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Technical code for monitoring of building and bridge structures

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Foreword

In accordance with the requirements of the Announcement of Ministry of Housing and Urban-Rural Development on the Printing and Issuing of the 2011 Engineering Construction Standard and the Amendment Plan (JIANBIAO [2011] No. 17), the code compilation group complied this code after making extensive investigation, carefully summarizing the practical experiences, making reference to the relevant international standards and advanced foreign standards, AND collecting extensive comments.

The main technical contents of wood specification are: 1. General Provisions; 2. Terms and Symbols; 3. Basic Requirements; 4. Monitoring Methods; 5. High-rise Building and Structure; 6. Long-span Spatial Structures; 7. Bridge Structures; and 8. Other structures.

The provisions of in this code which are marked in bold are mandatory provisions AND must be strictly implemented.

As for this Code, the Ministry of Housing and Urban-Rural Development is responsible for the interpretation of the mandatory provisions, AND the China Academy of Building Research is responsible for the interpretation of specific technical contents. Any comments or recommendations in the implementation of this standard place send to the China Academy of Building Research (Address: No.30 Beisanhuan East Road, Beijing 100013, China).

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Technical code for monitoring of building and bridge structures

1 General provisions

1.0.1 In order to standardize the building and bridge structure monitoring technology and the corresponding analysis and early warning, to achieve advanced technology, reliable data and reasonable economy, this code is hereby formulated.

1.0.2 This code is applicable to the monitoring of engineering structures such as high-rise buildings and structures, long-span spaces, bridges and seismic isolation structures, as well as the monitoring of existing structures affected by the crossing construction.

1.0.3 Construction and bridge structure monitoring shall, in addition to complying with the provisions of this code, also comply with the relevant requirements of the current notational standards.

2 Terms and symbols

2.1 Terms

2.1.1 Structural monitoring

Frequent, continuous observation or measurement of the state of the structure.

2.1.2 Construction monitoring

Structural construction monitoring.

2.1.3 Post construction monitoring

Structural post construction monitoring.

2.1.4 Monitoring system

It is integrated by the software and hardware for the purposes of achieving a certain monitoring function, composed of the monitoring equipment.

2.1.5 Monitoring equipment

It refers to, in the monitoring system, the collective name of sensors, collectors and other hardware.

2.1.6 Transducer/sensor

An equipment or device that senses a given measurement results AND transforms it into a usable output signal in accordance with certain principles, usually consisting of a sensing element and a conversion element.

2.1.7 Times of monitoring

Number of monitoring per unit time.

2.1.8 Precaution value for monitoring

It refers to, in order to ensure the safety or quality of the engineering structure and the surrounding environment, the warning value set for the monitoring amount indicating the possible abnormal or dangerous state of the monitoring object.

2.1.9 Monitoring system stability

The performance of the monitoring system to maintain its normal working characteristics after long-term use.

2.1.10 Monitoring equipment durability

It refers to the capability of the monitoring equipment, under normal use and maintenance conditions, to comply with the predetermined functional requirements with time.

2.1.11 Sensor frequency range

It refers to the frequency range in which the change of the input signal frequency will not cause the sensitivity and phase to change beyond the limits.

2.1.12 Structural analyzing model updating

It refers to the process of making the model calculation and analysis results as close as possible to the actual measurements through identifying or correcting the parameters in the analysis model.

2.1.13 Crossing construction

It refers to the construction process of making the underground project pass through the existed structure.

2 It shall check the sources of the interference signal, AND it shall take effective measures to treat it;

3 It is preferable for the monitoring system for post construction monitoring to inherit the data monitored during construction, AND it is preferable to make comparative analysis and identification.

3.2.4 Monitoring system sampling frequency shall comply with the monitoring requirements.

3.2.5 During the monitoring period, the monitoring result shall be timely compared with the results of structural analysis. When the monitoring data is abnormal, the monitoring object and monitoring system shall be checked in time. When the monitoring value exceeds the warning value, the alarm shall be immediately issued.

3.2.6 Them measurement point shall comply with the following requirements:

1 It shall reflect the actual status and change trend of the monitoring object, AND it is preferable to make the measurement point locate at a position having the maximum monitoring parameter;

2 It is preferable for the location and quantity of the measurement points to be determined in accordance with the structure type, design requirements, construction process, monitoring items and structural analysis results;

3 The quantity and arrangement range of the measurement points shall be redundant, AND it shall increase the measurement points at important positions;

4 It may use the structural symmetry to reduce the number of measurement points;

5 It shall facilitate the installation, measurement and reading, maintenance and replacement of monitoring equipment;

6 It shall not hinder the construction and normal use of the monitoring object;

7 It is preferable to shorten the signal transmission distance under the preconditions of complying with the above requirements.

