Foreword

According to the requirement of the document Jian Biao [2011]No. 17-Notice on Printing and Distribution the Development and Revision Plan of Engineering Construction Standards and Codes in 2011 issued by the Ministry of Housing and Urban-Rural Development, after extensive investigation and study, the code developing group has conscientiously summed up practical experience, referred to relevant international standards and advanced foreign standards, and set this code based on widely soliciting opinions.

The main technical contents of this code are general provisions, terms and symbols, basic requirements, monitoring methods, high-rise buildings and structures, long-span spatial structures, bridge structures, and other structures.

The provisions printed in bold are compulsory ones and must be strictly implemented.

The Ministry of Housing and Urban-Rural Development of the People's Republic of China oversees the administration of this code and the explanation of the compulsory provisions. China Academy of Building Research (CABR) is responsible for explaining the specific technical contents. During the code implementation process, the relevant opinions and advice can be posted to CABR (Address: 30 North 3rd Ring East Road, Beijing, postcode 100013).

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Contents

1 General Provisions

1.0.1 This code is formulated to standardize the monitoring technology and the corresponding precaution analysis to ensure advanced technologies, reliable data, and reasonable cost for monitoring of building and bridge structures.

1.0.2 This code applies to monitor, high-rise buildings and structures, long-span spatial structures, bridge structures, isolated structures, and existing structures influenced by crossing construction.

1.0.3 Monitoring of building and bridge structures shall meet the requirements of this code and the relevant current national standards.

2 Terms and Symbols

2.1 Terms

2.1.1 structural monitoring

Frequently and continuously observing or measuring the structural state.

2.1.2 construction monitoring

Structural monitoring during construction.

2.1.3 post construction monitoring

Structural monitoring during service life.

2.1.4 monitoring system

Software and hardware integration with certain monitoring functions composed of monitoring equipment.

2.1.5 monitoring equipment

General designation of hardware such as transducers/sensors, acquisition instruments, etc., in the monitoring system.

2.1.6 transducer/sensor

Instruments or devices be able to sense measured signals and convert them to usable output signals according to a specific rule, and usually consisting of sensing and transduction elements.

2.1.7 times of monitoring

The number of monitoring times per unit time.

2.1.8 precaution value for monitoring

The alarming value of monitoring quantities indicates the possible abnormal or dangerous state of the monitoring object, to ensure the safety or quality of engineering structures and the surroundings safety.

2.1.9 monitoring system stability

The operational performance of the monitoring system is normal after long-term use.

2.1.10 monitoring equipment durability

The monitoring equipment meet the expected functional requirements over time under regular use and maintenance conditions.

2.1.11 sensor frequency range

In this frequency range, the input signal frequency change cannot cause the sensor sensitivity and phase changes beyond the limit.

2.1.12 structural analyzing model updating

The process of approaching calculation results as close as possible to the actual measured values through identifying or updating the parameters of the structural analyzing model.

2.1.13 crossing construction

The construction process of underground engineering crosses the existing structures.

2.2 Symbols

f_n——the nth natural frequency;

l——length or span;

n——mode order;

P——pushing force;

r——wire resistance;

T——cable force;

δ——relative deformation;

ε——strain;

ρ——mass per unit length.

3 Basic Requirements

3.1 General Requirements

3.1.1 Structural monitoring of buildings and bridges shall be divided into construction monitoring and post construction monitoring.

3.1.2 Construction monitoring should be combined with mensuration, observation, inspection, and engineering control. Post construction monitoring should be carried out by using a monitoring system with automatic data acquisition.

3.1.3 Patrol inspection and system maintenance shall be carried out during monitoring.

3.1.4 Construction monitoring should be considered in conjunction with post construction monitoring.

3.1.5 Before monitoring, the monitoring purpose shall be clarified according to the monitoring requirements of all parties and design documents. The monitoring scheme shall be formulated in combination with factors such as engineering structural characteristics, site and surrounding environmental conditions.

3.1.6 Monitoring requirements shall be put forward at the design stage for structures that need to be monitored:

3.1.7 The monitoring scheme of the following engineering structures shall be especially demonstrated:

1 Class A or complex Class B seismic protection classification of high-rise buildings and structures, long-span spatial structures.

2 Extra-large and complex bridge structures.

3 Engineering structures that are resumed to construction or use through detection, treatment, and evaluation after a severe accident.

4 Engineering structures with complex monitoring schemes or need to be demonstrated.

3.1.8 The precaution values shall be set for monitoring of building and bridge structures, and these values shall meet the control requirements of engineering design and monitored objects.

3.1.9 Protection and maintenance measures shall be taken for monitoring facilities during the monitoring.

3.1.10 The monitoring of building and bridge structures shall clarify its purpose and function. Without the permission of the monitoring implementation organization, it shall not be allowed to change the monitoring points or damage the monitoring equipment, such as sensors, cables, and acquisition instruments.

3.2 Monitoring System, Point and Equipment

3.2.1 A global or local monitoring system shall be established following the actual condition of the monitoring objects and the engineering sites. And a specialized monitoring room should be set up.

3.2.2 The monitoring system should have complete functions of sensing, conditioning, acquisition, transmission, storage, data processing and control, precaution, or condition assessment.

3.2.3 The monitoring system shall be parameterized and debugged according to the prescribed

method or process. It shall comply with the following requirements:

1 Initial state setting or zero balance processing of sensors is desirable before monitoring.

2 Interference signals shall be checked for sources, and effective measures shall be taken to deal with them.

3 The post construction monitoring system should inherit the data of construction monitoring and should conduct comparative analysis and identification.

3.2.4 The sampling frequency of the monitoring system shall meet the monitoring requirements.

3.2.5 During the monitoring, the monitoring results shall be timely compared with the structural analysis results. The monitoring object and system shall be checked in time when the monitoring data is abnormal. The alarm shall be immediately reported when the monitoring value exceeds the precaution value.

3.2.6 The monitoring points shall comply with the following requirements:

1 The monitoring points shall reflect the actual state and changing trend of the monitored object, and should be arranged at the locations of the largest monitoring values.

2 The location and number of monitoring points should be determined according to structure type, design requirements, construction process, monitoring projects, and structural analysis results.

3 The monitoring points shall be redundant in number and layout scope, and shall be added in important parts.

4 The number of monitoring points may be reduced by using the symmetry of structure.

5 It should be easy to install, test and read, maintain, and replace the monitoring equipment.

6 The construction and normal use of the monitored objects shall not be impeded.

7 On the basis of meeting the above requirements, the transmission distance of signals should be shortened.

3.2.7 The monitoring equipment shall comply with the following basic requirements:

1 The selected monitoring equipment shall meet the requirements of the monitoring period, monitoring projects and methods, and system functions. The monitoring equipment shall also have stability, durability, compatibility, and scalability.

2 The signal-to-noise ratio of the measured signals shall meet the requirements of actual engineering analysis.

3 The monitoring equipment shall be calibrated before use.

4 The installation method of equipment shall be selected according to the requirements of the monitoring methods and monitoring functions. The equipment installation shall be firm. The installation technology and durability shall meet the requirements of use during the monitoring.

5 After installation, the site markings and layout diagrams of the monitoring equipment shall be conducted in time, and shall be filed for future reference.

3.2.8 The monitoring sensors shall meet the basic requirements specified in Article 3.2.7 of this code, in addition to the following requirements:

1 The selection of sensors shall be based on the requirements of monitoring objects, projects, and methods. It shall follow the principle of advanced technology, stable performance, and cost-effectiveness.

2 The sensors with compensation function should be adopted.

3 The sensors shall meet the monitoring system requirements for sensitivity, bandpass,

dynamic range, measuring range, linearity, stability, power supply mode, and service life, etc.

3.2.9 The operating environment of the monitoring equipment shall comply with the following basic requirements:

1 The distance from signal cables and monitoring equipment to high-power radio emission sources, high-voltage transmission lines and microwave radio signal transmission channels should be accordance with the relevant requirements of the current national standard GB 50311 *Code for engineering design of generic cabling system*.

2 The monitoring receiving equipment should not be near large area of water, large-scale buildings, metal nets, and radio interference sources that strongly reflect signals;

3 When using satellite locationing system for monitoring, the height angle of obstacles in the view field should not be greater than 15°.

3.3 Construction Monitoring

3.3.1 Construction monitoring shall provide technical support to ensure construction safety, control the structural construction process, optimize construction technology and achieve structural design requirements.

3.3.2 Construction monitoring should focus on the following components and joints:

1 Components with significant stress changes or high stress levels.

2 Components or joints with significant deformation.

3 Components or joints that subject to larger construction loads.

4 Critical joints that control the structural geometric configuration.

5 Other important components or joints that reflect the critical characteristic of structural internal force and deformation.

3.3.3 The construction monitoring items may include strain monitoring, deformation and crack monitoring, environmental and effects monitoring. Deformation monitoring may include foundation settlement monitoring, vertical deformation monitoring, and horizontal deformation monitoring. Environmental and effects monitoring may include wind field and wind-induced response monitoring, temperature and humidity monitoring, and vibration monitoring.

3.3.4 The structural analysis for structures and components shall be conducted before construction monitoring and shall comply with the following requirements:

1 The internal force checking should be calculated according to the fundamental combination of load effects. The comparison between the structure analysis values and the measured strain values shall be calculated according to the characteristic combination of load effects. The deformation checking shall be calculated according to the characteristic combination of load effects.

2 The structural analysis shall consider gravity loads of constant and live. Foundation settlement, temperature effects, wind loads, and wave effects may be taken into account according to the engineering needs.

3 The structural analysis shall be based on the actual construction scheme. If the scheme is adjusted during the construction, the structural analysis of the whole construction shall be updated accordingly. When the assumed calculation parameters are significantly different from the monitoring data in the early stage of construction, the calculation parameters shall be adjusted in time. The calculation results shall be corrected and applied to the next stage of the construction

monitoring.

4 The load parameters and measured parameters of components and materials should be adopted.

5 The structural analysis model shall be checked with the structural design model.

6 The structural analysis shall be combined with the construction scheme, using actual construction process, and consider the intermediate working conditions where risks may occur.

7 The influence of temporary construction supports on structures shall be fully considered.

3.3.5 The precaution values for construction monitoring shall be based on the on the principle of zoning, grading, and staging according to the different safety and quality control goals. Combined with the construction structural analysis results, the corresponding limit requirements and the precaution values of different critical degrees are proposed for the monitored components or joints. The precaution values shall meet the requirements of the relevant current specifications for construction quality acceptance.

