larger the ξ value is, the less uniform the load transverse distribution and the weaker the transverse connection of the structure.

5.7.7 The sketching of the test curve shall include the following contents:

1 List all data in a comparison table, the measurement deflection (or strain) of the main measurement points and the corresponding theoretical calculation values for each load case, and then sketch out their relation curve.

2 Sketch out the relation curve of the deflection (or strain) with the load efficiency (or load) about the main control points for each load case.

3 Sketch out the distribution diagram of critical section displacement (or strain), the deflection diagram along the longitudinal (transverse) bridge axis, and the distribution diagram of the section strain along the depth (width) direction under each load test case.

***Background*:**

The test curve visually displays the test results. The test curves are usually used to show comparisons of themeasurement strains and the theoretical calculation values, the deflection (strain) of the main control points, the course curve of the load, and the distributions of deflection *and strain. The test results may be assessed through these curves to determine whether abnormalities exist and structural work state as well as deflection (strain) distribution law are in the course of natural.*

5.7.8 The analysis of test results shall include the following contents:

1 The verification coefficient shall include strain (stress) verification coefficient and deflection verification coefficient, and their values shall be calculated according to formula (5.7.6-1). The strain (stress) and deflection verification coefficients shall be in accordance with the range (shown in Table 5.7.8-1).

Table 5.7.8-1 The range for verification coefficient for ordinary bridge test

Bridge type	Strain (or Stress) verification coefficient	Deflectionverification coefficient
Reinforced concrete slab bridge	0.20 ~ 0.40	0.20 ~ 0.50
Reinforced concretegirder bridge	0.40 ~ 0.80	0.50 ~ 0.90
Prestressed concrete bridge	0.60 ~ 0.90	0.70 ~ 1.00
Masonry arch bridge	0.70 ~ 1.00	0.80 ~ 1.00
Reinforced concrete arch bridge	0.50 ~ 0.90	0.50 ~ 1.00
Steel bridge	0.75 ~ 1.00	0.75 ~ 1.00

2 For the linear elastic working condition, the measurement displacement (or strain) at the measurement points shall be linearly related with its theoretical value.

3 For conventional structures, the strain distribution in the depth direction of the main critical sections of the structure or components shall conform to the plane section assumption.

4 The smaller the relative residual deflection (or strain) at the main control points is, the better the structure is for elastic working condition. The value of ΔS_p should not exceed 0.2. Otherwise, the bridge is exhibiting inelastic behavior. Accordingly, the reason shall be analyzed and load test shall be conducted again if necessary.

5 For newly-built bridges, the crack width under the test load shall not exceed the allowable value specified in *Specifications for Design of Highway Reinforced Concrete and Prestressed Concrete Bridges and Culverts* (JTG 3362), and the unclosed width shall be narrowed to 1/3 of the allowable value after unload. For existing bridges, the crack width should not exceed that specified in *Specifications for Inspection and Evaluation of Load-bearing Capacity of Highway Bridges* (JTG/T J21) with reference in Table 5.7.8-2.

Crack limit Table5. 7. 8-2

<table>
<tr><th>Classification</th><th colspan="3">Crack location</th><th>Maximum of crack width (mm)</th><th>Remark</th></tr>
<tr><td rowspan="5">Reinforced concrete girder</td><td colspan="3">Vertical crack near the main rebar</td><td>0. 25</td><td></td></tr>
<tr><td colspan="3">Inclined crack in the web</td><td>0. 30</td><td></td></tr>
<tr><td colspan="3">Composite girder interface</td><td>0. 50</td><td>Penetrating crack is not allowed in interface.</td></tr>
<tr><td colspan="3">Transverse diaphragm and girder end</td><td>0. 30</td><td></td></tr>
<tr><td colspan="3">Supporting pad stone</td><td>0. 50</td><td></td></tr>
<tr><td rowspan="3">Fullyprestressed concrete girder</td><td colspan="3">Vertical crack</td><td>Not allowed</td><td></td></tr>
<tr><td colspan="3">Transverse crack</td><td>Not allowed</td><td></td></tr>
<tr><td colspan="3">Longitudinal crack</td><td>0. 20</td><td></td></tr>
<tr><td rowspan="3">Type Aprestressed concrete girder</td><td colspan="3">Vertical crack</td><td>Not allowed</td><td></td></tr>
<tr><td colspan="3">Transverse crack</td><td>Not allowed</td><td></td></tr>
<tr><td colspan="3">Longitudinal crack</td><td>0. 20</td><td></td></tr>
<tr><td rowspan="3">Type Bprestressed concrete girder</td><td colspan="3">Vertical crack</td><td>0. 15</td><td></td></tr>
<tr><td colspan="3">Transverse crack</td><td>0. 15</td><td></td></tr>
<tr><td colspan="3">Longitudinal crack</td><td>0. 20</td><td></td></tr>
<tr><td rowspan="3">Brick/stone/ concrete arch</td><td colspan="3">Transverse crack in main arch</td><td>0. 30</td><td>Crack length is less than half of the section depth</td></tr>
<tr><td colspan="3">Longitudinal crack in main arch</td><td>0. 50</td><td>Half crack length is less than one-eighth of the span</td></tr>
<tr><td colspan="3">Joint of Arch Wave and Arch Rib</td><td>0. 20</td><td></td></tr>
<tr><td rowspan="7">Pier and abutment</td><td colspan="3">Pier and abutment cap</td><td>0. 30</td><td rowspan="6">Penetrating crack is less than half of the section dimension</td></tr>
<tr><td rowspan="5">Pier and abutment body</td><td rowspan="2">influenced by erosive water frequently</td><td>Rebar</td><td>0. 20</td></tr>
<tr><td>No rebar</td><td>0. 30</td></tr>
<tr><td rowspan="2">Located in water with no erosion</td><td>Rebar</td><td>0. 25</td></tr>
<tr><td>No rebar</td><td>0. 35</td></tr>
<tr><td colspan="2">Located in dry ditch or seasonal river</td><td>0. 40</td></tr>
<tr><td colspan="3">freeze-thaw cycle part</td><td>0. 20</td><td></td></tr>
</table>

6 If the values specified in (5) are exceeded, the reason shall be analyzed by combining the calculation results of the verification coefficient, and corresponding solution shall be adopted.

***Background*:**

Based on a statistical analysis of the static testverification coefficients for 65 reinforced concrete arch bridges in China, the suggested values are provided in this Specifications. For steel bridges, tests and research show that because of the smaller structural variability, the theoretical value and the experimental value are usually consistent with each other, and the range for the verification coefficients is quite small. Based on experience from the bridge load test verification coefficients in recent years, the value in Table 5. 7. 8 may be applied for both existing bridges and newly-built bridges.

For bridges of the same type, the smaller theverification coefficient is, the greater the structure safety margin. If the verification coefficient is too large or too small, the reasons shall be analyzed from different aspects. If the verification coefficient is too large, it may be due to lower material strength or elasticity modulus of the structure, poor connection performance for different conponents and/or lower stiffness. If the verification coefficient is too small, it may be due to higher material strength or elasticity modulus, collaboration of the deck pavement & sidewalk and the girders (ribs), the joint action of spandrel structure and the arch ring, the influence of theoretical calculation or simplified mode, etc. Weighing errors of the load weights in the test and errors of the instruments also have certain influence on the verification coefficient. Generally speaking, the verification coefficient of newly-built bridges is smaller, and the verification coefficient of aged bridges is larger. When the verification coefficient exceeds the normal range, a comprehensive analysis and judgement are usually needed in combination with dynamic load test results.

For conventional structures, themeasurement strain distribution of the critical sections of structure or components along the girder depth shall conform with the plane section assumption. The relationship curve between the measurement deflection or strain at the control points and the load tends to be a straight line. All above indicates that the bridge structure and components are behaving elastically.

6 Dynamic Load Test

6.1 General

6.1.1 The natural frequency and impact factor of the bridge structure shall be measured in a dynamic load test. In one of the following cases, the vibration mode shape and damping ratio of the structure shall be included in the dynamic load test. If necessary, the dynamic deflection and dynamic strain of the bridge shall be tested, and the vehicular vibration features shall also be known.

1 For the girder bridges, T-shaped rigid frame bridges and continuous rigid frame bridges, which have single span over 80m, and the arch bridges, cable-stayed bridges, suspension bridges and other composite bridge structures, which have single span over 60m.