3.2.7 Monitoring equipment shall comply with the following basic requirements:

1 The selection of monitoring equipment shall comply with the requirements of monitoring period, monitoring items and methods, and system functions, and have stability, durability, compatibility and extendibility;

2 The signal to noise ratio of the measured signal shall comply with the analysis demands of the actual projects;

3 It shall make calibration before putting into use;

4 It shall select the installation method based on requirements for monitoring methods and monitoring functions, the installation shall be firm, AND the installation technology and durability shall comply with the use requirements in the monitoring period;

5 After the installation is completed, it shall make site identification in time and draw the monitoring equipment layout, AND archive it for reference.

3.2.8 The monitoring sensor shall, in addition to complying with the basic requirements of clause 3.2.7 of this code, also comply with the following requirements:

1 Sensor selection shall be based on the requirements of the monitoring object, monitoring item and monitoring methods, AND follow the principles of “advanced technology, stable performance, and cost-effectiveness”;

2 It is preferable to adopt the sensors having compensation functions;

3 The sensors shall comply with the requirements of the monitoring system for sensitivity, pass band, dynamic range, measurement range, linearity, stability, power supply method, life expectancy and other items.

3.2.9 Monitoring equipment operating environment shall comply with the following basic requirements:

1 The distance between signal cables, monitoring equipment and high-power radio transmission sources, high-voltage power transmission lines and microwave radio signal transmission channels shall comply with the relevant requirements of the current national standard Code for Engineering Design of Generic Cabling System GB 50311;

2 It is not preferable for the monitoring receiving devices to be close to the large area water, large building, metal mesh, or radio interference sources which have a strong signal reflection;

measurement point layout, construction process structural analysis results, and warning value;

3 Monitoring results, including: monitoring results of the monitoring parameters at each measurement point during construction period, comparison with structural analysis results, warning conditions and assessment results, changes of measurement points, records of handling anomalies during the monitoring period;

4 Monitoring conclusions and recommendations;

5 Warning report, treatment results and related appendixes.

3.3.14 The summary monitoring report shall reflect the monitoring conditions during the entire monitoring period. The report shall include the main contents of the monitoring report in each stage.

3.3.15 Monitoring records shall be completed on the monitoring site or in the monitoring system. The recorded data, texts and graphs shall be true, accurate, clear and complete AND shall not be arbitrarily altered.

3.3.16 Monitoring plan, monitoring report, and original records shall be archived. The original records shall include the calculation documents of structural analysis of the construction process, the monitoring records and comparative analysis results of structural deformation and strain monitoring, the records of handling anomalies, the warning reports and disposal result.

3.4 Post construction monitoring

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

3.4.2 Post construction monitoring items may include deformation and fracture monitoring, strain monitoring, cable force monitoring and environment and effect monitoring. Deformation monitoring may include foundation settlement monitoring, structural vertical deformation monitoring and structure horizontal deformation monitoring; environmental and effect monitoring may include wind and wind-induced response monitoring, temperature and humidity monitoring, seismic and seismic response monitoring, traffic monitoring, erosion and corrosion monitoring.

1 Monitoring results and comparison, including: the comparison between the monitoring results within a specified period of time and structural analysis results, and the warning value;

2 Monitoring conclusion.

3.4.14 Monitoring statements and the original records shall be archived.

4 Monitoring methods

4.1 General requirements

4.1.1 It is preferable for the monitoring items to include the strain monitoring, deformation and fracture monitoring, temperature and humidity monitoring, vibration monitoring, seismic and seismic response monitoring, wind and wind-induced response monitoring, cable force monitoring, and corrosion monitoring.

4.1.2 The monitoring parameters can be divided into static parameters and dynamic parameters. The selection of monitoring parameters shall comply with the requirements of monitoring, warning and evaluation of structural status.

4.2 Stress and strain

4.2.1 Strain monitoring may be achieved by resistance strain gauges, vibrating wire strain gauges, fiber strain gauges and other strain monitoring components.