3.3.6 The times of construction monitoring shall comply with the following requirements:

1 Each stage of construction process shall be monitored at least once during construction.

2 The times of monitoring shall be adjusted in real time according to the structural stress or deformation rate of the projects, which are guided to design and construct using the monitoring data.

3 The times of monitoring for complex engineering projects shall be determined on the basis of the structural forms, deformation characteristics, monitoring accuracy, and engineering geological conditions, etc.

4 Monitoring shall be carried out for shutdown and rework, respectively.

3.3.7 In case of the following situations, the monitoring times shall be increased:

1 Monitoring data reach or exceed the precaution values.

2 The structures affected by earthquakes, floods, typhoons, blasting, traffic accidents and other abnormal conditions.

3 Abnormal conditions such as deformation cracks or serious sudden cracks that may develop on the structural engineering structure site, the structural parts of the surrounding buildings (structures), and the ground may affect the safety of the project.

3.3.8 Monitoring data shall be processed and analyzed. Critical data should be analyzed and judged in real time, and abnormal data shall be verified and confirmed in time.

3.3.9 Construction monitoring shall be inspected in accordance with the progress of construction.

3.3.10 The procedures for construction monitoring may be implemented according to the flowchart shown in Figure 3.3.10.

3.3.11 The monitoring reports of the construction should be divided into periodic and summary reports. The periodic reports shall be submitted regularly during the monitoring, and the summary reports shall be submitted at the end of the monitoring.

3.3.12 The monitoring reports shall meet the monitoring scheme requirements with complete content, clear conclusions, and smooth writing. The reports shall provide accurate, reliable, and effective monitoring data and conclusions for the performance evaluation of the engineering structures during construction.

3.3.13 The periodic monitoring report shall include the following contents:

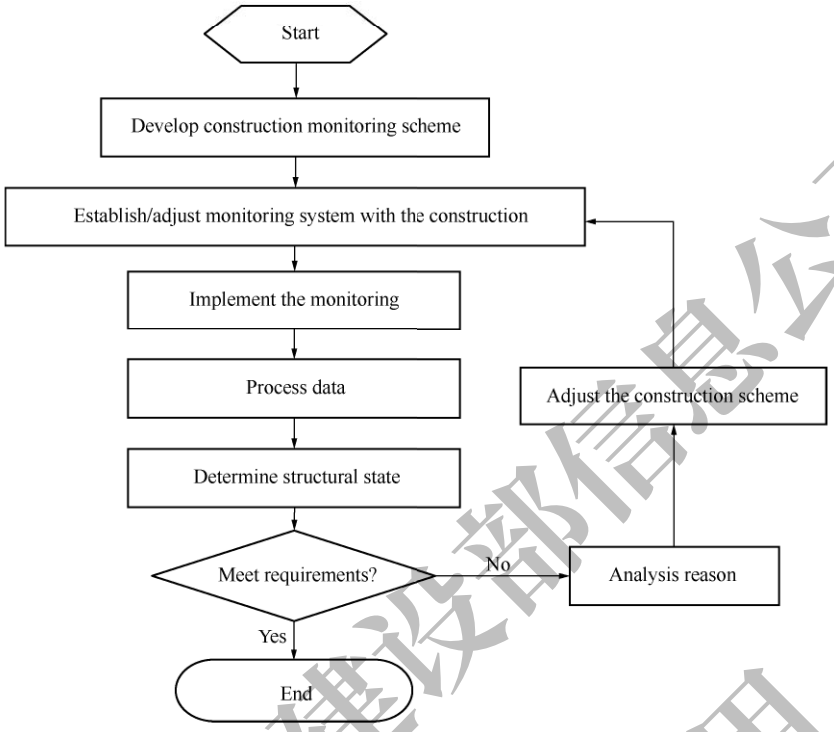

Figure 3.3.10 Flowchart of the construction monitoring

1 Overview of project and construction.

2 Monitoring methods and basis, including technical standards of monitoring basis, monitoring periods and times, monitoring parameters, monitoring equipment used and their main parameters, layout of monitoring points, structural analysis results of construction process and precaution values.

3 Monitoring results, including monitoring results for parameters of each measuring point, comparison with structural analysis results, precaution status and assessment results, changes of measuring points, and records for treatment of abnormal conditions during monitoring.

4 Monitoring conclusions and recommendations.

5 Precaution report, processing results and related attachments.

3.3.14 The summary monitoring report shall reflect the monitoring situations for the entire period, and shall include the main content of the monitoring report in each stage.

3.3.15 The monitoring records shall be completed at the monitoring site or in monitoring system. The recorded data, words and charts shall be true, accurate, clear, and complete, and shall not be altered at will.

3.3.16 The monitoring schemes, monitoring reports, and original records shall be archived. The original documents shall include calculations for structural analysis during the construction, monitoring records and comparative analysis results for structural deformation and strain monitoring, records for treatment of abnormal conditions, precaution reports and treatment results.

3.4 Post Construction Monitoring

3.4.1 Post construction monitoring shall provide technical support for the safe use of structures during service, structural design verification, structural model calibration and correction, structural damage identification, structural maintenance and repair, and the development and application of new methods and technologies.

3.4.2 The items of post construction monitoring may include deformation and crack monitoring, strain monitoring, cable force monitoring, environmental and effects monitoring. The deformation monitoring may include foundation settlement monitoring, vertical and horizontal structural deformation monitoring. The environmental and effects monitoring may include wind field and wind-induced response monitoring, temperature and humidity monitoring, earthquake and seismic response monitoring, traffic monitoring, scouring and corrosion monitoring.

3.4.3 Post construction monitoring should be long-term and real-time.

3.4.4 The structural analyzing model should be updated in the post construction monitoring for important structures, and the updated model shall reflect the current state of the structure.

3.4.5 The precaution for the post construction monitoring shall be based on the structural performance and combined with the long-term data accumulation to put forward limit requirements and different precaution values corresponding to the safety, serviceability, and durability of the structure. The precaution values shall meet the requirements of the current relevant national structural design standards.

3.4.6 The post construction monitoring system shall be able to work continuously, and should have the function of automatically generated monitoring reports.

3.4.7 When the monitoring data is abnormal or alarming, the monitoring system and structures shall be checked or inspected in time.

3.4.8 Periodic inspection and system maintenance for post construction monitoring shall be carried out regularly.

3.4.9 The procedures for post construction monitoring may be implemented according to the flowchart shown in Figure 3.4.9.

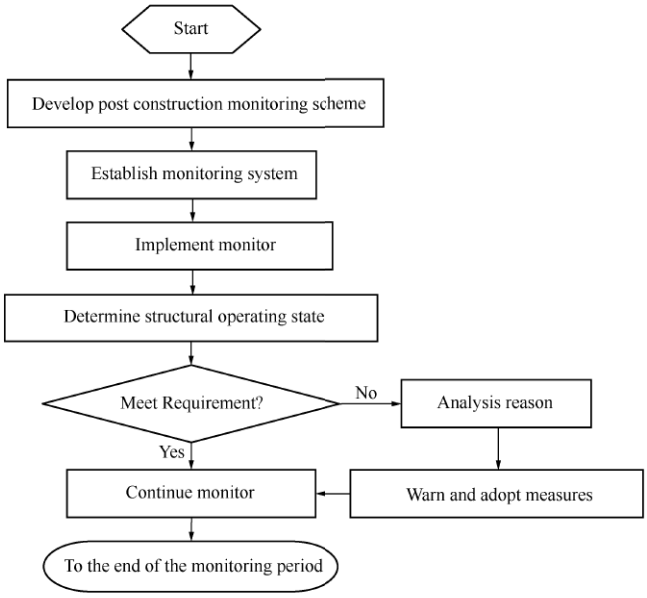

Figure 3.4.9 Flowchart of the post construction monitoring

3.4.10 The reports of the post construction monitoring may be divided into monitoring system reports and monitoring reports. The monitoring system reports shall be submitted at the completion of the monitoring system. The monitoring reports shall be automatically generated by the monitoring system during monitoring.

3.4.11 The monitoring reports shall provide true, reliable, and effective monitoring data and conclusions for the performance evaluation of the engineering structures in use.

3.4.12 The monitoring system reports shall include the project overview, construction process, monitoring methods and basis, monitoring items, and operation guidelines for the monitoring system.

3.4.13 The monitoring reports shall include the following contents:

1 Monitoring results and comparisons, including monitoring results for a defined period of time and comparison with the results of structural analysis, and precaution values.

2 Monitoring conclusions.

3.4.14 Monitoring reports and original records shall be archived.

4 Monitoring Methods

4.1 General Requirements

4.1.1 Monitoring items should include stress and strain, deformation and crack, temperature and humidity, vibration, earthquake and seismic response, wind field and wind-induced response, cable force, and corrosion.

4.1.2 Monitoring parameters can be divided into static and dynamic parameters. The selection of monitoring parameters shall meet the requirements for monitoring, precaution, and evaluation of structural state.

4.2 Stress Monitoring

4.2.1 Resistance strain gauge, vibrating string strain gauge, optical fiber strain gauge and other strain monitoring elements may be selected for stress and strain monitoring.

4.2.2 The strain gauge should be selected according to the monitoring purpose, engineering requirements, sensor technology, and environmental characteristics.

4.2.3 The strain gauge shall comply with the following basic requirements:

1 The span shall be compatible with the measuring range. The accuracy of strain measurement shall be 0.5% of the full span. The monitoring value should be controlled at 30% to 80% of the full span.

2 The strain gauge with large gauge length should be selected for the concrete components. The strain gauge with small gauge length is preferable in area of the stress concentration where strain gradient is large.

3 The strain gauge shall be temperature compensated.

4.2.4 The selection of different types of strain sensors shall comply with the following requirements:

1 The measuring and compensation gauges of resistance strain gauge shall be of the same specification, and shall be protected by shielding insulation.

2 The vibrating string strain gauge shall be calibrated with a matching frequency meter with a resolution shall of not greater than 0.5Hz.

3 The indicators of the optical fiber demodulation system shall comply with the regulations of the measured parameters for the monitored objects.

4 When the equipment composed of displacement sensors is used to monitor the strain, the gauge length error of the sensors shall be ±1.0%, and the minimum index value should not exceed 1.0% of the total strain to be measured.

4.2.5 The installation of strain sensors shall comply with the following requirements:

1 The validity of sensors shall be confirmed one by one to ensure they are working properly.

2 The installation location shall not deviate from the location of the monitored section by greater than 30 mm in all directions, and the installation angle deviation shall not be greater than 2°.