2 For the bridges with unusual vibration.

3 For cases when the structural performance cannot be systematically assessed by static load test alone.

6.1.2 For the multi-span (connection) bridges, the dynamic load test and static load test shall be conducted on the same span, if both tests are needed. In other cases, typical spans shall be chosen based on the needs of the structural evaluation.

Background:
For the dynamicload test of multi-span (connection) bridges, the choice of test span shall follow the principle of representativeness in structure type, and the principle of most unfavourable condition in technical and stress status of structure.

6.1.3 The load vehicle used in dynamic load test shall be in good condition and without abnormal vibration.

6.2 Test case and measurement section

6.2.1 The dynamic load test cases for bridge dynamic load test shall be determined based on the specific test parameters and the adopted excitation method.

6.2.2 The excitation method may be determined by the characteristics of the structure, the accuracy of the test, convenience and the actual situation on site. The ambient random excitation method, the truck excitation method, the vehicle bump excitation method, the vibrator excitation method and other excitation methods should be adopted.

***Background*:**
Theambient random excitation method (pulsating method) is the method of identifying the natural vibration parameters of a bridge through micro-vibration from stochastic excitation caused by wind load, seismic ground motions, or water flow, without any traffic load on the bridge deck and the irregular vibration source near the bridge site. The method requires averaging the energy of the collected long sample signals. The purpose is to eliminate the influence of stochastic factors. For bridges with low natural frequency, such as suspension bridges and cable-stayed bridges, the acquisition time is suggested to be no less than 30 minutes to ensure the frequency resolution and improve the signal noise ratio (SNR). For short-span bridges, the acquisition time may be reduced. The ambient stochastic method is more suitable for long-span flexible bridges.

Thetruck excitation method is the method of identifying the structural natural vibration parameters of the bridge with the residual vibration signal after the vehicles is driven off. This method is suitable for bridges with small damping. In order to improve signal noise ratio and obtain a residual vibration signal as strong as possible, some tests may be carried out by driving the vehicle (s) at different speeds. The bow-shaped bumps are set up in the appropriate cross section to stimulate vibration caused by the vehicle. The residual vibration signal is usually considered in combination with the vehicle travelling dynamic response test.

The vehicle bump excitation method is to induce the vibration of a bridge by letting the rear wheels of a single truck falling down suddenly from a triangular pad in a specified position. This method is more suitable for those bridges with large stiffness, which are not easily excited by other methods, such as masonry arch bridges and short-span girder bridges.

When the vehicle bump excitation method is used on girder bridges, the effect of the vehicle's weight shall be considered. Research shows that the influence of vehicle weight is not negligible for simply-supported girder bridges with spans shorter than 20 m.

The vibrator excitation method is the method to use a controllable sinusoidal-wave-excitation or sinusoidal-wave-scanning-excitation on an affixed point to excite the structure with asteady-state response. The method is of high precision, but it needs large-sized vibration instrument, which is inconvenient for transportation and may cause some damage on bridge decks during installation. This method shall be considered when high precision is necessary to identify the dynamic characteristics of bridge structures.

6.2.3 The measurement section selection and the measurement point arrangement shall conform to the following requirements:

1 The selection of measurement sections for bridge dynamic load test shall be determined according to the features of the structure vibration mode shape and the maximum vehicular dynamic response. Measurement sections are usually arranged at points every 1/8 or 1/16 of the span based on the bridge dimension. Pylons or high pier should be arrangedat points 3 ~ 4 segment divisions by height.

2 For simply supported bridges and continuous bridges, the measurement section shall be selected according to Table 6.2.3-1 ~ Table 6.2.3-3.

3 For long-span bridge vibration mode shape testing, the structure may be divided into several units to be tested separately. The overall tests are based on a fixed reference point (which shall keep away from the vibration mode shape nodes), which is involved in all tests of units. The vibration mode shape diagram for the whole bridge can then be fitted through relating the data of several test units to the reference point.

4 In the case of testing structural response with running vehicles, the location of maximum vibration response shall be chosen as the measurement section. For simple structures, the mid-span point should be the measurement section. For much more complex structure, the number of measurement sections shall be increased.

5 At least, one dynamic deflection measurement point used for the analysis of impact effect shall be laid at each section. When dynamic strain is used to evaluate impact effect, no less than two measurement points should be installed at each section at the location of maximum live load effect of the structure.

Table 6.2.3-1 Sensor layout scheme for the first 5 modes of simply supportedgirder bridge

modeorder	minimumnumber of sensors	locationof the measurement points
1	1	$L/2$
2	2	$L/4, 3L/4$
3	3	$L/6, L/2, 5L/6$
4	4	$L/8, 3L/8, 5L/8, 7L/8$
5	5	$L/10, 3L/10, L/2, 7L/10, 9L/10$

Background: L—span of simply supported girder bridge.

Table 6.2.3-2 Sensor layout scheme for the first 4 modes of the continuous girder bridge with two equal spans

Modal Order	Minimum number of sensors	Location of themeasurement points
1	2	$L/4, 3L/4$
2	4	$L/8, 3L/8, 5L/8, 7L/8$
3	6	$L/12, 3L/12, 5L/12, 7L/12, 9L/12, 11L/12$
4	8	$L/16, 3L/16, 5L/16, 7L/16, 9L/16, 11L/16,$ $13L/16, 15L/16$

Background: L—total length of bridge.

Table 6.2.3-3 Sensor layout scheme for the first 3 modes of the continuous girder bridge with three equal spans

Modal Order	Minimum number of sensors	Location of themeasurement points
1	3	$L/6, L/2, 5L/6$
2	6	$L/12, 3L/12, 5L/12, 7L/12, 9L/12, 11L/12$
3	9	$L/18, 3L/18, 5L/18, 7L/18, 9L/18, 11L/18, 13L/18,$ $15L/18, 17L/18$

Background: L—total length of bridge.

6.2.4 The dynamic response test case shall include the following:

1 Obstacle-free vehicle travelling test: tests should be conducted with a certain of vehicle speed in the range of 5 ~ 80 km/h. The vehicle speed should be kept constant, while the tests shall be repeated 2 to 3 times in each vehicle speed test case.

2 Obstructed vehicle travelling test: a bow-shaped bump may be set as shown in Figure 6.2.4 to simulate an irregular surface deck condition during the test, in which the speed should be taken in 5 ~ 20 km/h. The bump is arranged at a location where impact effect on the structure is significant.

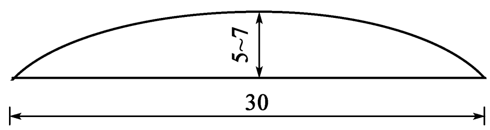


Fig. 6.2.4 Schematic diagram ofcross-sectionof bow-shaped barrier (unit: cm)

3 Braking test: The vehicle speed should be taken as 30 ~ 50 km/h, and the braking location shall be the position with large dynamic response. For floating bridge systems, the longitudinal displacement of the main girder shall be tested.

***Background*:**
As for the test requirements, the test vehiclemay be a single truck, two trucks or more. When two or more trucks are loaded, special attention is usually paid to coordination among the vehicles.

The speed of theobstacle-free vehicle travelling test shall be determined with consideration for design speed, pavement width, bridge deck profile, road condition, etc. The actual speed may be determined by the velocimeter or the starting-ending time at specific locations from the recorded signal. In the premise of safety, a higher speed is usually suggested. Impact factor is a random variable related to the roughness of bridge deck, vehicle-bridge coupled vibration, etc. Since there is an obvious randomness, it may greatly affect the objectivity of evaluation. Therefore, for each vehicle speed case, 2 ~ 3 repeated tests shall be carried out.

6.2.5 Obstacle-free vehicle travelling testing should be the first choice, while obstructed vehicle travelling testing and braking test may be chosen according to the actual situation.

6.3 Test Content

6.3.1 The natural vibration characteristics test of the bridge shall include the vertical bending, transverse bending-torsion natural vibration characteristics. The characteristics of bending natural vibration in longitudinal vertical plane of the bridge shall be tested based on the purpose and requirements of the test. The times of bridge tests ordered shall not be less than that specified in Table 6.3.1.