4.2.2 It is preferable to select the strain gauges based on monitoring purposes and engineering requirements, as well as sensor technology and environmental characteristics.

4.2.3 Strain gages shall comply with the following basic requirements:

1 Range shall be compatible with the measurement range, the strain measurement accuracy shall be 0.5% of full scale, AND it is preferable for the monitoring value to be controlled at 30% ~ 80% of full scale;

2 It is preferable to select large-scale strain gauge for the concrete structures; AND as for the stress concentration area of higher strain gradient, it is preferable for the small-scale strain gauge;

3 The strain gauges shall have temperature compensation function.

4.3.4 As for the deformation monitoring, it shall establish a reference network, AND the plane coordinate system and elevation system can be in line with the system used in construction. AND as for the local relative deformation measurement, it may not establish a reference network, BUT is shall consider the impact of the structural overall deformation on the monitoring results.

4.3.5 Deformation baseline monitoring shall reduce the impact of environmental factors such as temperature.

4.3.6 The results of deformation monitoring shall be corrected in combination with the environment and effect monitoring results.

4.3.7 The measurement range of the deformation monitoring instrument shall be 2 ~ 3 times the estimated value or allowed value of the measurement point displacement; AND when using the mechanical testing instrument, the accuracy shall be 1/10 of the estimated displacement of the measurement point.

4.3.8 Monitoring signs shall be designed in accordance with the characteristics of different engineering structures; AND the monitoring signs shall be firm, applicable, and easy to protect.

4.3.9 Monitoring of foundation pit shall be carried out in accordance with the relevant provisions of the current national standard “Technical code for monitoring of building excavation engineering” GB 50497. When optical instrument method or satellite positioning system method is used for deformation monitoring, it shall follow the relevant provisions of the current national standard “Code for engineering surveying” GB 50026; AND the vibration displacement monitoring shall be in accordance with the provisions of clause 4.5 of this code.

4.3.10 For structures with large cumulative deformation in construction phase, the compensation technology shall be adopted to correct the elevation of engineering structure in accordance with the design requirements. It is preferable for the final elevation to be in line with the design elevation, AND the technology of elevation compensation shall be combined with prediction and monitoring.

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

1 When monitoring items include horizontal displacement and vertical displacement, it is preferable for the frequency of the both to be consistent with each other;

1 The length of the crack and the width of the larger crack can be measured using a steel rule or a mechanical testing instrument. Direct measurement can be made by crack width test card or the electronic crack observation instrument, AND each measurement point shall not be measured for at least 3 times; it is not preferable for the minimum scale value of the crack width test card to be more than 0.05 mm; AND when using the electronic fracture observation instrument, the measurement accuracy shall be 0.02 mm;

2 The crack of width less than 1 mm may be measured by the electrical instrument method, AND the instrument resolution shall not be greater than 0.01 mm;

3 If it is needed to monitor the displacement changes at two points at both sides of the crack, it may use the structural crack monitoring sensors, which include vibrating wire gauge, strain gauge or optical fiber type displacement gauge, the sensor range shall be greater than the crack warning width, AND the sensor measurement direction shall be perpendicular to the crack direction;

4 As for the cracked structure, it is preferable to monitor the crack width change; AND as for the structure without cracks, it is preferable to monitor the structural strain change.

4.4 Temperature and humidity

4.4.1 Temperature and humidity monitoring may include the environment and component temperature monitoring AND environmental humidity monitoring.

4.4.2 Mass concrete temperature monitoring shall be in accordance with the relevant provisions of the current national standard “Code for construction of mass concrete” GB 50496.

4.4.3 It is preferable for the temperature monitoring accuracy to be ±0.5 °C, AND it is preferable for the humidity monitoring accuracy to be ±2% RH.

4.4.4 Environment and component temperature monitoring shall comply with the following requirements:

1 The measurement point for temperature monitoring shall be arranged in a position of larger temperature gradient changes, which shall be symmetrical and uniform, AND shall reflect the vertical and horizontal temperature field change principles of the structures;

4.6.2 The monitoring parameters are mainly the acceleration of earthquakes and seismic responses. Other parameters such as force and displacement may also be monitored in accordance with the project requirements.