3 The wires or cables of different types of sensors should be led out and protected separately. The sensors without an electronic identification number shall be marked with sensor number on the cable.

4 The installation shall be secure, and should be welded or bolted for long-term monitoring.

5 The equipment shall be inspected in time after installation and used only when it meets the requirements. Any problems found, the equipment shall be dealt with or replaced in time.

6 The sensors shall be debugged, and the static initial values shall be determined after installation.

4.2.6 Strain monitoring shall be synchronized with the time deformation monitoring and real-time monitoring should be adopted.

4.2.7 The data processing of the strain monitoring shall comply with the following requirements:

1 When using resistance strain gauge, the wire resistance shall be corrected for the measured strain by the following equations:

For half-bridge measurement:

$$\varepsilon = \varepsilon'\left(1+\frac{r}{R}\right) \tag{4.2.7-1}$$

For full-bridge measurement:

$$\varepsilon = \varepsilon'\left(1+\frac{2r}{R}\right) \tag{4.2.7-2}$$

where:

ε——corrected strain value;

ε'——uncorrected strain value;

r——wire resistance(Ω);

R——resistance of resistance strain gauge(Ω).

2 The fiber optic strain gauge and vibrating string strain gauge shall be converted according to the calibration coefficient.

4.3 Deformation and Crack Monitoring

4.3.1 Deformation monitoring may be divided into horizontal displacement monitoring, vertical displacement monitoring, three-dimensional displacement monitoring, and other displacement monitoring.

4.3.2 According to the types of monitoring instruments, monitoring methods may be divided into mechanical testing instrument methods, electrical testing instrument methods, optical instrument methods, and satellite locationing system methods.

4.3.3 Monitoring items and methods shall be determined by the deformation characteristics of structures or components.

4.3.4 A datum network shall be established for deformation monitoring, using a plane coordinate system and an elevation system that are consistent with the system used for construction. The local relative deformation monitoring may not establish a datum network, but the influence of the overall structural deformation on the monitoring results shall be considered.

4.3.5 The monitoring of the deformation datum value shall reduce the influence of environmental factors such as temperature.

4.3.6 The deformation monitoring results shall be corrected in combination with the results of environmental and effects monitoring.

4.3.7 The span of deformation monitoring instrument shall be 2 to 3 times the estimated or permissible displacement value of the monitoring point. The accuracy of mechanical testing instrument shall be 1/10 of the estimated displacement of the monitoring point.

4.3.8 The monitoring signs shall be designed according to the characteristics of different engineering structures. The monitoring sign points shall be firm, applicable, and easy to protect.

4.3.9 The foundation pit monitoring shall be carried out in accordance with the relevant requirements of the current national standard GB 50497 *Technical code for monitoring of building excavation engineering*. When optical instrument method and satellite locationing system method are used for deformation monitoring, it shall be carried out in accordance with the relevant requirements of the current national standard GB 50026 *Code for engineering surveying*. The vibration displacement monitoring shall be carried out in accordance with the requirements specified in Section 4.5 of this code.

4.3.10 For structures with large cumulative deformation in construction, the compensation technology shall be adopted to correct the elevation of the engineering structure according to the design requirements, and the final elevation should be consistent with the design elevation. Elevation compensation technology shall be carried out by combining prediction and monitoring.

4.3.11 The times of deformation monitoring shall comply with the following requirements:

1 The times of monitoring should be the same when monitoring items include both horizontal and vertical displacement.

2 Structural monitoring may start from the completion of the foundation pad or foundation slab.

3 The first monitoring shall be carried out in two consecutive independent measurements, the median of which shall be taken as the initial value of deformation measurement.

4 In case of temporary shutdown in the construction process, one measurement shall be carried out at shutdown and rework, respectively. Monitoring may be carried out on a case-by-case basis during the shutdown.

5 The times of monitoring shall be increased when the monitoring data reaches the precaution value, or abnormal deformation occurs.

4.3.12 The three-dimensional displacement may be monitored by optical instrument method, satellite locationing system method, and photography method, depending on the site conditions and accuracy requirements.

4.3.13 Tilt and deflection monitoring shall comply with the following requirements:

1 The selection of tilt monitoring method and related technical requirements shall be carried out in accordance with the relevant requirements of the current national standard GB 50026 *Code for engineering surveying*.

2 The tilt sensor should be used for tilt monitoring of important components. Fixed or portable tilt sensors may be selected according to the monitoring requirements.

3 The times of monitoring shall be determined according to the change rate of tilt or deflection, and should be coordinated with the times of horizontal and vertical displacement monitoring. Additional monitoring or continuous monitoring shall be carried when increased tilt

and deflection is detected.

4.3.14 Crack monitoring should be carried out by means of measurement, observation, detection, and monitoring method independently or in combination with each other.

4.3.15 Crack monitoring parameters include crack length and width . Crack monitoring shall comply with the following requirements:

1 The crack length and the width of large cracks may be measured by steel ruler or mechanical testing instrument. For direct measurement, crack width inspection card and electronic crack observation instrument may be used, and each monitoring point should not be measured less than 3. The minimum scale value of the crack width inspection card should not be greater than 0.05 mm. The resolution of the electronic crack observer shall be greater than 0.02 mm.

2 For the cracks with a width less than 1 mm, the electric measuring instrument method may be used. The resolution of the instrument shall not be greater than 0.01 mm.

3 Structural crack monitoring sensors may be used to monitor changes in displacement at two points on both sides of the crack, including vibrating wire-type crack gauge, strain-type crack gauge or optical fiber-type displacement gauge. The span of the sensors shall be greater than the warning width of the crack, and the measurement direction of the sensor shall be perpendicular to the crack strike.

4 It is advisable to monitor the change in width of cracks in structures that have cracked, and monitor the change in strain of structures that have not yet cracked.

4.4 Temperature and Humidity Monitoring

4.4.1 Temperature and humidity monitoring may include environmental and component temperature monitoring and environmental humidity monitoring.

4.4.2 Temperature monitoring of mass concrete shall be carried out according to the relevant requirements of the current national standard GB 50496 *Code for construction of mass concrete*.

4.4.3 The temperature monitoring accuracy should be ± 0.5℃. The humidity monitoring accuracy should be ± 2% RH.

4.4.4 Temperature monitoring of environment and components shall comply with the following requirements:

1 The temperature monitoring points shall be arranged at the locations with larger changes in temperature gradient. The arrangement of temperature monitoring points should be symmetrical and uniform, and shall reflect the law of change in the vertical and horizontal temperature fields of the structure.

2 1 to 3 points shall be installed in the relatively independent spaces, with additional measurement points being advisable for larger areas or spans, and for areas where the stresses and deformations of structural components are strongly influenced by the environmental temperature.

3 The atmospheric thermometer may be installed on the surface of the structure together with an anemometer, and shall be directly placed in the atmosphere to obtain the representative temperature value.

4 When monitoring the temperature field distribution of the whole structure and the relationship between the structure temperature of different parts and the environmental temperature, the monitoring points should cover the entire structure area.

5 The temperature sensor with large measuring span, high accuracy, good linearity and stability should be adopted.

6 The times of monitoring should be consistent with that of structural stress monitoring and deformation monitoring.

7 For long-term temperature monitoring, the results shall include daily average temperature, daily maximum temperature, and daily minimum temperature. For structural temperature distribution monitoring, the isothermal maps should be drawn.

4.4.5 The environmental humidity monitoring shall be in accordance with the following requirements:

1 The humidity should be expressed by relative humidity, and the monitoring range of hygrometer shall be 12% RH to 99% RH.

2 Humidity sensors are required short response time, small temperature coefficient, good stability, and low humidity hysteresis effect.

3 Atmospheric hygrometers should be installed together with thermometers and anemometers, they should be arranged in the part of the structure where humidity changes a lot and has a big impact on the durability of the structure.

4 For long-term humidity monitoring, the monitoring results shall include the daily average humidity, daily maximum humidity, and daily minimum humidity.

4.5 Vibration Monitoring

4.5.1 Vibration monitoring shall include vibration response monitoring and vibration excitation monitoring. The monitoring parameters are acceleration, velocity, displacement, and strain.

4.5.2 Vibration monitoring methods may be divided into relative and absolute measurement methods.

4.5.3 The relative measurement method to monitor structural vibration displacement shall comply with the following requirements:

1 There shall be a fixed reference point relative to the measured engineering structure.

2 The monitored object shall be firmly set up with measuring point markings such as targets and reflectors.

3 Measuring instruments may choose automatic tracking total station, laser vibrometer and image recognition instrument.

4.5.4 The absolute measurement method should use inertial sensors with the space immovable points as the reference coordinate, to measure the absolute vibration displacement, velocity, and acceleration of engineering structures. This method shall comply with the following requirements:

1 Acceleration measurement may choose to use force balance acceleration sensor, electric velocity pendulum acceleration sensor, ICP piezoelectric acceleration sensor, and piezoresistive acceleration sensor. Velocity measurement may choose to use electric displacement pendulum velocity sensor, also may obtain velocity value by integrating the output of acceleration sensor in signal amplifier. Displacement measurement may choose to use electric displacement pendulum velocity sensor output in signal amplifier to integrate to obtain the displacement value.

2 The vibration displacement, velocity, and acceleration of the structure under vibration loads shall be measured in a certain period of time.

4.5.5 Before vibration monitoring, structural dynamic characteristics test should be carried out.

4.5.6 For dynamic response monitoring, the monitoring points shall be selected at the vibration-sensitive positions of engineering structures. For dynamic characteristic analysis, the vibration monitoring points should be arranged at the key points of vibration mode to be identified, and should cover the whole structure, or may be added to local parts of the structure according to the demand. When the number of monitoring points is large, the arrangement may be optimized.

4.5.7 The acquisition and processing of vibration monitoring data shall comply with the following requirements:

1 The sampling frequency shall be selected according to different structural forms and monitoring purposes.

2 Filter shall be selected according to monitoring parameters.

3 The appropriate window function shall be selected to process the data.

4.5.8 The span of the dynamic strain monitoring equipment shall not be less than 2 to 3 times the estimated measurement value, and the resolution of monitoring equipment shall meet the minimum strain measurement requirements to ensure a high signal-to-noise ratio. The accuracy of vibration displacement, velocity and acceleration monitoring shall be determined according to the frequency and amplitude of the vibration, the purpose of the monitoring and other factors.