Table 6.3.1 Bridge test order

Type	Simply supportedgirder bridges	continuous girder bridges and arch bridges	Cable-stayed bridges and suspension bridges
Number ofmode order	1	3	9

6.3.2 Dynamic response tests shall include dynamic deflection, dynamic strain, dynamic acceleration, velocity and impact factor.

Background:

If it is difficult to test the bridge dynamic deflection, it is recommended to test the dynamic strain to obtain the strain impact factor.

6.4 Loads for Test

6.4.1 For the obstacle-free vehicle travelling test, the same load-carrying vehicle may be used as that in the static load test. The local effect caused by vehicle axles shall not exceed the load effect of vehicle. The damage is avoided to the structural components, such as transverse girder, bridge deck, etc.

6.4.2 The efficiency of the obstacle-free vehicle travelling test may be calculated according to Equation 6.4.2, where η_d should be of high value, but shall not exceed 1:

$$\eta_d = \frac{S_d}{S_{i\max}} \tag{6.4.2}$$

where:

η_d—dynamic load test efficiency;

S_d—maximum internal force or deformation of the critical section under the dynamic load test;

$S_{i\max}$—maximum internal force or deformation of the critical section under the control design load (impact load neglected).

6.4.3 If the dynamic load response with one single vehicle is low, the obstacle-free vehicle travelling test should be conducted by arranging one truck on each lane, aligned side by side, travelling synchronously without changing transverse spacing.

Background:

For the bridges in Clause 6.1.1, the load efficiency ratio of a single vehicle may be low. The travelling vehicle test is usually carried out with a row of vehicles travelling synchronously. For the test safety, no more than one truck is arranged in the longitudinal direction of bridge. In practice, the load efficiency ratio may be reduced appropriately for the test safety.

For precast structures, on the premise of safety, the dynamic deflection test is usually carried out in accordance with the wheel track of the vehicles. The travelling lane shall be marked on the bridge deck if necessary.

6.4.4 Obstructed vehicle travelling test and the braking test may be carried out with one or more load-carrying vehicles, in the same way as the obstacle-free vehicle travelling test.

6.5 Control and Records of Test Process

6.5.1 The test process control shall include the following:

1 Pre-load test shall be carried out before the formal test to check the reliability of the test system. In the state of no-load, the zero-drift for dynamic strain and dynamic deflection signal within the proposed acquisition time should not exceed 5% of the anticipated maximum values.

2 The testing scheme or the parameter setting of the instrument should be adjusted according to the results of preload test. Based on the adjusted test scheme and load procedure, the test shall be conducted by monitoring and recording various parameters, taking measures to prevent the influence of electromagnetic fields, walkie-talkies and mobile phones on the test results.

3 In the formal test process, according to the observations and test results, judges shall be made as whether the structural state is normal, whether the measurement data is abnormal, and whether the test needs to be terminated for safety. The measurement data shall be checked and validated after each load test. If abnormal amplitudes, serious zero drift, abnormal electromagnetic interference, high noise, etc. are observed, the test shall be repeated after trouble clearing.

4 The integrity of the recorded information shall be ensured on the test load parameters, sensor's specification, sensitivity, numbering and connection channel number, adapter, sampling frequency, filter frequency, conversion coefficient, etc.

5 After all the tests, the important measurement data shall be checked and preliminary analysis shall be performed on site to ensure the accuracy and integrity of the measurement data.

***Background*:**
The bridge dynamic testinstrument is low-current instrument, which needs to be kept far away from electromagnetic sources. Necessary shielding measures shall be taken. The use of walkie-talkies, mobile phones and other communication instrument near the instruments may produce unexpected disturbances, which usually requires verification before the test.

6.5.2 The instrument system performance for dynamic load test shall meet the requirements of test on the measurement range, accuracy, resolution, stability, amplitude-frequency characteristic and phase-frequency characteristic. The sensor shall be installed in close contact with the structure without relative vibration.

6.5.3 The amplitude resolution of dynamic deflection and dynamic strain signal used for the calculation of impact factor shall not be higher than 1% of the maximum measurement value.

***Background*:**

In acquisition and processing of the dynamic deflection and dynamic strain signals, if the amplitude resolution is too low, the result of the dynamic increment andimpact factor will leave a relatively big margin of error. When the amplitude resolution is 1% *of the max. value of time history curve and the supposed impact factor is* 0.10, *the impact factor error from the amplitude resolution shall be within* 5%.

6.5.4 In data acquisition and spectral analysis, the sampling and analysis of parameters shall be set reasonably. The frequency resolution should be no more than 1% of the measured natural frequency.

6.5.5 Sampling frequency should be the most useful signal frequency more than 10 times higher. For signal acquisition time, the number of spectrum average should be ensured no less than 20 times for spectral analysis. The common acquisition and analysis parameter settings are list ed in Table 6.5.5.

Table 6.5.5 Main parameters of dynamic signal acquisition and their relationships

No	Parameter	Symbols	Unit	Relationship	Recommended values
1	Sampling frequency	f_S	Hz	$f_S = \frac{1}{\Delta T}$ (△T is Sampling interval)	$f_S \geqslant 10f_{max}$
2	Analyzing bandwidth	f_b	Hz	$f_b = \frac{f_y}{K}$ ($K>2$, instrument adopt defaults value when using dynamic signal analyzer)	f_b is related with f_S
3	Frequency resolution	$\triangle f$	Hz	$\Delta f = \frac{f_b}{n_l} = \frac{f_s}{Kn_l} = \frac{f_s}{m_l}$	$\triangle f \leqslant 0.01 f_{max}$
4	Data block length	m_i	Point	$m_l = K \times n_l = f_S \times t$	m_i is related with n_l
5	Number of lines	n_l	Line	$n_i = \frac{f_b}{\Delta f} = \frac{f_s}{K\Delta f}$	Calculated from other parameters
6	Sample Time length	t	s	$t = \frac{m_l}{f_s} = \frac{n_l}{f_b}$	Derived by other parameters

Note: f_{max}-Maximum usable frequency。

6.5.6 Under forced vibration, such as truck excitation or vehicle bump excitation, the acceleration, velocity and dynamic deformation of the bridge structure should be directly tested.

***Background*:**
For ultra-low-frequency stochastic signals, precision cannot be guaranteed by calculus (especially second-order calculus), and the result is stochastic. Therefore, the use of indirect physical operation shall be avoided.

6.6 Test Results Analysis

6.6.1 The test signal shall be checked and judged, and the necessary preprocessing is suggested, such as digital filtering and removal of abnormal data.

6.6.2 The structural natural frequencies can be acquired by natural frequency spectral analysis method, waveform analysis method or modal analysis method. The natural frequencies should be validated by multiple tests from different analysis methods. The difference between the single measured frequency and mean frequencies of the test shall not exceed ±3%.

***Background*:**
(1) Waveform analysis method is suitable for the natural vibration signal with single frequency. Taking a number of periodic natural vibration waveforms, the average natural frequencies may be worked out with the time coordinate. In the case of the test signal including the superposition of more than one vibration signal, the signal is usually segregated by the band-pass filter to obtain the natural vibration signal of single frequency, and then the frequency is computed, as shown in Fig. 6-1.

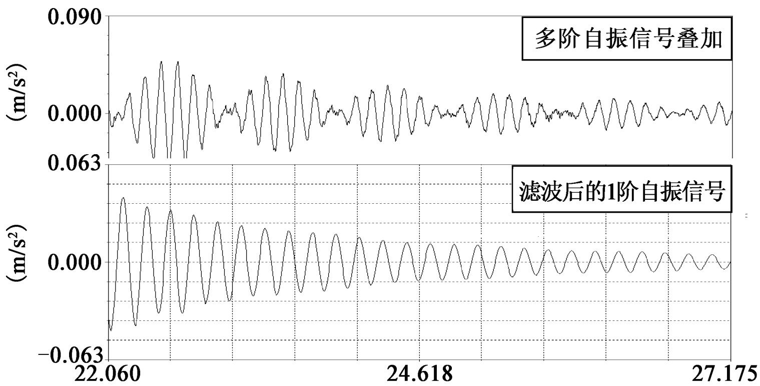


Fig. 6-1 Segregation of multi-order superposition vibration signals of a continuousgirder bridge

(2) The spectral analysis method is usually used to determine all the frequencies of natural

vibration signal. The data used for analysis does not include those from forced vibration.