4.6.3 Structure earthquake and seismic response monitoring shall comply with the following requirements:

1 Monitoring program shall include the type of monitoring system, measurement point layout, technical indicators of instrument, monitoring equipment installation and management and maintenance requirements;

2 Measurement points shall be arranged in accordance with fortification intensity, seismic fortification category and structure importance, structure type, and topographic and geological conditions;

3 The monitoring system can be arranged in coordination with the vibration response such as wind, impact and traffic AND shall be combined with the earthquake damage detection facilities;

4 The measurement points cloth shall be able to reflect the seismic response of earthquake and the upper main structure;

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

4.7 Wind and wind-induced response

4.7.1 It is preferable for the wind-sensitive structure to be subjected to wind and wind-induced response monitoring.

4.7.2 Wind and wind-induced response monitoring parameters shall include wind pressure, wind speed, wind direction and wind-induced vibration response. It is preferable to include the wind attack angle for the bridge structure.

4.7.3 The wind pressure monitoring shall comply with the following requirements:

1 It is preferable to select the pressure sensor having a micro-pressure range which can measure the positive and negative pressure for the wind pressure monitoring, AND it may also select the dedicated wind pressure gauge, AND the monitoring parameter is the air pressure;

2 The air pressure sensor installation shall avoid the impact on the engineering structure of the facade, and take effective protection

shall arrange the sensors based on the monitoring objective and contents;

2 The wind-response measurement points can be arranged with a variety of sensors which can measure different physical quantities;

3 The strain sensor shall, based on the results of the analysis, be arranged in a position higher in stress or strain larger OR a position the stiffness can reflect the structure wind response characteristics;

4 It is preferable to arrange the displacement sensors at the structure location having limiting requirements for displacement, AND the recorded results of the displacement sensor shall be compared with the displacement limit value.

4.8 Other items

I. Cable force monitoring

4.8.1 Cable force monitoring shall comply with the following requirements:

1 The monitoring methods may include pressure gauge measurement jack hydraulic method, pressure sensor measurement method, and vibration frequency method;

2 It is preferable for the monitoring accuracy of the pressure gauge measurement jack hydraulic method and vibration frequency method to be 5.0% of the full range, AND it is preferable for the monitoring accuracy of the pressure sensor measurement method to be 3.0% of the full range;

3 The acceleration sensor frequency range of the cable force monitored by vibration frequency method shall cover the cable vibration base frequency, AND when using the measured frequency to calculate the cable force, it shall establish the model for the cable and the elastic supporting structure at both ends of the cable as a whole for joint analysis;

4 When designing the cable monitoring system, it is preferable for it to be integrated with the structure internal pipeline and communications equipment;

5 The cable power monitoring warning value shall be determined combining the engineering design limit value, structural design requirements, and the control requirements of the monitoring object.

4.8.2 The cable force monitoring shall comply with the following requirements:

the design documents or other provisions, it is preferable for the high-rise building and structures to be subjected to the construction monitoring once complying with one of the following conditions:

1 The high-rise building and structures during the construction process of which the large scale temporary bracing structure is added;

2 The high-rise building and structures during the construction process of which the whole or partial structure is stressed complexly;

3 Large-volume concrete structures which are significantly affected by such factors as temperature change, concrete shrinkage, creep, sunshine, and other environmental factors AND the structure containing extra-long members and special cross-sections;

4 The high-rise building and structures for which the construction program has significant impact onto the structure internal force distribution;

5 The high-rise building and structures having strict requirements for settlement and shape & location;

6 The high-rise building and structures affected by the neighboring construction operations.

5.1.3 In addition to the high-rise building and structures which shall be subjected to post construction monitoring in accordance with the requirements of the design documents or other provisions, it is preferable for the high-rise building and structures to be subjected to the post construction monitoring once complying with one of the following conditions:

1 The high-rise building and structures having a height of 300 m and above;

2 The high-rise building and structures for which the construction process causes significant difference between the final shape and location and the designed shape and location;

3 The high-rise building and structures with seismic isolation system;

4 Other high-rise building and structures that are sensitive to structural deformation.

5.1.4 The foundation pit work having an excavation depth greater than or equal to 5 m OR excavation depth of less than 5 m but the site geological conditions and the surrounding environment more complex as well as other foundation pit works which requires monitoring shall be subjected to monitoring in

5.2.13 The strain monitoring frequency shall, in addition to complying with the requirements of clause 4.2.6 of this code, also comply with the following requirements:

1 For the connected, post-assembled delay components or structures with temporary support, before and after the closure of connected structures, before and after the fixation of delay components, and before and after the support is removed, it shall increase the monitoring frequency for the corresponding components having larger stress changes;

2 It shall comply with the provisions of item 2 to 4 of clause 5.2.7 of this code, AND it may also make reference to the other items in clause 5.2.7 of this code.