4.5.9 Dynamic strain monitoring shall comply with the following requirements:

1 Dynamic strain monitoring may be carried out using resistance strain gauges or optical fiber strain gauges.

2 Dynamic monitoring equipment shall be statically calibrated before use. For dynamic strain monitoring with high frequency, dynamic calibration should be added.

4.6 Earthquake and Seismic Response Monitoring

4.6.1 The following structures shall be monitored for seismic response monitoring:

1 Large public buildings exceeding 160 m, 120 m, and 80 m in height at the fortification intensities of 7, 8, and 9, respectively.

2 Extra-large bridges of particular importance.

3 Structures with design requirements or special requirements.

4.6.2 The main monitoring parameters are ground motion and seismic response acceleration, and other parameters such as forces and displacements may also be monitored according to engineering requirements.

4.6.3 Structural ground motion and seismic response monitoring shall comply with the following requirements:

1 The monitoring scheme shall include the type of monitoring system, the layout of monitoring points, the technical indicators of the instruments, and the requirements for installation and management and maintenance of monitoring equipment.

2 The monitoring points shall be arranged according to the fortification intensity, anti-seismic classification, structural importance, structural type, and topographical and geological conditions.

3 The monitoring system may be arranged in an integrated manner with wind, impact, traffic and other vibration responses, and shall be combined with the seismic damage inspection facilities.

4 The layout of monitoring points shall be able to reflect the ground motion and the seismic response of superstructure.

5 The main technical indicators of monitoring equipment may be implemented in accordance with Appendix A of this code.

4.7 Wind Field and Wind-induced Response Monitoring

4.7.1 Wind field and wind-induced response monitoring should be carried out for wind-sensitive structures.

4.7.2 The monitoring parameters of wind field and wind-induced response shall include wind pressure, wind speed, wind direction, wind-induced vibration. Wind attack angle should be included for bridge structures.

4.7.3 Wind pressure monitoring shall comply with the following requirements:

1 The wind pressure monitoring should use a pressure sensor with a micro pressure range and measurable positive and negative pressure, or a special blast wind pressure gauge. The monitoring parameter is air pressure.

2 The wind pressure sensor shall be installed with no influence on the facade of engineering structures, and shall be protected effectively. The corresponding data acquisition equipment shall have a time compensation function.

3 The wind pressure monitoring points should be determined according to the data of wind tunnel tests and the results of structural analysis. In the absence of wind tunnel test data, the monitoring points may be arranged according to the characteristics of wind load distribution and the results of structural analysis.

4 The contour figure of the wind pressure distribution on the monitored surface should be provided for the project of surface wind pressure monitoring.

4.7.4 The range of wind pressure gauge shall meet the requirements of the wind field in the structural design, and adjustable range wind pressure gauge may be selected. The accuracy of the wind pressure gauge shall be $\pm$ 0.4% of the full range, and shall not be less than 10 Pa, the nonlinearity shall be within $\pm$ 0.1% of the full range, the response time shall be less than 200 ms. The range of anemometer shall be larger than the design wind speed, the wind speed monitoring accuracy shall be 0.1 m/s, the wind direction monitoring accuracy should be 3°.

4.7.5 Wind speed and direction monitoring shall comply with the following requirements:

1 Computational fluid dynamics numerical simulation or wind tunnel test should be adopted to analyze the wind-affected area in the structure.

2 Mechanical and ultrasonic anemometers should be set in pairs.

3 The anemometer shall be installed outside the zone affected by winds flow around the structure.

4 The anemometer with high sampling frequency should be adopted, the frequency shall not be less than 10 Hz.

5 The monitoring results shall include fluctuation wind speed, average wind speed and wind direction.

4.7.6 Wind-induced response monitoring shall comply with the following requirements:

1 The wind-induced response monitoring shall be implemented in different directions. During

on-site monitoring, sensors shall be arranged according to the monitoring purposes and contents.

2 Various sensors to measure different physical quantities may be arranged at the monitoring points of wind-induced response.

3 Based on the previous dynamic analysis, the strain sensors shall be set where the stress or strain is large and the location of stiffness mutation which reflects the wind-induced response characteristics of the structure.

4 The displacement sensors should be arranged in the structural parts where displacement limits are required. The results recorded by displacement sensors shall be compared with the displacement limit.

4.8 Other Items Monitoring

Ⅰ Cable Force Monitoring

4.8.1 Cable force monitoring shall comply with the following requirements:

1 The monitoring methods may include the pressure gauge measuring jack oil pressure method, the pressure sensor measuring method, and the vibration frequency method.

2 The accuracy of the pressure gauge measuring jack oil pressure method and the vibration frequency method should be 5.0% of the full range. The accuracy of the pressure sensor method should be 3.0% of the full range.

3 The frequency response range of the acceleration sensor for monitoring the cable force by the vibration frequency method shall cover the fundamental frequency of the cable vibration. When the measured frequency is used to calculate the cable force, the cable and the elastic support structure at both ends of the cable shall be modeled and analyzed together.

4 The cable force monitoring system should be designed to coordinate with the internal pipelines and communication equipment.

5 The precaution values of rope force monitoring shall be determined in combination with the engineering design limits, structural design requirements, and control requirements of monitored object.

4.8.2 Cable force monitoring should comply with the following requirements:

1 It shall ensure that the anchor cable meter is installed concentric.

2 When monitoring by the vibration frequency method, the sensor shall be installed away from the lower anchor point of the cable and close to the mid-point of the cable, and the acceleration sensor for measuring the cable force shall be positioned at a distance greater than 0.17 times the cable length from the end of the cable.

3 Daily monitoring should avoid adverse weather effects, and should be carried out at the moment of minimum sunshine temperature difference in a day, and the temperature and wind speed at that time should also be recorded.

Ⅱ Corrosion Monitoring

4.8.3 Corrosion monitoring may be carried out in areas with high chloride ion content or affected by corrosion, or where there are design requirements.

4.8.4 Corrosion monitoring shall comply with the following requirements:

1 Corrosion monitoring scheme shall include corrosion monitoring method, monitoring parameters, monitoring positions, and monitoring frequency.

2 Electrochemical method should be used for corrosion monitoring. Electrochemical monitoring method includes current monitoring, potential monitoring, or both current and potential monitoring.

3 Corrosion monitoring parameters may include structural corrosion potential, corrosion current and concrete temperature.

4 The positions of corrosion monitoring shall be determined according to the monitoring purposes, combined with structural characteristics, special parts, structural connection positions, different positions of corrosion rates, and other factors. The monitoring points should be arranged at typical areas where forces and corrosive environmental loads act respectively and typical nodes under corrosive environmental loads.

5 The corrosion sensor shall be able to distinguish the corrosion types and measure the corrosion rate. It may be arranged in two ways: external and embedded. For new structures, the sensors may be buried in the predetermined positions during the construction. For existing structures, the sensors may be placed at adjacent position of the corresponding monitoring points in the structure.

4.9 Patrol Inspection and System Maintenance

4.9.1 Patrol inspection shall include deformation and cracking of structures and components within the monitoring, layout of monitoring points and monitoring equipment or other contents determined in combination with local experience.

4.9.2 System maintenance shall ensure the normal operation of the monitoring system and update the system.

4.9.3 Patrol inspection shall comply with the following requirements:

1 The patrol inspection is mainly based on visual inspection, and may be supplemented by hammer, brazier, ruler, magnifying glass and other equipments, as well as camera and photography.

2 When precaution signals are triggered, patrol inspection shall be strengthened; when any abnormal or dangerous situation is found, the relevant units shall be informed in time.

3 The focus of the patrol inspection is to confirm that the locations of the reference points and monitoring points have not changed and are in good condition, and to confirm that the monitoring equipment is operating normally and in a protected state.

4 The patrol inspection should be carried out by people who are familiar with project, and are relatively fixed.

5 The patrol inspection shall be recorded.

5 High-rise Buildings and Structures

5.1 General Requirements

5.1.1 In addition to the requirements of the design documents, high-rise buildings and structures with a height of 250 m and above or with significant compression deformation of vertical structural components shall be monitored during construction, and high-rise buildings and structures with a height of 350 m and above shall be monitored during use.

5.1.2 Except for the high-rise buildings and structures that shall be monitored during construction as required by the design documents or otherwise specified, high-rise buildings and structures should be monitored during construction when any of the following conditions are met:

1 High-rise buildings and structures where large temporary support structures are added during construction.

2 High-rise buildings and structures subject to complex overall or partial structural forces during construction.

3 Mass concrete structures that are significantly affected by environmental factors such as temperature changes, concrete shrinkage, creep, and sunlight, as well as structures containing extra-long components and special cross-sections.

4 High-rise buildings and structures whose construction scheme has a significant influence on the distribution of internal forces in the structure.

5 High-rise buildings and structures with strict requirements for settlement and configuration.

6 High-rise buildings and structures affected by adjacent construction operations.

5.1.3 Except for the high-rise buildings and structures that shall be monitored during use according to the requirements of the design documents or otherwise specified, high-rise buildings and structures should be monitored during use when any of the following conditions are met:

1 High-rise buildings and structures with a height of 300 m and above.

2 High-rise buildings and structures with large difference between the final configuration and design target configuration are caused by the construction process.

3 High-rise buildings and structures with seismic isolation systems.

4 Other High-rise buildings and structures that are sensitive to structural deformation.

5.1.4 Excavation engineering with depth greater than or equal to 5 m or less than 5 m but with more complex geological conditions and surrounding environment on site and other excavation engineering requiring monitoring shall be implemented. The monitoring implementation shall be carried out in accordance with the requirements of the current national standards GB 50497 *Technical code for monitoring of building excavation engineering*.

5.1.5 Monitoring items during construction of high-rise buildings and structures shall be selected according to Table 5.1.5 based on the project characteristics.

5.1.6 Monitoring items during use of high-rise building and structure shall be selected according to Table 5.1.6 based on the structural characteristics.

Table 5.1.5 Monitoring items during construction

	Monitoring of foundation settlement	Monitoring of deformation		Monitoring of strain	Monitoring environmental and effects			Monitoring of excavation support
		Vertical	Horizontal		Wind	Temperature and humidity	Vibration	
High-rise buildings	★	★	★	★	▲	▲	▲	▲
High-rise structures	★	★	★	★	▲	▲	▲	▲

Note: ★ item shall be monitored, ▲ item should be monitored.