(3) When using the vehicle bump excitation method, the natural freguency of the measured structure is usually modified by the Equation (6-1) for bridges with spans shorter than 20m:

$$f_0 = f\sqrt{\frac{M_0 + M}{M_0}} \qquad (6\text{-}1)$$

where:

f_0—*The natural frequency of the structure;*

f—*Measured vibration frequency with additional mass effect;*

M_0—*The equivalent mass of bridge structure at the excitation location;*

M—*Additional mass.*

Through the excitations of suddenly-appliedload by two different masses, the vibration frequencies f1 and f2 may be repectively measured. With the additional masses being M_1 *and* M_2, *the equivalent mass of the bridge* M_0 *may be then worked out through Equation (6-1).*

(4) For truck excitation method, the exact moment when the vehicle leaving the bridge is suggested to be accurate to avoid treating the forced vibration as free vibration. The starting point of free vibration is usually determined according to the initial position of the static response in the dynamic deflection and dynamic strain signal, (Fig 6-2), then the forced vibration response is discarded by using the data truncation function. The length of the truncated data shall meet the frequency resolution requirements.

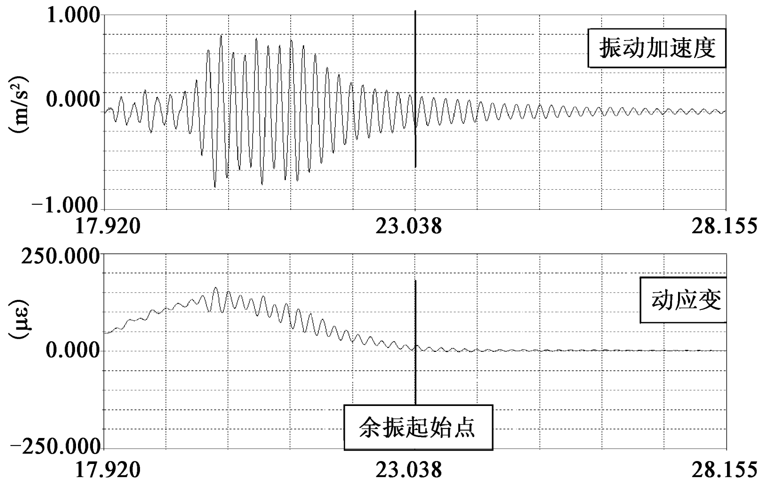


Fig. 6-2 Determination of the starting point of the excitation residual vibration of a sports car

6.6.3 The damping of bridge structure may be obtained by the waveform analysis method, half power band width method or modal analysis method. The structural damping parameter should be determined as the mean value of the multiple test results, and the deviation of the measured results in single test and mean value of the test shall not exceed ±20%.

(1) Waveform analysis method. The waveform from the signal superposition is segregated into a single frequency signal (as shown in Fig. 6-3). The damping ratio may be calculated by Eq. (6-2):

$$D = \frac{1}{\pi n} \ln \frac{A_i - A_i}{A_{i+n} - A_{i+n}} \tag{6-2}$$

where:

D—Damping ratio;

n—The number of waves participating in the calculation, which is no less than 3;

A_i—The first "peak" that participates in the calculation;

A'_i—The first "troughs" that participated in the calculation;

A_{i+n}—The last "peak" that participated in the calculation;

A'_{i+n}—The last "troughs" that participated in the calculation.

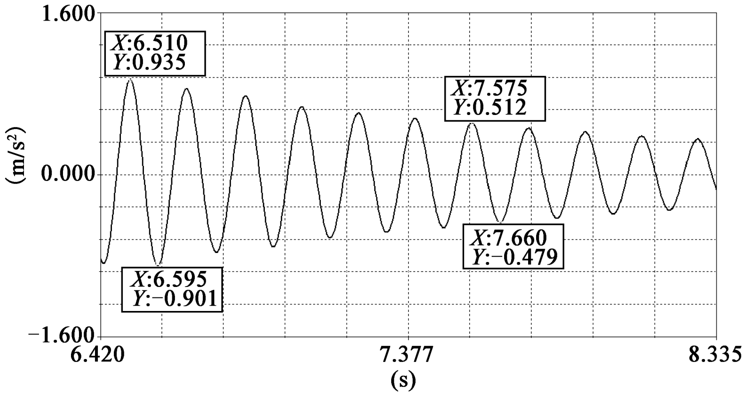


Fig. 6-3 The diagram of damping ratio calculation bywaveform analysis method

(2) The half-power bandwidth method is used to calculate the damping parameter by means of half-power point bandwidth for every order of natural vibration. With this method, the frequency resolution $\triangle f$ shall not be more than 1% of the natural frequency so as to ensure the accuracy of interpolation calculation, as shown in Fig. 6-4 and Eq. (6-3):

Damping ratio:

$$D = \frac{n}{\omega_0} = \frac{\omega_2 - \omega_1}{2\omega_0} = \frac{f_2 - f_1}{2f_0} \tag{6-3}$$

where:

f_0—Natural frequency;

f_1, f_2—The frequency of the half power point, i. e. the frequencies related with the peak of 0.707 times of power spectrum.

6.6.4 The vibration mode shape parameters should be identified by means of ambient excitation. Special software should be adopted to analyze the vibration mode shape, natural frequency and damping ratio.

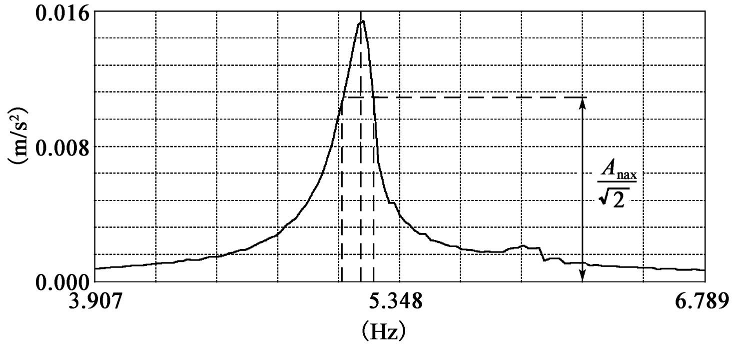


Fig. 6-4 Identification of damping ratio with half-power band width method

***Background*:**

There are a number ofcomplicated methods to identify the vibration mode shape parameters. Research shows that when the modal parameters are identified by the ambient excitation method, the stochastic subspace method shall be considered first as it can provide better precision.

6.6.5 The dynamic deflection time-history curve in obstacle-free vehicle travelling test is preferred in calculating the impact factor. For the high speed driving test of the short-span bridge, the maximum static deflection or strain shall be obtained by using the digital low-pass filter method as the error of direct extraction is large. As it is difficult to measure the super long-span bridges under the limit of field condition, the dynamic strain time-history curve is used to calculate the impact factor, as shown in Fig. 6.6 5:

$$\mu = \frac{f_{\text{dmax}}}{f_{\text{jmax}}} - 1 = \frac{f_{\text{dmax}}}{\frac{f_{\text{dmax}} + f_{\text{dmin}}}{2}} - 1 = \frac{f_{\text{dmax}}}{f_{\text{dmax}} - \frac{f_{\text{p-p}}}{2}} \tag{6.6.5-1}$$

where:

f_{dmax}—maximum amplitude of dunamic deflection;

f_{jmax}—center track of the wave form amplitude, or by low-pass filtering;

f_{dmin}—the trough corresponding to the f_{dmax};

$f_{\text{p-p}}$—the difference between the peak and trough.