IV Wind and wind-induced response monitoring

5.2.14 When obtaining average wind speed and direction, and when it is not easy to install the monitoring mast on the top of the structure during construction, it may install the anemometer on the top of the construction tower crane higher above the top of the structure.

5.3 Post construction monitoring

I. Deformation monitoring

5.3.1 Deformation monitoring measurement point can be at the following locations:

1 Characteristic components affecting structural safety, key points of significant deformation, corners of bearing wall columns, and large structural section transformations; main corners, space separated by 2 ~ 3 plinths, and top and bottom of settlement joints, both sides of engineering structural cracks, the abrupted change of structure, and the main component having great slope change;

2 Connection component between structural bodies AND both sides of the partition of different structures;

3 On the wall or column of the middle part of the structural façade, AND it is not preferable for the number of measurement points on one side of the wall to be less than 3.

5.3.2 It may select the spire, lightning rod, cylinder (ball) body edge having obvious characteristics as the monitoring points of high rise building and structures.

5.3.18 When monitoring the gradient temperature of the structure, it is preferable to arrange the measurement points on the direct sunlight exposure surface of the structure, the relative structure back surface, and within the structure along the structure height, AND the number of measurement points on the same plane of the structure shall be not less than 3.

5.3.19 As for the environmental temperature and humidity monitoring, it is preferable to locate the temperature or humidity sensor in the thermometer screen with air circulation 1.5 m above ground or floor surface.

5.3.20 As for the temperature monitoring within the structure, measurement points can be arranged on the inner wall of the structure which facilitates maintenance and repair. It is preferable to uniformly locate the points by diagonal or plum-style, AND it shall avoid the doors and windows vents.

6 Long-span spatial structure

6.1 General requirements

6.1.1 In addition to the long-span spatial structure which shall be subjected to construction monitoring in accordance with the requirements of the design documents or other provisions, the long-span spatial structure shall be subjected to the construction monitoring once complying with one of the following conditions:

1 Grid and multi-layer steel shell structure or cable membrane structure having a span of more than 100 m;

2 Single layer shell structure having a span greater than 50 m;

3 Large-span composite structure having a single-span length greater than 30 m;

4 Steel structure having a structural cantilever length greater than 30 m;

5 Large-span spatial structure for which there is significant difference between the stressing state or the internal force or position & shape of some bars during the construction period AND the forming loading analysis results of the one-time forming integral structure due to the effects of the construction methods or sequences.

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

6.2.2 Deformation monitoring during construction may include deflection of members, offset of center axis of support, height difference of highest and lowest supports, height difference of adjacent supports, axis of rod, perpendicularity of member, and sloping deformation monitoring.

6.2.3 After finishing the spatial structure installation, when monitoring the main span deflection, the measurement points may be determined by the design unit. When there is no design requirement, it shall monitor the mid-span deflection for the span of 24 m and below; AND it shall monitor the deflection at the mid-span and quarter-point along span direction for the span more than 24 m.

6.2.4 During membrane structure monitoring, it shall track the spatial coordinates of the monitored membrane surface control points, AND the control point height deviation shall neither be greater than 1/600 of the membrane structure rise at this point NOR be greater than 20 mm; AND the horizontal deviation shall be not more than 1/300 of the membrane structure rise at this point NOR be more than 40 mm.

6.2.5 When lifting the draw bar, it shall monitor the height difference of the four corners of the spatial structure, AND the lifting height difference shall neither be not more than 1/400 of the distance between the lifting points NOR more than 100 mm, OR otherwise it can be determined through verification.

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

6.2.7 During the structure slip construction process, the deformation, stress and slip synchronization of the key points of the structure shall be monitored.

6.2.8 When monitoring vertical displacement, it is not preferable for the support, mid-span, and inter-span measurement point spacing of the long-span spatial structure to be more than 30 m, AND it shall be not less than 5 points.

6.2.9 The monitoring frequency for deformation shall comply with the requirements of clause 4.3.11 of this code, AND it shall make monitoring for at least once in the lifting and unloading process when the weight change is 50% and 100% respectively.