Table 5.1.6 Monitoring items during use

	Monitoring of foundation settlement	Monitoring of deformation		Monitoring of strain	Monitoring of environmental and effects		
		Vertical	Horizontal		Wind	Temperature and humidity	Seismic
High-rise buildings	▲	▲	★	▲	▲	▲	★
High-rise structures	▲	▲	★	▲	▲	▲	★

Note: ★ item shall be monitored, ▲ item should be monitored.

5.1.7 The monitoring of high-rise buildings and structures shall be combined with structural analysis. The structural analysis shall comply with the following requirements:

1 The structural analysis for the construction process of outrigger trusses and suspension components shall be carried out and reflect the sequence of design, actual construction, and the connection mode of nodes truly.

2 The structural analysis shall take into account the influence of the stiffness changes such as the installation and stiffness generation of structural components, and the setting and removal of supports as required by the accuracy of engineering. The influence of geometric nonlinearity and shrinkage and creep of concrete materials should be considered.

3 In the structural analysis, the settlement deformation of the entire building, the cumulative deformation of the floors, and the deformation and internal forces in critical areas shall be predicted according to the actual construction scheme, so as to provide guidance for the adjustment of the construction and monitoring scheme, and to ensure the horizontality and elevation of the completed structure meet the design requirements.

4 The stiffness of the connecting beams in frame-shear wall or shear wall structures should not be reduced.

5.2 Construction Monitoring

Ⅰ Settlement Monitoring

5.2.1 In the settlement monitoring, the working base point shall be introduced and monitored first, and then the settlement monitoring points shall be arranged in different zones. The settlement monitoring points should be consistent with the horizontal displacement monitoring points.

Ⅱ Deformation Monitoring

5.2.2 Deformation monitoring during construction may include axis monitoring, elevation monitoring, relative deformation monitoring of connecting components between building shapes, and three-dimensional spatial deformation monitoring at key structural points.

5.2.3 Sunlight deformation monitoring should be carried out for structures with a construction period of more than one year or for structures in areas with large temperature difference between day and night.

5.2.4 Deformation monitoring points shall be arranged in areas with large structural deformation or sensitive deformation reaction.

5.2.5 During the sliding form construction, the horizontality and verticality of the sliding-form construction shall be monitored.

5.2.6 During the construction of cantilever and conjoined structures, the construction position and configuration of the cantilever stage shall be monitored.

5.2.7 The deformation monitoring times of high-rise buildings and structures shall comply with the following requirements in addition to the requirements of Article 4.3.11 of this code:

1 Monitoring is performed once for each additional floor during the underground construction.

2 Monitoring is performed once for each additional 1 to 5 floors during the above-ground structure construction.

3 During the construction period of key floors or parts, the monitoring times shall not be less than twice that of the daily monitoring.

4 For high-rise structures, except for the important stressed intersections, the corresponding structural intersections may be selected at certain height intervals for monitoring. Monitoring shall be performed at least once when the weight reaches 50% and 100% of the total weight.

Ⅲ Strain Monitoring

5.2.8 Strain monitoring shall be carried out during the main construction process of load change and boundary condition change.

5.2.9 The monitoring points shall be arranged in the characteristic position components, transition position components, complex stress components, and components with large changes in internal force during construction.

5.2.10 The arrangement of testing sections and monitoring points shall reflect the actual stress conditions of the corresponding components. For post-installed delayed temporary supports components, monitoring points shall reflect the changes in the stress conditions of the components during construction.

5.2.11 For facilities that generate large temporary loads on the structure during construction, strain monitoring should be carried out on the corresponding stressed parts and on the facility itself.

5.2.12 For the main beam of the tower crane support frame structure and the embedded part structure of the corbel, the stress monitoring points and monitoring schemes of the main beam of

the support frame and the embedded parts of the corbel shall be determined according to the stress characteristics of the tower crane support frame structure and the site construction conditions.

5.2.13 The monitoring times of strain shall comply with the requirements of Article 4.2.6 of this code, in addition to the following requirements:

1 For conjoined, post-installed delay components or structures with temporary supports, the times of monitoring shall be increased for components with relatively large stress changes before and after the conjoined components are enclosed, before and after the delay components are fixed and before and after the supports are removed.

2 It shall comply with the requirements of paragraphs 2 to 4 of Article 5.2.7 of this code, and other paragraphs of Article 5.2.7 of this code may be reffered to the implementation.

Ⅳ Wind Field and Wind-induced Response Monitoring

5.2.14 When the average wind speed and direction are obtained, and it is not easy to install a monitoring mast on the top of the structure during construction, the anemometer may be installed on the top of the construction tower crane higher than the top of the structure.

5.3 Post Construction Monitoring

Ⅰ Deformation Monitoring

5.3.1 The following locations may be selected for the deformation monitoring points:

1 Characteristic component affecting structural safety, key points with significant deformation, corners of load-bearing wall columns, large engineering structure section transformations. Main wall corners, 2 to 3 column foundations at intervals, top and bottom of settlement joints, both sides of the engineering structures cracks, structural mutations, and large changes in the slope of major components.

2 The connecting components between the structural shapes and the two sides of the boundary between different structures.

3 There should be no less than 3 monitoring points on the wall or column in the middle part of the facade of the structure, and on one side of the wall.

5.3.2 Spires, lightning rods, and edges of cylinders (spheres) with obvious features may be selected as the deformation monitoring points for the high-rise structures.

5.3.3 For high-rise buildings and structures that are sensitive to seasonal effects and temperature effects under uneven sunlight, sunlight deformation monitoring shall be carried out.

5.3.4 The settlement and deformation of high-rise buildings and structures should be monitored at least once every 3 months in the first year after construction, at least 2-3 times in the second year, and at least once a year after the third year.

Ⅱ Strain Monitoring

5.3.5 The strain monitoring points shall be selected for the components with large stress and the unfavorable stress. The monitoring points should not be too scattered, and should obey the principle of zonal concentration.

5.3.6 The following important parts or components should be subject to strain monitoring:

1 The transition parts and the adjacent upper and lower floors.

2 The rods and adjacent parts of the outrigger truss with greater stress.

3 Structural irregular locations and adjacent parts such as giant columns, giant diagonal braces, out-of-plane retraction of vertical members, and discontinuous areas of vertical stiffness distribution.

4 Other important parts and components.

5.3.7 For structures that have experienced major quality accidents during construction or post construction and have been remedied and confirmed to be safe, the strain conditions of the remedial parts should be monitored.

Ⅲ Wind Field and Wind-induced Response Monitoring

5.3.8 For high-rise buildings and structures that have been subjected to wind tunnel tests, monitoring points should be arranged according to the results of wind tunnel tests. For high-rise buildings and structures without wind tunnel tests, monitoring points should be arranged in the free field and components and node positions that are sensitive to wind-induced responses, and should coordinate with the arrangement of monitoring points for ground motion and seismic response monitoring.

5.3.9 The monitoring points shall be set at the top floor of the engineering structure, the ground floor, the place where the structural stiffness and mass change abruptly, and the stiffness center or geometric center of key floors with high safety requirements. When analyzing the dynamic characteristics, the vibration monitoring points shall be arranged at different heights of the structure, and should be at the mass center of each section of the structure, and shall avoid the nodes of the vibration mode.

5.3.10 The anemometer at the top of high-rise buildings and structures should be 1 m higher than the top and within the coverage of the lightning rod. The environmental wind speed monitoring should be installed in a relatively open field about 100 m～200 m away from the structure, and 10 m above the ground.

5.3.11 When there are verification requirements for wind-sensitive buildings (structures), the wind pressure distribution on the surface of the buildings (structures) may be monitored.

5.3.12 Monitoring points should be arranged in the comfort control area to monitor the corresponding control parameters.

Ⅳ Earthquake and Seismic Response Monitoring

5.3.13 Earthquake and seismic response monitoring points shall be arranged on the bottom of the structural basement, the top of the structural top floor, and at least two intermediate floors. It shall be combined with the structural vibration monitoring points to determine the location of the monitoring points.

5.3.14 The monitoring points for translational vibration monitoring should be arranged at the stiffness center of the building.

5.3.15 The monitoring points for torsional vibration monitoring should be arranged at the point of maximum rotation around the edge of the structure.

5.3.16 For high-rise buildings and structures that have been tested by shaking table model, the

monitoring points may be arranged according to the results of the shaking table model test.

V Temperature and Humidity Monitoring

5.3.17 For the structural temperature and humidity monitoring, the monitoring points may be arranged in the specified structure alone or in combination with the strain monitoring points.

5.3.18 For the monitoring of structural gradient temperature, monitoring points should be arranged along the height of the structure on the surface exposed to direct sunlight, the opposite structure back and the inside the structure. There shall be no less than three monitoring points on the same horizontal plane of the structure.

5.3.19 For environmental temperature and humidity monitoring, the temperature or humidity sensor should be arranged in an air-circulating louver box at a height of 1.5 m from the ground or floor.

5.3.20 For temperature monitoring in the structure, the monitoring points may be arranged on the structural inner wall, which is convenient for repair and maintenance. It should be evenly distributed in diagonal or plum blossom style, and shall avoid doors and windows vents.

6 Long-span Spatial Structures

6.1 General Requirements

6.1.1 Except for the long-span spatial structures that are required to be monitored during construction by design documents or other regulations, the long-span spatial structures shall be monitored during construction when one of the following conditions is met:

1 Grid frame and multi-layer reticulated shell steel structures or cable-membrane structures with spans greater than 100 m.

2 Single-layer reticulated shell structures with a span greater than 50 m.

3 Long-span composite structures with a single-span greater than 30 m.

4 Steel structures with cantilevered length greater than 30 m.

5 Large-span spatial structures that are affected by the construction method or sequence, the structural force state or the internal force or configuration of some members are significantly different from the forming loading analysis results of the one-time forming overall structure.

6.1.2 Super-high, overweight, and long-span formwork support systems with a height greater than 8 m or a span greater than 18 m, a total construction load greater than 10 kN/m^2 and a concentrated line load greater than 15 kN/m shall be monitored.

6.1.3 Except for long-span spatial structures that are required to be monitored during post construction by design documents or other regulations, the long-span spatial structures shall be monitored when one of the following conditions is met:

1 Grid frame and multi-layer reticulated shell steel structures with a span greater than 120 m.

2 Single-layer reticulated shell structures with a span greater than 60 m.

3 Steel structures with cantilevered length greater than 40 m.

6.1.4 The monitoring items during construction of long-span spatial structure shall be selected in accordance with Table 6.1.4 based on the engineering characteristics. The important support or tire frame that affect the structural construction safety may be monitored according to the monitoring requirements of the structural system.