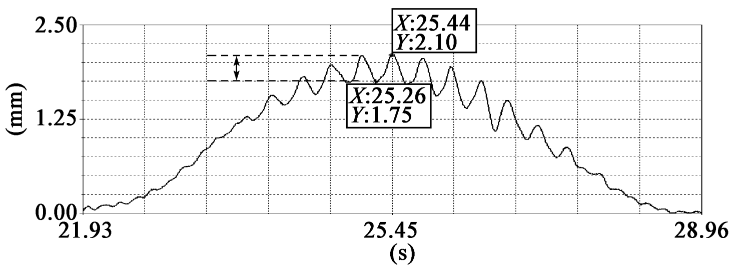


Fig. 6.6.5 The diagram ofimpact factor calculation

***Background*:**

1 Currently there is a lack of practical and reliable dynamic deflection test instrument that can *satisfy the requirements of the resolution for the super long-span bridges. Therefore, the dynamic strain is usually used to calculate the impact factor when it is impossible to measure the dynamic deflection. Although the dynamic strain is a local index, the statistic shows that the strain increasing coefficient and the impact factor are in good accordance in most cases. The average of a multiple-point test is usually used to ensure the reliability of the results.*

2 When the maximum static deflection is derived directly from the dynamic deflection or dynamic strain time-history curve, the results may be affected by subjective factors, which is especially significant in the high-speed driving test for the short-span bridge. Therefore, it is more reliable by using the digital low-pass filtering method to find the maximum static deflection or strain. Generally speaking, the frequency of quasistatic response is usually much lower than that of dynamic response. The dynamic response of the signal may be filtered by the suitable low-pass filter with the spectral analysis method to obtain the quasistatic response. The statistical data shows that this method is highly reliable. In the practice, the filter type and cut-off frequency shall be chosen rationally and the necessary contrast verification shall be made to ensure the complete quasistatic response. Usually, the impact factor obtained by low-pass filtering is slightly smaller than that of direct method.

3 For arch bridges and some concrete bridges, the measured dynamic response is usually small. For example, the dynamic strain amplitude is often between $(5 \sim 20) \times 10^{-6}$, so the noise effect of the instrumentation cannot be neglected. The analysis shows that the sample with a noise greater than 3% of the maximum amplitude of the signal cannot be used in calculating impact factor.

When theimpact factor is calculated by direct method, the ratio of the maximum magnitude of the time history to the corresponding static effect shall be considered. The ratio of the maximum magnitude to the corresponding equivalent "static" effect shall also be considered. Even though the idea is straightforward, the calculation of the static effect under the vehicle load by the digital filter is complicated. Meanwhile, the impact of the vehicle on the critical section when it is moving to a certain position is considered, regardless of the comprehensive impact effect of the vehicle moving at different locations. If all the local "peak" and "trough" of dynamic response and the corresponding "static" load of the response are weighted to calculate the impact factor, impact factor formula may be set as below:

$$\begin{cases} 1 + \mu_i = \dfrac{Y_{\max i}}{Y_{\mathrm{msax}i}} \\ Y_{\mathrm{msax}i} = \dfrac{1}{2}(Y_{\max i} + Y_{\min i}) \\ \alpha_i = \dfrac{Y_{\max i}}{\sum_{i=1}^{n} Y_{\max i}} \\ \mu = \sum_{i=1}^{n} \mu_i \alpha_i \end{cases} \tag{6-4}$$

where:

Y_{maxi}—*A "peak" in the dynamic deflection or dynamic strain time-history curve of the bridge when a vehicle travels along the bridge*;

Y_{mini}—*The corresponding "trough" dynamic response related to* Y_{maxi};

Y_{meani}—*The mean response of the point under the action of "static" load*;

μ_i—*Local impact factor corresponding to "trough" and "peak".*

α_i—*Weighted coefficient.*

Although this method is complicated, it can reflect the impact of the vehicle on the section during the whole process.

6.6.6 The impact factor should be taken as the mean value of many points in the same section (or part). The maximum value may be taken if many tests are conducted.

6.6.7 Analytical calculations and data management shall include the following:

1 Load efficiency ratio of dynamic load test.

2 The statistical characteristics of time domain for dynamic deflection, dynamic strain, acceleration, etc. under various test cases, including the values of maximum, minimum, mean and its variance.

3 Time-history curves of main measurement points under typical test cases.

4 Typical natural frequency spectrum.

5 Comparison list between the measured natural frequencies and the calculated frequencies.

6 Correlation curve or list of impact factor and vehicle speed.

7 Other necessary data or information, such as charts, curves, photographs.

6.6.8 Analysis of bridge structural performance shall be conducted according to the following methods:

1 Comparing the measured natural frequency with the calculated frequency. If the measured frequency is higher than the calculated frequency, it may be believed that the actual stiffness of the structure is greater than the theoretical stiffness, and vice versa.

2 Comparing the measured natural frequency, vibration mode shape and damping ratio with the calculated data or the historical data, whether the bridge technical status has changed

can be known by observing change patterns for preliminary evaluatation.

3 Comparing the measured impact factor value with the design impact factor value, analysis of the reasons shall be conducted if themeasurement value is larger than the design value.

***Background*:**

1 The natural frequency has a definite relationship with the structure stiffness. As it is easier to accurately measure the natural frequency, the use of natural frequency to evaluate the stiffness of the bridge is also highly reliable. If any defect is apparent in the structural components, the natural freguency usually lowers and abnormal vibration mode shape will appear.

2 Where there exist defects in the bridge structure, it usually causes abnormal vibration mode shape. The abnormal segment is usually the segment with the defect. The damping ratio may be compared with the historical data of the same bridge, or the historical data of the similar bridges, so that the condition of the bridge structure may be evaluated and any degradation of it may be found. If the damping ratio of a bridge is obviously larger than the normal value, there will likely be defects or degradation of the bridge structure.

7 Field Implementation

7.1 General

7.1.1 During and after the test, detailed inspections shall be carried out on the parts that have a greater impact on the load (parts with greater force, weak parts, original defects, etc.).

7.1.2 The measurement sensors and instrument shall be protected before applying load from sunlight, wind and rain, vibration and other interference.

7.1.3 The communication of on-site workers shall be ensured during the test.

7.1.4 The test scaffold shall be firm, reliable and sufficiently rigid, and scaffold deformation affecting test accuracy shall be prohibited during the testing period. The load and measurement shall be stopped if the test accuracy is influenced by the test scaffold deformation as a result of large wind speed in the field. The test scaffold must be strictly protected from being touched during the measurement.

Background:
Test scaffold refers to a support that is specially designed for the installation of test instruments and provides a datum point.

7.1.5 The work platform shall be set separately from the test scaffold, and the forces applied to each shall be completely independent. The work platform must be solid and reliable, which must support the corresponding load and satisfy functional needs. The safety of overall and partial strength on the bridge shall be ensured as for the spots of the test on the bridge.

***Background*:**
The work platform is used for the installation of instruments or device, and for measurement, performing or walking. It may be constructed by the bridge inspection vehicle or with scaffolding. For bridges with side suspenders or stayed cables, the inspection vehicles may not be used for installation of instruments and device due to the length constraints of their booms.

7.2 Site Layout

7.2.1
The survey location for locating and arranging shall conform to the following requirements:

1 A particular layout plan shall be prepared before installing the test sensors.

2 Logging is necessary if the layout plan has to be adjusted when installing the test sensors.

3 Tansmission cables with the same resistance value shall be used when the cable is selected to collect multi-point strain signals. The data line and measurement points shall be numbered beforehand. The sensor and the structure surface shall be well-bonded with no bubbles. When the sensor and data line are welded, it shall be ensured that the welding is good and there is no slag. Moisture protection shall be carried out for measurement points if necessary.

4 The base of the test instrument shall be completely detached from the structure when a dial gauge is used for deformation measurement. The measurement range shall satisfy the structural deformation requirement. When the deformation is measured by precision leveling instrument or total station, the datum points shall be set up and the measurement points shall be numbered beforehand.

5 When the dynamic measurement point is set up, the sensor shall be bonded firmly to the structure.

7.2.2 When the on-site instrument is arranged, the safety of the data collector shall be ensured.

7.2.3 Markings load location shall conform to the following provisions:

1 Before the test, all load cases and locations shall be marked. The content of the marking shall include key information, such as load case number, load position, etc.

2 If necessary, marking points shall be protected from rain(water) and snow. When load is carried out at night, the necessary lighting facilities or reflective marking materials shall be prepared.

7.2.4 The weighing and marking of loaded vehicles shall conform to the Clause 5.4.5.

7.3 Safety

7.3.1 The safety status of testing personnel, equipment, and instruments shall be checked to avoid accidents before, during and after the load test.

7.3.2 During the load test, the load and unload process of the vehicle shall be well planned. The parking location of vehicle and load position should be determined to shorten the time of load and unload.

Background:
When the vehicle is parked onthe bridge which is not the test bridge, the safety of the bridge must be ensured with enough parking distance.