III. Strain monitoring

6.2.10 During the construction and installation process, stress monitoring shall select the key stress parts to continuously collect the monitoring signals, AND the measured results are compared with the calculation results in time. AND it shall issue warning when finding the nonconformance of the monitored results or quantity to the structural analysis results.

7.2.4 During the construction of cable tower higher than 30 m AND the construction or pier more than 15 m, it shall make levelness and perpendicularity monitoring.

7.2.5 Horizontal and vertical deformation of cantilever construction girders shall be monitored.

7.2.6 During deformation monitoring, it shall stop the mechanical work on the bridge which may affect the monitoring results. As for the construction process such as the cable installation and cantilever work which is sensitive to the sunlight, the deformation monitoring shall consider the sunlight effect AND the correction shall be made.

7.2.7 The monitoring frequency of deformation monitoring shall comply with the following provisions in addition to the requirements of clause 4.3.11 of this code:

1 In the bridge system transitional construction process AND the segment increase process of segment construction, it shall make continuous deformation monitoring;

2 The integrally casted or hoisted bridge shall be monitored at least once for the load increase of 50% and 100%, respectively.

III. Strain monitoring

7.2.8 It is preferable for the key components and their key parts under monitoring to include the characteristic position components, suspension boom or slings, stay cables, main cables, components with large changes in internal force during construction, key positions reflecting the stressing characteristics of components, and local position stressed complexly.

7.2.9 During the construction process of complex brackets, cable tower and hanging towers, the main temporary facilities shall be subjected to strain monitoring.

7.2.10 The strain monitoring frequency shall also comply with the following provisions in addition to the provisions of clause 4.2.6 of this code:

1 In increasing the segment for the segment construction bridges, it shall be subjected to strain monitoring;

2 In the system conversion process, it shall be subjected to strain monitoring;

7.3.1 The post construction deformation monitoring items shall include vertical displacement, horizontal displacement and inclination.

7.3.2 Deformation monitoring measurement points shall reflect the overall structural changes in performance, AND the following parts and items shall be subjected to deformation monitoring:

1 Mid-span vertical displacement;

2 Springer vertical displacement, horizontal displacement and inclination, and vertical displacement of key position of arch top and rib;

3 The horizontal displacement of the main tower top of the cable-stayed bridge AND the vertical displacement of the key positions of each of the main girders.

4 The spatial displacement of the key positions of the suspension bridge main cable, the horizontal displacement of the anchor or main cable anchorage point, the horizontal displacement of the cable tower top, AND the vertical displacement of the main girder at each span;

5 The displacement of expansion joints.

7.3.3 The post construction deformation monitoring frequency shall be determined in combination with the bridge structure characteristics and service life, which shall be not less than the regular inspection frequency; AND it is preferable to make monitoring for the ultra-large bridge.

II. Strain monitoring

7.3.4 Strain monitoring measurement points shall be arranged in accordance with the stressing characteristics of the bridge structure.

7.3.5 Strain monitoring shall be set with the warning value in accordance with the strain amplitude of the structure during use.

7.3.6 The cable force monitoring of the suspension boom or sling, stay cable or main cable shall comply with the following requirements:

1 It shall select the representative cable from the cables of different specifications and models to uniformly arrange the measurement points;

2 It shall select the cable with the largest cable force, the cable with the largest stress amplitude, and the cable with the lowest safety factor for monitoring.

determine the measuring range and accuracy of the depth sounder, flow speed meter, and water level gauge.

7.3.18 Monitoring parameters for erosion monitoring may include erosion depth, flow rate and water level. Monitoring points shall be arranged at the region of maximum erosion and the region of weak pile foundations based on the special study reports and the type of piles.

VII. Traffic load

7.3.19 For the bridge structure with large traffic flow, frequent heavy vehicles, or requiring load static and dynamic response comparative analysis, it is preferable to make dynamic traffic load monitoring.

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

7.3.21 Dynamic weighing system range shall be determined based on the load capacity of the restricted vehicles of the bridge and the actually estimated vehicle load capacity, AND meanwhile its size and type selection shall consider the lane width and vehicle wheelbase. Dynamic weighing monitoring system shall have automatic data recording capabilities, AND shall be compatible with the software and hardware interfaces of other monitoring system.

7.3.22 It is preferable for the measurement point to be arranged on the cross-section along the bridge access direction of the main bridge with small vibration. The vehicle shaft speedometer and camera shall be matched. Camera monitoring direction shall be of the vehicle coming direction.