6.1.5 The monitoring items during the post construction of long-span spatial structures shall be selected in accordance with Table 6.1.5 based on the structural characteristics.

Table 6.1.4 Monitoring items during construction

	Foundation settlement monitoring	Deformation monitoring		Strain Monitoring	Environmental and effects monitoring			Bearing displacement monitoring
		Vertical	Horizontal		Wind	Temperature	Vibration	
Grid structures	▲	★	○	▲	○	▲	○	○
Reticulated shell structures	▲	★	○	▲	○	▲	○	★
Suspended cable structures	▲	★	○	★	○	▲	○	▲

Table 6.1.4(Continued)

	Foundation settlement monitoring	Deformation monitoring		Strain Monitoring	Environmental and effects monitoring			Bearing displacement monitoring
		Vertical	Horizontal		Wind	Temperature	Vibration	
Membrane structures	▲	★	○	★	○	▲	○	○
Cantilever structures	▲	★	○	▲	○	▲	○	○
Temporary supports	○	★	○	★	○	○	○	
Special structures	▲	▲	○	▲	○	▲	○	○

Note: 1. ★ item shall be monitored, ▲ item should be monitored, ○ item may be monitored, item not to be monitored.

2. Special structure refers to the structure type other than the above structures.

Table 6.1.5 Monitoring items during post construction

	Foundation settlement monitoring	Deformation monitoring		Strain Monitoring	Environmental and effects monitoring			Bearing displacement monitoring
		Vertical	Horizontal		Wind	Temperature	Vibration	
Grid structures	▲	★	○	▲	○	▲	○	○
Reticulated shell structures	▲	★	○	▲	○	▲	○	▲
Suspended cable structures	▲	★	○	▲	○	▲	○	▲
Membrane structures	▲	★	○	▲	○	▲	○	○
Cantilever structures	▲	★	○	▲	○	▲	○	○
Temporary supports	▲	★	○	▲	○	▲	○	○
Special structures	▲	★	○	▲	○	▲	○	○

Note: 1. ★ item shall be monitored, ▲ item should be monitored, ○ item may be monitored.

2. Special structure refers to the structure type other than the above structures.

6.2 Construction Monitoring

Ⅰ Foundation Settlement Monitoring

6.2.1 During the unloading of super static structures, the foundation settlement shall be monitored. The foundation settlement monitoring of long-span spatial structures may be carried out in accordance with the provisions in Article 5.2.1 of this Code.

Ⅱ Deformation Monitoring

6.2.2 Deformation monitoring during construction may include component deflection, bearing center axis offset, highest and lowest bearing height difference, adjacent bearing height difference, axis of member, rod axis component verticality, and tilting deformation monitoring.

6.2.3 After the space structure is installed, when monitoring the deflection value of the main span, the location of the monitoring point may be determined by the design unit. When there is no requirement in the design, the mid-span deflection shall be monitored for spans of 24 m or less, the mid-span and quarter-point deflections in the span direction shall be monitored for spans greater than 24 m.

6.2.4 During the monitoring of the membrane structures, the spatial coordinates of the control points on the membrane surface shall be tracked and monitored. The height difference of the control points should not be greater than 1/600 of the vector height of the membrane structure at this point, and shall not be greater than 20 mm. The horizontal difference shall not be greater than 1/300 of the vector height of the membrane structure at this point, and shall not be greater than 40 mm.

6.2.5 In the hoisting of rod, the height difference of four corners of spatial structure shall be monitored, and the lifting height difference shall not be greater than 1/400 of the distance between lifting points, and should not be greater than 100 mm, or determined by checking calculations.

6.2.6 During the removal of temporary support of long-span spatial structure, the deformation and stress of the key points of the structure shall be monitored.

6.2.7 During the construction of structural sliding, deformation, stress and sliding synchronization of structural key points shall be monitored.

6.2.8 The distance between the bearing, mid-span and inter-span measuring points of the long-span spatial structure should not be greater than 30 m, and should not be less than 5 points for the vertical displacement monitoring.

6.2.9 The monitoring times of deformation monitoring shall comply with the requirements specified in Article 4.3.11 of this Code, it shall be no less than once when the weight changes by 50% and 100% during hoisting and unloading.

Ⅲ Strain Monitoring

6.2.10 In the process of construction and installation, stress monitoring shall be selected in key stress parts, continuously collect monitoring signals, and compare the measured results with the calculated results in time. Early warning shall be given when the monitoring results or values are inconsistent with the structural analysis.

6.2.11 The monitoring of structure unloading construction process shall comply with the requirements specified in Article 6.2.6 of this Code, in additional to each step after unloading in place first 5 min ～ 10 min stationary, and then collect data. When the monitoring value exceeds the warning value, the alarm shall be given in time.

6.2.12 When monitoring the surface pretension of the membrane structure, the monitoring stage shall be determined according to the construction procedure, and each membrane surface parts shall have representative monitoring points, which shall be evenly distributed.

6.2.13 The monitoring points for cable force monitoring shall be representative, and evenly distributed. There should be contrasting monitoring points at different locations of a single cable or steel tie rod, the change of cable force at different locations of the same cable may be monitored. Horizontal cables, vertical cables, tension cables and auxiliary cables shall be arranged with monitoring points.

6.2.14 The monitoring times of strain monitoring shall comply with the requirements specified in Article 4.2.6 of this Code, and it shall be increased when hoisting and unloading monitoring.

6.3 Post Construction Monitoring

Ⅰ Deformation Monitoring

6.3.1 The arrangement of monitoring points for deformation monitoring during post construction shall be selected according to Table 6.3.1.

Table 6.3.1 The layout of monitoring points during post construction

	Grid structures, reticulated shell structures, cable structures, membrane structures, special structures	Cantilever structures
Vertical	Mid-span	Cantilever end eaves
Horizontal	Bearing, end	—

Ⅱ Strain Monitoring

6.3.2 Strain monitoring should be carried out for key bearings and main components under stress during post construction. Strain monitoring should be carried out at the root of the cantilever end of super-large cantilever structures or the parts with greater stress.

6.3.3 The cable force shall be monitored regularly during the service period of the cable structure. When the positive or negative deviation between the cable force and the design value is greater than 10%, an early warning shall be given in time and the cable force shall be adjusted or compensated.

Ⅲ Wind Field and Wind-induced Response Monitoring

6.3.4 When monitoring the wind field and wind-induced response of the main membrane surface of the membrane structures, the monitoring area should be divided into the main monitoring area of wind pressure wind vibration and wind pressure and the auxiliary monitoring area of wind pressure. The monitoring items are membrane surface vibration and wind pressure on the upper and lower surfaces.

7 Bridge Structures

7.1 General Requirements

7.1.1 In addition to the bridge structures required by the design documents or other requirements that shall be monitored during construction, bridge structures shall be monitored during construction when one of the following conditions is met:

1 Long-span bridges with a single-hole span greater than 150 m.

2 Bridges with additional large temporary structures.

3 Bridges with complex overall or partial structural stress.

4 Mass concrete structures, large-scale prefabricated components and bridge structures with special sections that are significantly affected by environmental factors such as temperature change, concrete shrinkage, creep, and sunlight.

5 Important bridge structures with system conversion.

6 Bridge structures with strict requirements on settlement and deformation.

7.1.2 For particularly important large bridge, monitoring shall be carried out during post construction.

7.1.3 In addition to the bridge structures specified in Article 7.1.2 of this Code, required by the design documents or other requirements that shall be monitored during post construction, the bridge structure should be monitored during post construction when one of the following conditions is met:

1 Beam bridges with a main span greater than 150 m.

2 Cable-stayed bridges with a main span greater than 300 m.

3 Suspension bridges with a main span greater than 500 m.

4 Arch bridges with a main span greater than 200 m.

5 Other bridge structures in complex environments or with special structures.

7.1.4 Important large-scale temporary facilities shall be monitored during the bridge construction, and the monitoring items shall be selected according to Table 7.1.4 based on the engineering characteristics.

Table 7.1.4 Monitoring items during construction

	Foundation settlement monitoring	Deformation Monitoring		Strain Monitoring	Environmental and effects monitoring		
		Vertical	Horizontal		Wind	Temperature	Vibration
Beam bridges	★	★	○	★	○	★	○
Arch bridges	★	★	▲	★	○	★	○
Cable-stayed bridges	★	★	▲	★	★	★	○
Suspension bridges	★	★	▲	★	★	★	○

Note: 1 ★ item shall be monitored, ▲ item should be monitored, ○ item may be monitored.

2 The horizontal displacement of the arch foot of the thrust arch bridge shall be set as the "item shall be monitored".

7.1.5 The monitoring items during post construction of the bridge structures shall be selected in accordance with Table 7.1.5 based on the structural characteristics.

Table 7.1.5 Monitoring items during post construction

	Foundation settlement monitoring	Deformation monitoring		Strain Monitoring	Environmental and effects monitoring			Vehicle load	Dynamic response	Bearing reaction and displacement
		Vertical	Horizontal		Wind	Temperature and humidity	Seismic			
Beam bridges	▲	★	○	★	○	★	▲	★	▲	▲
Arch bridges	▲	★	▲	★	○	★	▲	★	▲	▲
Cable-stayed bridges	▲	★	▲	★	★	★	▲	★	▲	▲
Suspension bridges	▲	★	▲	★	★	★	▲	★	▲	▲

Note: 1 ★ item shall be monitored, ▲ item should be monitored, ○ item may be monitored.

2 Vehicle load refers to traffic monitoring.

7.1.6 The monitoring requirements of different types of bridges during the post construction shall comply with the requirements specified in Appendix B of this Code.

7.2 Construction Monitoring

Ⅰ Foundation Settlement Monitoring

7.2.1 The pier and abutment of continuous beam bridge, the arch foot of arch bridge, the pier and pylon of cable-stayed bridge or suspension bridge, and the pier and abutment of all types of high-speed railway bridges shall be monitored for settlement during construction.

7.2.2 The settlement monitoring shall reflect the change of load and load action, and the transformation of the structural system.

Ⅱ Deformation Monitoring

7.2.3 Deformation monitoring during construction may include axis monitoring, deflection monitoring, and tilt deformation monitoring.

7.2.4 Horizontality and verticality monitoring shall be carried out for the construction of cable towers with height greater than 30 m and piers with height greater than 15 m.