7.3.3 Safety for structure and scaffold shall be ensured through structural calculation. In the process of loading and unloading, safety shall be guaranteed by monitoring abnormal reaction of structure or scaffold and analyzing the changing patterns of collected data.

7.3.4 Appropriateness for power connection, grounding, rainproof (waterproof), dustproof, windproof and lightning protection shall be guaranteed. All instrument shall be handled and placed gently and properly. During transportation, the packaging shall be handled according to the anti-vibration and dustproof requirements of the instrument.

8 Reporting

8.0.1 The test report shall conform to Appendix E.

8.0.2 The summary of the project shall include the following:

1 The main technical descriptions: the project to be tested, the bridge name, the construction or the service age, the starting and ending point or center station, the type of structure, the span combination, the cross-section form of bridge structure, the type of substructure, the control load, the number of traffic lanes, etc.

2 No less than one picture of overall structure, drawings with the elevation, plan and cross-section.

***Background*:**
In the case of a bridge where thedesign number of lanes is inconsistent with the number of operating lanes (such as a three-lane design with only two-lane in operation) shall be explained to show the load criterion in the test.

8.0.3 The purposes and basis of the test shall include the following:

1 The purpose of the test shall be explained according to the type of bridge structure and the nature of control load.

2 The standard, specifications, design drawings, as-built drawings and other relevant information on which the test is based shall be listed.

8.0.4 The test contents shall be described separately according to the static load test and the dynamic load test.

8.0.5 The test instrument shall include the name (model), the instrument serial number, the main technical parameters, etc., which may be provided in the list.

8.0.6 The static load test report shall include:

1 Description of bearings, piers, protection structure, bridge deck structure and driving conditions, structural internal force analysis results, test section selection, testing point layout about strain and deflection, test load vehicle or load selection, test cases, description for load position, test process, test results and analysis, and static load test conclusions.

2 The software to analyze the internal forces of the structure, main material parameters and the results of the internal force analysis of the bridge structure should be succinctly explained. The calculation method should be provided.

3 Themeasurement section should be selected according to the calculation result. The measurement items of load measurement section should be explained.

4 The number and layout of the strain and deflection should be provided based on themeasurement sections together with illustration.

5 The vehicle model and axle weight redistribution should be explained. The density and volume of the added mass should be explained, if such method is adopted with the test load efficiency provided.

6 The longitudinal and transverse bridgeload positions should be listed sequentially according to the order of the measurement section, supplemented by the illustration.

7 The main test procedures of test preparation, preload, load and unload should be briefly described.

8 Themeasurement values, the average value, the residual values, the theoretical calculation values and the verification coefficients of the strain and deflection under each condition should be given in a list. The measurement values and theoretical values of the representative measurement points should be plotted for clear observation of the distribution condition or the structural response under experimental load.

9 The static load test conclusions, including the geometrical and mechanical parameters of the test section, should be provided. Themeasurement data should be provided to judge

whether the condition of the structure meets the requirements of design and satisfies the conclusion of static load test.

8.0.7 The dynamic load test report shall include the following:

1 Dynamic load test report shall include: structural dynamic analysis, selection of measurement sections, sensor location, test load selection, test cases, test results and analysis, and dynamic load test conclusion.

2 Structural dynamic analysis shall include the theoretical calculation and vibration mode shape description of the structural natural frequency specified in Clause6.3.1.

3 The position of the measurement section and the arrangement of the sensors on the longitudinal and cross-sections shall be described.

4 The number of vehicles, weight of vehicles and other test load information shall be explained.

5 The cases of the obstacle-free vehicle travelling test and vehicle jumping test shall be explained.

6 The test results and analysis shall include dynamic signal processing method, structure natural frequency, damping ratio, impact factor test result and diagram. The test results shall be compared with theoretical calculation value.

7 The conclusion of dynamic load test shall include the key parameters of structural dynamic test and the evaluation of structural condition.

8.0.8 The conclusions of the load test shall include the following:

1 The final conclusions of the load test shall include the conclusions of static load test, dynamic load test and the conditions of crack during the test.

2 In the static load test conclusions, analysis based on the results of the symmetrical and off-center load cases shall be made, including the geometric and mechanical parameters of the test section, the calibration coefficients of strain and deflection. Whether the condition of the structure satisfies the requirements of design or target load may be determined according to the measurement data.

3 Dynamic load test shall explain the dynamic performance and structural response of the structure with the main dynamic test parameters. Evaluation shall be made based on the comparison between theoretical value and measurement value.

4 Whether cracks appear, how they change, or other situation during test shall be made clear. Photos of main crack need to be provided, and the effect of crack on the structure needs to be analyzed.

8.0.9 Technical recommendations shall rely on the conclusions of the load test. They may include specific recommendations for the structure, such as speed limit, vehicle weight limit, closed traffic, maintenance, reinforcement or reconstruction, etc.

8.0.10 The report appendix shall cover the following:

1 Original measurement data and work photos.

2 The photos of load test.

3 Other supporting information that is needed in the body of appendix.

Appendix A
Technical Requirements for Test Instruments of Bridge Static Parameters

A.0.1 The strain (or stress) testinstrument shall meet the requirements of Table A.0.1.

Table A.0.1 Technical Requirements for strain (or stress) **testinginstrument**

Measurement content	Instrument name	Minimum partition value(με)	Common measurement range(με)	Data acquisition and analysis system		Background
				Instrument name	Technical parameters	
Strain	Dial gauge	2	±(5~2000)	—	—	With accessories
	Lever extensometer	2	±(50~200)	—	—	With accessories
	Hand-held strain gauge	5	±(100~20000)	—	—	With accessories
	Resistance strain gauge	1	±20000	Strain test and analysis system	①Measurement strain range: ±20000με; ②resolution: 1με;	Surface mount resistors
	Vibrating string type Vstrain gauge	1	±3000	Vibrating chord type transducer, frequency measurement instrument or synthetic tester	① Measurement range: vibrating chord frequency: 400~6000hz; ② measurement accuracy: frequency precision: 0.05hz	Surface paste

continued

Measurement content	Instrument name	Minimum partition value($\mu\varepsilon$)	Common measurement range($\mu\varepsilon$)	Data acquisition and analysis system		Background
				Instrument name	Technical parameters	
Strain	Fiber grating strain gauge	2	±6000	Fiberbragg grating demodulator	Accessible sensing unit >64; Scanning frequency >60hz; Wavelength resolution not greater than 1pm	Surface pasting, buried

Background: 1. The measurement steel component (or the steel bar in the concrete) strain, the standard distance should be no less than 6 mm distance strain gauge. The surface strain of concrete structure shall be measured, and the large scale strain gauge with a distance of noless than 80 ~ 100 mm is suitable.
2. Or use otherinstrument that can meet the technical requirements.

A.0.2 The deformation test instrument shall meet the requirements of Table A.0.2.

Table A.0.2 Technical requirements for deformation testinstrument

Measurement content	Instrument name	Minimum partition value	Common measurement range	Background
Deformation	Dial gauge	0.001mm	0 ~ 10mm	Configure installation accessories
	Dial indicator	0.01mm	1 ~ 50mm	
	Precision leveling instrument	0.3mm	—	
	Total station	Angle measurement: precision is 0.5″; Ranging: standard measurement accuracy 1.0mm + $10^{-6}l$。	—	Monitor the atmospheric environment during use and make corrections if necessary
Deformation	Displacement meter	0.01 ~ 0.03mm	20 ~ 100mm	Configure installation accessories
	Theodolite	0.5mm	—	
	Connecting pipe	0.1mm	<300mm	Equipped with a reading instrument
	Satellite positioning system	Coordinate measurement: Level: 5mm + $10^{-6}l$; Vertical: 10mm + $2 \times 10^{-6}l$	—	meet the needs of large-span bridge deformation measurement

Background: 1. Or use other instrument that can meet the technical requirements.
2. L is the observation distance.

A. 0. 3 The crack test instrument shall meet the requirements of Table A. 0. 3.

Table A. 0. 3 Technical requirements forcrack testing instrument

Measurement content	Instrument name	Minimum partition value	Common measurement range	Background
Crack	Scale magnifier	0. 01mm	—	
	Crack gauge	0. 01mm	< 200mm	Configure installation accessories
	Dial gauge	0. 001mm	0 ~ 10mm	

Background: Or use other instrument that can meet the technical requirements.