7.2.5 The horizontal and vertical deformation of the main beam of cantilever construction shall be monitored.

7.2.6 During deformation monitoring, the mechanical operations on the bridge that may affect the monitoring results shall be stopped. For the construction process of cable installation and cantilever construction which are sensitive to sunlight, the deformation monitoring shall consider the influence of sunlight, and corrections shall be made.

7.2.7 The monitoring frequency of deformation monitoring shall meet the following requirements, in addition to the requirements specified in Article 4.3.11 of this Code.

1 Continuous deformation monitoring shall be carried out during the process of bridge system transformation construction and new segment construction.

2 Bridges of integral casting or hoisting shall be monitored at least once when the load is increased by 50% and 100% respectively.

Ⅲ Strain Monitoring

7.2.8 The key components and their key parts to be monitored should include the characteristic position components, suspenders or slings, stay cables, main cables, components with large internal force changes during the construction, key positions reflecting the force characteristics of components, and the local positions of complex force.

7.2.9 The complex supports, buckle towers, and main temporary facilities in the construction of hanging towers shall be subject to strain monitoring.

7.2.10 The times of strain monitoring shall meet the following requirements in addition to the requirements specified in Article 4.2.6 of this Code.

1 Strain monitoring shall be carried out for bridges constructed by segments in the process of adding new segments.

2 Strain monitoring shall be carried out in the process of system transformation.

3 The integrally poured or hoisted bridge shall be monitored at least once when the load is increased by 50% and 100% respectively.

Ⅳ Environmental and Effects Monitoring

7.2.11 Environmental and effects monitoring may include temperature, wind field and wind-induced response monitoring. The temperature monitoring results shall be compared with the deformation and strain monitoring results. Wind field and wind-induced response monitoring shall be carried out with early warning values combining with the structural characteristics.

Ⅴ Other Monitoring during Construction

7.2.12 The monitoring during the rotation construction shall meet the following requirements:

1 During the rotation construction, the temporary cable and tower structure of the rotation shall be incorporated into the main structure monitoring system. The monitoring shall include the whole process of erection, loading, bearing, and landing.

2 The mechanical parameters, geometric parameters and rotation speed of the main structure and the rotation temporary structure shall be monitored.

7.2.13 Monitoring during the incremental launching construction, the temporary structure shall be incorporated into the main structure monitoring system. The mechanical parameters, geometric parameters, and incremental launching speed of the main structure and the temporary structure shall be monitored.

7.2.14 Monitoring during jacking construction shall comply with the following requirements:

1 The jacking speed, synchronization and the stability of the jacked structure shall be monitored.

2 The deformation and strain monitoring points shall be determined according to the structural force characteristics.

7.3 Post Construction Monitoring

Ⅰ Deformation Monitoring

7.3.1 Deformation monitoring items during post construction shall include vertical displacement, horizontal displacement, and tilt angle.

7.3.2 The deformation monitoring points shall reflect the overall performance changes of the structure, and the following parts and items shall be monitored:

1 Vertical displacement in mid-span.

2 Vertical and horizontal displacements and tilt angles of arch feet, vertical displacements at vault and key positions of arch ribs.

3 Horizontal displacement at the top of the main tower of the cable-stayed bridge and vertical displacement at the key positions of the main girders of each span.

4 Spatial displacement at key position of main cable of suspension bridge, horizontal displacement of anchorage or anchorage point of main cable, horizontal displacement at top of cable tower, and vertical displacement of main girder of each span.

5 Displacement of expansion joints.

7.3.3 The times of deformation monitoring during post construction shall be determined in combination with the characteristics of bridge structures and the service life, and shall not be less than the times of regular inspection. Real-time monitoring should be carried out for extra-large bridges.

Ⅱ Strain Monitoring

7.3.4 Strain monitoring points shall be arranged according to the force characteristics of the bridge structure.

7.3.5 Strain monitoring shall set an early warning value according to the amplitude of structural strain change during post construction.

7.3.6 Strain monitoring of suspenders or slings, stay cables or main cables shall comply with the following requirements:

1 The representative cables shall be selected from each type of cable to evenly arrange the monitoring points.

2 The cable with the largest cable force, the cable with the largest stress amplitude and the cable with the smallest safety factor shall be selected for monitoring.

3 The arrangement of monitoring points should include upstream, downstream, mid-span, and side-span.

7.3.7 Fatigue monitoring shall be carried out for steel bridges, and monitoring parameters may include fatigue stress and steel structure temperature.

Ⅲ Dynamic Response Monitoring

7.3.8 Dynamic response monitoring shall take into account the dynamic characteristics test. Monitoring items may include natural frequency, vibration mode and damping ratio of structure.

Ⅳ Foundation Settlement Monitoring

7.3.9 Foundation settlement monitoring shall be carried out in accordance with the requirements specified in Article 7.2.1 of this Code.

Ⅴ Bearing Reaction and Displacement Monitoring

7.3.10 Bearing reaction and displacement monitoring shall comply with the following requirements:

1 Bearing reaction or partial load monitoring equipment may be arranged at single-column bridges, curved bridges, inclined bridges that are susceptible to overturning damage, bridges prone to foundation settlement, and large span bridges with negative reaction force. Monitoring items shall include bearing displacement, bearing reaction force or lateral inclination of bridge.

2 Force-measuring bearing should be selected for the monitoring of bearing reaction. Force-measuring bearing shall be reset the zero point, loaded the standard weight to correct the bearing parameters before use.

3 The monitoring of the bearing displacement shall be able to identify the bearing disengagement. When using displacement monitoring equipment to monitor the bearing displacement, the measuring direction of the sensor shall be parallel to the bearing reaction direction.

Ⅵ Environmental and Effects Monitoring

7.3.11 Environmental and effects monitoring shall be based on Article 7.1.5 of this Code, and the monitoring items such as corrosion, rainfall and scour may be added according to the importance of bridge structure and the characteristics of bridge location.

7.3.12 The wind field and wind-induced response monitoring points shall be arranged at the bridge deck of the main span and the top of the cable tower, with no shelter in all directions.

7.3.13 Temperature and humidity monitoring points shall be arranged at the bridge deck, steel box girders, cable towers and inside the anchor room where temperature and humidity change greatly or have a large influence on the structure. Monitoring parameters shall include ambient temperature, relative humidity and relative humidity inside the structure.

7.3.14 The ground motion and ship collision response monitoring points shall be arranged in a relatively fixed position close to the earth, and shall be installed at the top of the bridge bearing platform, the root of the cable tower and the anchor chamber of the anchorage.

7.3.15 The bridge of cable structure system may be monitored for rainfall. The rain gauge may be arranged on the bridge deck and the top of the cable tower when wind and rain vibration-related analysis or design requirements are required. At the same time, it should be arranged in the same location as the anemometer and other environmental monitoring equipment. Monitoring parameters should include rainfall and rainfall intensity.

7.3.16 The bridge foundation erosion should be monitored when the following situations are met:

1 Area where the erosion rate or erosion depth is determined to be great based on structural analysis or erosion model tests.

2 Area where the measured erosion rate is greater than the structural analysis result during use.

3 Area where erosion depth has reached or exceeded the design value.

4 Area where later engineering construction has caused changes to the riverbed, affecting the original erosion rule of the structure.

5 Area where is not easy to carry out routine erosion monitoring, or structural erosion changes dramatically needing for high-frequency monitoring.

7.3.17 Depth sounder, current meter and water level meter with continuous output function should be selected for erosion monitoring. The range and accuracy of the depth sounder, current meter and water level meter shall be determined according to the maximum erosion depth at the bridge site.

7.3.18 Erosion monitoring parameters may include erosion depth, velocity and water level. The monitoring points shall be arranged according to the special research report and the pile foundation type, the largest erosion area and the weak area of pile foundation.

Ⅶ Vehicle Load Monitoring

7.3.19 Dynamic traffic load should be monitored for bridge structures with high traffic flow, heavy vehicles or needing comparative analysis of static and dynamic responses.

7.3.20 Traffic load monitoring items may include traffic flow, vehicle type and distribution, vehicle speed, and headway.

7.3.21 The range of the dynamic weighing system shall be determined by the limited vehicle load of the bridge and the actual estimated vehicle load, while its size selection shall take into account the lane width and vehicle wheelbase. The dynamic weighing monitoring system shall have automatic data recording function and shall be compatible with the hardware and software interfaces of other monitoring systems.

7.3.22 The monitoring points should be arranged on the section of the main bridge with low vibration in the bridge direction. Axle speed meter and camera shall be matched, and the monitoring direction of the camera shall be the incoming vehicles direction.

8 Other Structures

8.1 Isolated Structures

8.1.1 In addition to the isolated structures required by the design document or otherwise specified to be monitored, the isolated structures shall be monitored during construction and post construction when one of the following conditions is met:

1 Bridge isolated structures.

2 High-rise isolated buildings with structural height greater than 60 m or height-to-width ratio greater than 4.

3 Long-span space isolated structures with structural span greater than 60 m.

4 Isolated structures with a single area greater than 80000 m^2.

8.1.2 The monitoring points of the isolated layer shall be set at the key part of the isolated layer. Horizontal and vertical displacement of the isolated layer shall be monitored during construction. The acceleration of the isolated layer and the top layer of the structure shall be monitored during post construction.

8.1.3 Isolated bearing deformation monitoring may be divided into horizontal shear deformation monitoring and vertical compression deformation monitoring, and monitoring shall comply with the following requirements:

1 The vertical compression deformation of isolated bearing shall be monitored during construction.

2 The horizontal shear deformation and vertical compression deformation of isolated bearing should be monitored during post construction.

3 Under the normal use of the isolated bearing, after the construction of the isolated main structure is completed, it shall be taken as the initial state. The maximum horizontal shear deformation shall not be greater than 50 mm, and the maximum vertical compression deformation shall not be greater than 5 mm.

4 For buildings with post-pouring belt, each zone of post-pouring belt shall be set with monitoring points at the center point and at least one corner point.

5 During the inspection of construction and post-construction, the complete isolation of isolated joints shall be ensured.

6 Monitoring equipment may choose total station, displacement meter or single-point settlement meter. The instrument parameters may be determined according to the requirements specified in Appendix A of this Code.

8.2 Crossing Construction

8.2.1 Underground engineering crossing existing structures is divided into normal and lateral crossing, and the following situations shall be monitored for the crossing construction:

1 Underground engineering is normal crossing the existing structures.

2 The monitoring scope of the subway interval structure and pipeline lateral crossing the

existing structure is generally within 30 m on both sides of the subway structure and the outer edge of the pipeline. In the construction site of the subway station, the monitoring scope shall be appropriately increased according to the surrounding environment of the station and the existing structure.

8.2.2 Monitoring items may be divided into two categories: monitored items and optional monitored items. The monitored items include settlement monitoring and inspection, and the optional monitored items include strain monitoring and tilt monitoring.

8.2.3 When the underground engineering crosses the existing engineering structure, the monitoring of the surrounding structure settlement caused by the crossing construction shall meet the following requirements:

1 For urban bridges, the settlement monitoring points shall be arranged on the piers, and the number of symmetrically arranged points on each pier shall not be less than 2. When it is inconvenient to arrange points on the piers, the points may be arranged on the beams and plates above the cover beams or the bearings.

2 For large-scale overpasses, each ramp bridge shall be set with at least one working base point which may be arranged on the adjacent piers outside the affected area. When there are no adjacent piers, the farthest monitoring point may be used as the working base point.

3 The buildings (structures) deformation monitoring arrangement shall be implemented in accordance with the requirements of the current national standard GB 50026 *Code for engineering surveying*.

4 Inspection shall be conducted diary during the monitoring.

8.2.4 Real-time monitoring shall be carried out for important structures to be crossed during the construction.

Appendix A Technique Requirement of Sensors

A. 0. 1 The main technical indicators of acceleration sensor shall meet the requirements of Table A. 0. 1.

Table A. 0. 1 The main technical indicators of acceleration sensor

Item	Force balance accelerometer	Electric accelerometer	ICP piezoelectric accelerometer
Sensitivity ($V \cdot m^{-1} \cdot s^{-2}$)	±0. 125	±0. 3	±0. 1
Full-scale output (V)	±2. 5	±6	±5
Frequency response (Hz)	0～80	0. 25～80	0. 3～1000
Dynamic Range (dB)	≥120	≥120	≥110
Linearity error (%)	≤1	≤1	≤1
Operating environmental temperature(℃)	−10～+50	−20～+50	−10～+50
Signal conditioning	Linear amplification, integration	Linear amplification, integration	ICP conditioning amplification

A. 0. 2 The main technical indicators of speed sensor shall meet the requirements of Table A. 0. 2.

Table A. 0. 2 The main technical indicators of speed sensor

Item	Technical indicator	Comment
Sensitivity ($V \cdot m^{-1} \cdot s^{-1}$)	±1～25	Adjustable
Full-scale output (V)	±5	
Frequency response (Hz)	0. 1～100	Adjustable
Dynamic Range (dB)	≥120	
Linearity error (%)	≤1	
Operating environmental temperature(℃)	−20～+50	
Signal conditioning	Linear amplification, integration, filtering	

A. 0. 3 The ground motion and seismic response monitoring instrument is mainly composed of force balance accelerometer and recorder. The main technical indicators of force balance accelerometer shall meet the requirements of Table A. 0. 1, and the main technical indicators of recorder shall meet the requirements of Table A. 0. 3.

A. 0. 4 The signal acquisition analyzer is composed of acquisition card and analysis software. The technical indicators of acquisition card of the signal acquisition analyzer shall meet the requirements of Table A. 0. 4.

Table A. 0. 3 The main technical indicators of recorder

Item	Technical indicator	Item	Technical indicator
Number of channels	≥ 3	Sampling rate	Program-controlled, at least 2 levels, maximum sampling rate not less than 200SPS
Full-scale input (V)	≥ ±5	Time service	Standard UTC, internal clock stability better than 10^{-6}, synchronization accuracy better than 1 ms
Dynamic Range (dB)	≥ 120	Data communication	RS-232 real-data stream serial port, communication rate 9600, 19200 optional
Conversion accuracy (bit)	≥ 20	Data storage	CF card flash, ≥4Gb
Trigger mode	Bandpass threshold trigger, STA/LTA ratio trigger, external trigger	Inter-channel delay	0
Environmental temperature (℃)	−20～+70	Software	Including communication program, graphic display program, other utility programs and monitoring, and diagnostic commands
Environmental humidity	< 80%	—	—

Table A. 0. 4 Technical indicators of acquisition card

Item	Technical indicator
Sampling rate (sps)	50～1000
A/D digits	Not less than 16 digits (not less than 14 of effective digits)
Sampling method	Acquisition channel synchronization, each channel uses a separate A/D
Dynamic range (dB)	≥ 80
Input range (V)	±10
Interface	USB interface, LAN interface
Data storage length	Not less than 5 hours of sampling data

A. 0. 5 The technical indicators of horizontal displacement monitoring sensor of isolated bearing shall meet the requirements of Table A. 0. 5.

Table A. 0. 5 Technical indicators of displacement sensor

Item	Technical indicator
Maximum measurable displacement (cm)	±50
Frequency range(Hz)	0～5 (When the cable length is 5 m)
Sensitivity (mV/cm/V)	10
Linearity	≤ 0. 2%
Resolution (mm)	0. 2

Appendix B Monitoring Requirement of Different Types of Bridges

B. 0. 1 The monitoring of the beam bridges during the post construction shall meet the following requirements:

1 Load monitoring items may include temperature and humidity, ground motion and ship collision response, and dynamic traffic load. Structural response monitoring items may include main girder deflection, main girder horizontal displacement, structural dynamic response, and critical section stress.

2 The deflection of beam bridges may be monitored by using static level gauges or hydraulic sensors based on the principle of connecting pipes. The torsion monitoring of main girder shall be carried out for two-way six-lane and above beam bridges. The longitudinal displacement of the beam ends should be monitored by the drawstring displacement meter.

3 External prestress should be monitored by pressure sensor or magnetic flux sensor.

B. 0. 2 The monitoring of the arch bridges during post construction shall meet the following requirements:

1 Load monitoring items may include wind load, temperature and humidity, ground motion and ship collision response, and dynamic traffic load. Structural response monitoring items may include arch rib deformation, horizontal displacement of bridge deck, structural dynamic response, critical section stress, sling force and boom force.

2 Appropriate monitoring equipment shall be selected for structural spatial deformation monitoring. For steel arch bridges with a span greater than 300 m, GPS method should be used to monitor the spatial displacement in the vault. The bridge deck deflection should be monitored by static level or hydraulic sensor based on the principle of connecting pipe. The longitudinal displacement of beam end should be monitored by drawstring displacement meter.

3 Tie rod tension of tied arch bridge may be monitored by pressure sensor or magnetic flux sensor. Sensors shall be calibrated before installation, and installed during construction.

4 Representative boom force may be monitored by vibration sensor or magnetic flux sensor.

B. 0. 3 Monitoring of cable-stayed bridges during post construction shall meet the following requirements:

1 Load monitoring items may include wind load, temperature and humidity, ground motion and ship collision response, and dynamic traffic load. Structural response monitoring items may include main beam deflection, main beam horizontal displacement, structural dynamic characteristics, tower deformation, critical section stress, fatigue stress, and cable-stayed force.

2 Appropriate monitoring equipment shall be selected for structural spatial deformation monitoring. The tilt meter or GPS method should be adopted for deformation monitoring of tower top. For cable-stayed bridges with steel main beams over 600 m or concrete main beams over 400 m, GPS method should be used to monitor the vertical, lateral, longitudinal, and torsional displacements of the entire cross-section in the middle of the beam, and a static level or hydraulic sensor based on the principle of

connecting pipes is used to monitor the deflection. For cable-stayed bridges with two-way 6 lanes and above, the torsion monitoring of the main beam should be carried out. The longitudinal displacement of the main beam end should be monitored by a drawstring displacement meter.

3 Cable-stayed force should be monitored by pressure sensor or vibration sensor. The pressure sensor shall be calibrated before installation, and the pressure sensor shall be installed before cable tensioning.

B. 0. 4 Monitoring of the suspension bridges during post construction shall meet the following requirements:

1 Load monitoring items may include wind load, temperature and humidity, ground motion and ship collision response, and dynamic traffic load. Structural response monitoring items may include main cable deformation, main beam horizontal displacement, structural dynamic characteristics, key section stress, fatigue stress, cable force and sling cable force.

2 Appropriate monitoring equipment shall be selected for structural spatial deformation monitoring. GPS method should be used for main cable deformation monitoring. Inclinometer or GPS should be used for cable tower top deformation monitoring. For suspension bridge with a span greater than 600 m in the middle of main beam span, GPS method should be used to monitor the vertical, horizontal, longitudinal, and torsional displacements of the entire section, and static level gauges or hydraulic sensors based on the principle of connecting pipes should be used to monitor the deflection. Suspension bridges with two-way 6 lanes and above shall be carried out for the torsion monitoring of main beam. The longitudinal displacement of main beam end may be monitored by drawstring displacement meter.

3 The main cable force may be monitored by pressure sensor or magnetic flux sensor. Sensors shall be calibrated before installation, and the installed during construction.

4 Representative sling and suspender forces may be monitored by vibration sensor or magnetic flux sensor.

B. 0. 5 During the post construction of railway bridge, the monitoring system shall have an automatic trigger function, which can completely record and store all data of the whole train from getting on the bridge to getting off the bridge. The following monitoring items may be selected according to the actual situation:

1 Stress and deformation of key components or parts of the main beam, the lateral and longitudinal displacement of the bearing, and the bearing reaction.

2 Transverse and vertical amplitude and vibration acceleration, dynamic deflection, and dynamic stress of the main beam.

3 Transverse and longitudinal amplitude of bridge piers.

4 Cable force.

5 Wheel rail force, including derailment coefficient and load shedding rate.

6 Dynamic axle load and speed of train.

Explanation of Wording in This Code

1 Word used for different degrees of strictness are explained as follows in order to mark the difference in executing the requirements in this code:

1) Words denoting a very strict or mandatory requirement:
"Must" is used for affirmation; "must not" for negation.

2) Words denoting a strict requirement under normal conditions:
"Shall" is used for affirmation; "shall not" for negation.

3) Words denoting a permission of slight choice or an indication of the most suitable choice when conditions permit:
"Should" is used for affirmation; "should not" for negation.

4) "May" is used as word denoting a permission of choice or an indication of the most suitable choice when conditions permit.

2 "Shall comply with …" or "shall meet the requirements of …" is used in this code to indicate that it is necessary to comply with the requirements stipulated in other relative standards and codes.

List of Quoted Standards

1 GB 50026 *Code for engineering surveying*

2 GB 50311 *Code for engineering design of generic cabling system*

3 GB 50496 *Code for construction of mass concrete*

4 GB 50497 *Technical code for monitoring of building excavation engineering*