A. 0. 4 Inclination testinstrument shall meet the requirements of Table A. 0. 4.

Table A. 0. 4 Inclination angle Test instrument Technical requirements

Measurement content	Instrument name	Minimum partition value	Common measurement range	Background
Inclinationangle	Leveling inclinometer	2. 5′	20′ ~ 1°	Fixed bracket
	Fiber grating inclinometer	5′	± 10°	Configure installation accessories
	Digital display inclinometer	1′	± 1° ~ ± 18°	Iron installation interface
	Two-axis inclinometer	1′	± 30°	Configure installation accessories

Background: Or use other instrument that can meet the technical requirements.

Appendix B Vibration-based Cable Force Measurement Method

B.0.1 Under the certain conditions, there is a corresponding relation between the tensile force of cable and the vibration frequency of cable. The tensile force may be calculated by the cable vibration frequency when the length, distribution quality and bending stiffness of the cable are known.

B.0.2 The measurement system and technical requirements mainly include the following:

1 The measurement system is composed of sensors, amplifiers, signal acquisition and analysis instruments.

2 Sensors, amplifiers and signal acquisition systemsshall be sufficiently sensitive to measure the transverse vibration signals of cables under natural ambient vibrationor artificial excitation.

3 The frequency response range of themeasurement system shall be able to meet the requirements of the natural frequency measurement of different cables, and its band width shall be sufficient.

4 Signal acquisition and analysisinstrument shall be anti-aliasing filter and frequency analysis function, and the frequency resolution shall be at least 0.01 Hz.

B.0.3 Tests and records shall contain the following:

1 The vibration signals of cablesmay be collected by means of ambient random vibration. When the test system is not sensitive enough, artificial excitation may be adopted.

2 The external damper of the cableshall be temporarily removed during measurement.

3 For the transverse vibration measurement of the cable, the sensor shall be fixed on the

cable stock with a special clamp or bandage. The installation position should be far away from the anchorage end of the cable.

4 The sampling frequencyshall be greater than or equal to 5 times of the 5^{th}-order natural frequencies of the cable, and no less than 100 Hz. Recording time shall be greater than 5 mins. The signal quality shall be observed during the date collection on the site.

5 The natural frequency of the 5 ~ 10 order is obtained by using the method of self-spectral analysis. The analysis parameters, such as data length, bandwidth, spectral line number, overlapping ratio, window function and spectral average times shall be selected according to the requirements of random signal processing. All above is to reduce the analysis error and have a frequency resolution of no greater than 0.01 Hz.

6 The order of the measured natural frequency and frequency leakageshall be judged. It may be judged based on the frequency difference between adjacent steps in the measured multi-order natural frequencies. When the frequency difference of each adjacent order is approximately equal and is close to the measured first order frequency, there is no frequency leakage phenomenon. Otherwise, there exists frequency leakage phenomenon.

B.0.4 Calculation of cable force

1 The calculation methods, based on the initial measured frequency or fundamental frequency, may be adopted. The calculation results should be verified from different analytical methods.

2 The calculation methods of the cable force based on the measured frequency of the previous order are listed as below:

1) According to the measured natural frequency value of the first order, the mean value of the first 5-order calculation should be taken as the measurement value of cable force.

2) When the bending stiffness of the cable may be neglected, the cable force is calculated by the formula:

$$T = \frac{4\rho L^2 f_n^2}{n^2} \qquad \text{(B.0.4-1)}$$

3) When the bending stiffness of cable cannot be neglected and the constraint conditions of both ends are simplified to simple support, the cable force is calculated by the following formula:

$$T = \frac{4\rho L^2 f_n^2}{n^2} - \frac{n^2 \pi^2 EI}{L^2} \qquad \text{(B.0.4-2)}$$

Where:

T—Cable Force;

f_n—The nth-order natural frequencies of the cable;

L—Effective length of cable;

n—Order of natural frequency;

EI—Bending stiffness of cable;

ρ—Line density of cable.

3 Calculation method of cable force based onfundamental frequency.

The fundamental frequency f_1 of the cable may be obtained by frequency spectral analysis. If the fundamental frequency f_1 of the cable cannot be obtained, and the frequency difference of the adjacent order in the first 10 order natural frequencies is approximately equal, the mean value of frequency difference or multiple frequency difference may be substituted for the fundamental frequency f_1. The cable force T may be calculated according to the flow chart in Fig. B. 0.4. And ξ is the parameter that reflects the influence of the cable´s bending stiffness, and the T' is the calculation process variable.

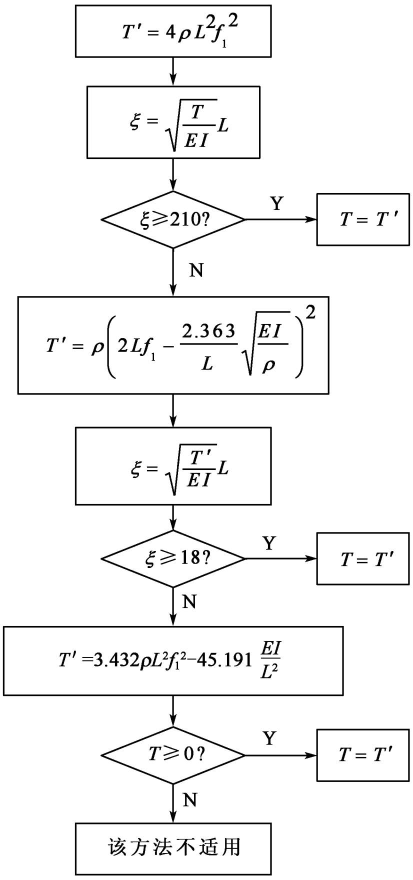


Fig. B.0.4 Calculation flow of cable force based on fundamental frequency f_1

Appendix C Technical Requirements for Test Instruments of Bridge Dynamic Parameters

C.0.1 The test instrument of the bridge natural vibration characteristics shall meet the technical requirements of Table C.0.1.

C.0.1 Technical requirements for natural vibration parameters test instrument

Measurement content	Measurement system		Data acquisition and analysis system		Note
	Instrument name	Scope of application	Instrument name	Technical parameters	
Dynamic characteristic parameter	Magneto-electric sensor and amplifier	① Measurement range: displacement ±20mm; acceleration ±0.5g; ②Frequency response: 0.3 ~ 20hz; ③ May be used in driving test and pulsating test	A collection system composed of computer and corresponding software	① Input voltage range 0 ~ ±5(10)v; ②Frequency response: 0 ~ 5khz; ③Sample frequency not less than 1khz;	
	Sensorand dynamic strain gauges	① Measurement range: ±5g; ②Frequency response: 0 ~ 100hz; ③May be used in driving test			

continued

Measurement content	Measurement system		Data acquisition and analysis system		Note
	Instrument name	Scope of application	Instrument name	Technical parameters	
Dynamic characteristic parameter	Piezoelectricsensorand charge amplifier	① Measurement range: ±100g; ②Frequency response:0.5 ~ 1khz; ③May be used in driving test, cable force measurement, high sensitivity can also be used for pulsating test	A collection system composed of computer and corresponding software	① Input voltage range 0 ~ ±5(10)v; ②Frequency response:0 ~ 5khz; ③Sample frequency not less than 1khz;	
	Servosensorand amplifier	①Measurement range: ±5g; ②Frequency response:0 ~ 100hz; ③May be used in driving test and pulsating test			
	Capacitivesensorand amplifier	①Measurement range: ±5g; ②Frequency response:0 ~ 100hz; ③May be used in driving test and pulsating test			

Background: Other instrument may be used as long as the technical requirements are conformed.

C.0.2 The bridge dynamic response test instrument shall meet the technical requirements of Table C.0.2.

Table C.0.2 Technical requirements for dynamic response testing instrument

Measurement content	Measurement system		Data acquisition and analysis system		Background
	Instrument name	Scope of application	Instrument name	Technical parameters	
Strain	Electrical resistance strain gauge (sheets) and dynamic strain gauges	① Measurement range: ±15000με; ②Frequency response:0 ~ 10khz; ③May be used in driving test.	A collection system composed of computer and corresponding software;	① Input voltage range 0 ~ ±5(10)v; ②Frequency response:0 ~ 5khz; ③Sample frequency not less than 1khz	May be embedded or installed

continued

Measurement content	Measurement system		Data acquisition and analysis system		Background
	Instrument name	Scope of application	Instrument name	Technical parameters	
Strain	Fiber optic strain gauge and modem	① Measurement range: ±6000με; ②Resolution: 1με; ③May be used in driving test.	Fiberbragg grating demodulation instrument	Sample frequency: no less than 100hz;	May be embedded or installed
Displacement	Resistance strain type displacement gauge and dynamic strain gauge	① Measurement range: ±15000με; ②Frequency response: 0 ~ 20hz; ③May be used in low-speed driving test	A collection system composed of computer and corresponding software	① Input voltage range 0 ~ ±5(10)v; ②Frequency response: 0 ~ 5khz; ③Sample frequency not less than 1khz;	Contact measurement requires a table rack
	Photoelectric displacement measurement device	① Measurement range: 500m; ②Frequency response: ± 2. 5 m (when maximum ranging); ③Frequency response: 20hz; ④May be used in driving test.			Non-contact measurement
	Optical electricdy namicdeflection meter	① Measurement distance: 5 ~ 500m ② Measurement accuracy: ± 0. 02 ~ ± 0. 03mm, related to measurement distance	—	—	Non-contact measurement

Background: Or use other instrument that can meet the technical requirements.

Appendix D
Test Record of Cracks in Concrete During Load Test

Table D. 0. 1　Concrete Crack inspection Record form

Bridge name:　　　　　　　　　　　　　　　　　　　　　　　　Component Name:

<table>
<tr><td rowspan="3">Cracknumber</td><td colspan="6">Crack test Value</td></tr>
<tr><td colspan="2">Testcases 1</td><td colspan="2">Testcases 2</td><td colspan="2">·········</td></tr>
<tr><td>Crack length (m)</td><td>Crack width (mm)</td><td>Crack length (m)</td><td>Crackwidth (mm)</td><td>Crack length (m)</td><td>Crackwidth (mm)</td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Total crack length (m)</td><td colspan="3"></td><td colspan="2">Total crack Length__(m)
(crack width≥0. 2 mm)</td></tr>
<tr><td colspan="7">Distribution and direction ofcrack</td></tr>
<tr><td colspan="7"></td></tr>
</table>

Record:　　　　　　　　　　　　　　Review:　　　　　　　　　　　　　　Date:

Appendix E
Test Report Format

E.0.1　The cover should be in the following format:

××× Route ××× Bridge Load Test Report No. ××　Total Pages ×
Commissioning Agency: Testing Agency: (Report date)

E. 0. 2 The title page should use the following format:

Testing Agency Qualification CMA Recognized

× × × Route

× × × Bridge Load Test Report

No. × × Total Pages ×

Project leader: (Sign)

compiler: (Sign)

Report Reviewer: (Sign)

Authoritarian Agent: (Sign)

(Name and stamp of testing agency)

(Report Date)

E. 0. 3 The list of load testers should be in the following format:

Order	Name	Title	Profession	Certificate and No.	Resposibility
1					
2					
4					
5					
……					

E. 0. 4 The following format should be adopted for the load test summary:

<table>
<tr><td colspan="2">Project name</td><td colspan="4"></td></tr>
<tr><td colspan="2">Bridge name</td><td></td><td colspan="2">Bridge Completion Time</td><td></td></tr>
<tr><td colspan="2">Bridgestation</td><td></td><td colspan="2">Type ofBridge structure, span composition</td><td></td></tr>
<tr><td colspan="2">Test Bridge (segment) structural form</td><td></td><td colspan="2">Test Bridge (segment) span composition</td><td></td></tr>
<tr><td colspan="2">Load test Type</td><td></td><td colspan="2">Test control load</td><td></td></tr>
<tr><td rowspan="2">Load efficiency</td><td>Static Load</td><td></td><td rowspan="2">Load mode</td><td>Static Load</td><td rowspan="2"></td></tr>
<tr><td>Dynamic Load</td><td></td><td>Dynamic Load</td></tr>
<tr><td rowspan="2">Number of load cases</td><td>Static Load</td><td></td><td colspan="2" rowspan="2">Test date</td><td rowspan="2"></td></tr>
<tr><td>Dynamic Load</td><td></td></tr>
<tr><td colspan="2">Main conclusions of load test</td><td colspan="4"></td></tr>
<tr><td colspan="2">Technical suggestions</td><td colspan="4"></td></tr>
</table>

E.0.5 The report body directory shall include the following:

1 Project overview;

2 The purpose and basis of the test;

3 Test content;

4 Testinstrument;

5 Static load test;

6 Dynamic load test;

7 Test conclusion;

8 Technical suggestions;

9 Appendices.

Technical Terms in Chinese and English

序号	中 文 词 汇	英 文 词 汇
		B
1	百分表(千分表)	dial gauge
2	变形	deformation
3	补偿片	compensation gauge
		C
4	测试支架	test scaffold
5	车—桥耦合振动	vehicle-bridge coupled vibration
6	承载能力	load-carrying capacity
7	冲击系数	impact factor
8	冲击效应	impact effect
9	残余变形	residual deformation
		D
10	动挠度	dynamic deflection
11	电阻应变计	electrical resistance strain gauge
12	吊索(杆)	suspender
13	动荷载激振	dynamic excitation
14	动力参数	dynamic parameter
15	动力放大系数	dynamic amplification factor
16	动力特性	dynamic characteristic

续上表(continued)

序号	中 文 词 汇	英 文 词 汇
17	动力响应	dynamic response
18	动位移	dynamic displacement
19	动应变	dynamic strain
20	动载试验	dynamic load test
21	多梁(肋)式结构	multigirder
F		
22	分级加载	multiple-step loading
23	附加工况	additional load case
24	风荷载	wind load
25	风力	wind force
G		
26	固定参考点	reference point
H		
27	荷载试验	load test
28	荷载试验效率	load test efficiency
29	桁架拱桥	truss arch
30	横断面	cross-section
31	横向分布	transverse distribution
32	横向位移	lateral displacement
33	横向增大系数	lateral amplification factor
34	虎克定律	Hooke's law
35	环境随机振动	ambient random vibration
36	环境随机激振法	ambient random excitation
37	换算质量	equivalent mass
38	混凝土保护层	concrete cover
J		
39	加固	strengthening
40	校验系数	verification coefficient

续上表(continued)

序号	中 文 词 汇	英 文 词 汇
41	基频	fundamental frequency
42	交(竣)工	hand-over & complete construction
43	机械式测试设备	mechanical test equipment
44	计算长度	effective length
45	静力参数	static parameter
46	静载试验	static load test
	K	
47	抗弯刚度	bending stiffness
48	控制截面	critical section
	L	
49	裂缝	crack
	M	
50	锚固	anchorage
	N	
51	挠度	deflection
	P	
52	碰撞	collision
53	偏载试验	off-center load test
54	偏载工况	off-center load case
55	频谱分析	spectral analysis
	Q	
56	桥联	connection
57	缺陷	defect
58	倾角	inclination angle
59	桥面板	bridge deck
60	桥面平整度	surface roughness
61	强迫振动	forced vibration

续上表(continued)

序号	中 文 词 汇	英 文 词 汇
		S
62	损伤	damage
63	施工监控	construction monitoring and control
64	索(杆)力	cable（suspender）force
65	竖向位移	vertical displacement
		T
66	体外预应力	externalprestressing
67	跳车激振法	vehicle bump excitation
		W
68	位移	displacement
69	弯扭耦合	bending-torsion coupling
70	微幅振动	micro-vibration
71	稳态振动	steady-state response
		X
72	行车激振法	truck excitation
73	相对残余位移	relative residualdisplacement
		Y
74	运营荷载	service load
75	异型桥梁	irregular bridge
76	应变花	strain gauge rosette
		Z
77	振型	vibration mode
78	阻尼比	damping ratio
79	中载试验	symmetrical load test
80	最不利受力原则	the most unfavorable condition Principle
81	主要工况	basic load case
82	组合体系桥梁	hybrid bridge

续上表(continued)

序号	中 文 词 汇	英 文 词 汇
83	置换混凝土	concrete replacement
84	粘贴板(片)材加固	bonded plate/sheet strengthening
85	中性轴	neutral axis
86	自振特性参数	natural vibrationparameter
87	自振频率	natural frequency