8 Other structures

8.1 Seismically isolated structure

8.1.1 In addition to the seismically isolated structure which shall be subjected to monitoring in accordance with the requirements of the design documents or other provisions, the seismically isolated structure shall be subjected to the construction and post construction monitoring once complying with one of the following conditions:

1 Bridge seismically isolated structure;

2 High-rise seismically isolated buildings with structure height greater than 60 m or height-to-width ratio greater than 4;

1 Underground construction is crossing the existing structure;

2 The monitoring range of the subway section structure AND the pipeline passing by the existing structure is generally 30 m at both sides of the subway structure and along the pipeline. In the subway station construction site, the monitoring range shall be appropriately increased depending on the surrounding environment and the existing structure of the station.

8.2.2 Monitoring items can be divided into two types: monitoring items and optional monitoring items. The monitoring items shall include the settlement monitoring and patrol inspection, AND the optional monitoring items shall include the strain monitoring and inclination monitoring.

8.2.3 When the underground work is crossing the existing engineering structure, the monitoring of the settlement of surrounding structures caused by the crossing construction shall comply with the following requirements:

1 As for urban bridges, the settlement measurement points shall be arranged on the pier, at least 2 symmetrical points on each pier; AND when it is not convenient to arrange the measurement points on the pier, it may arrange the points on the beam or plate above the cover girders or supports;

2 As for large-scale overpasses, each ramp bridge shall be arranged at least one working base point, which may be located on the adjacent pier beyond the affected zone; AND when there is no adjacent pier, it may use the farthest measurement point as the working base point;

3 The construction (structure) building deformation monitoring layout shall be in accordance with the requirements of the current national standard Code for engineering surveying GB 50026;

4 During the monitoring period, it shall make daily patrol inspection.

8.2.4 All the important structures to be crossed shall be monitored in real time during construction.

Appendix B Monitoring requirement of different types of bridges

B.0.1 Beam bridge post construction monitoring shall comply with the following requirements:

1 Load monitoring item may include temperature and humidity, ground motion and ship impact response, and dynamic traffic load; AND the structural response monitoring item may include deflection of main girder, horizontal displacement of main girder, structural dynamic response and key section stress.

2 The beam bridge deflection can be monitored by the use of static level or hydraulic sensor in accordance with the connection pipe principles, AND the beam bridges having two-way 6 lanes shall be subjected to main beam torsional monitoring; AND it is preferable to use the rope-type displacement meter to monitor the longitudinal displacement at the beam end.

3 It is preferable for the external prestress to be monitored by the pressure sensor or magnetic flux sensor.

B.0.2 The post construction monitoring of arch bridge shall comply with the following requirements:

1 Load monitoring item may include wind load, temperature and humidity, earthquake and ship impact response, and dynamic traffic load; the structural response monitoring item may include arch rib deformation, horizontal displacement of bridge deck, structural dynamic response, key cross-section stress, suspension cable force, and boom force.

2 Structural spatial deformation monitoring shall be made by appropriate monitoring equipment; as for the steel arch bridge having a span more than 300 m, it is preferable to use the GPS method at the arch top to monitor the spatial position change, it is preferable to use the static level or hydraulic sensor to monitor the deck deflection through the connection pipe principles, AND it is preferable to use the rope-type displacement meter to monitor the longitudinal displacement at the end of beam.

3 The tie rod tension of the tie-rod arch bridge can be monitored using a pressure sensor or a magnetic flux sensor. The sensor shall be calibrated prior to installation, AND be installed during construction.

4 Representative boom force can be monitored using a vibration sensor or a magnetic flux sensor.

B.0.3 Cable-stayed bridge post construction monitoring shall comply with the following requirements:

1 Load monitoring item may include wind load, temperature and humidity, earthquake and ship impact response, and dynamic traffic load; the structural response monitoring item may include the main beam deflection, the main beam horizontal displacement, structural dynamic characteristics, cable tower deformation, key cross-section stress, fatigue stress and stay cable tension.

2 Structural spatial deformation monitoring shall be made by selecting appropriate monitoring equipment. It is preferable to use the clinometer or GPS method to monitor the deformation of the cable tower top; it is preferable to use the GPS method to monitor the vertical, horizontal, longitudinal, and torsional displacement of the entire cross section at the mid-span of the main beam for the steel main beam cable-stayed bridge having a span of more than 600 m OR the concrete main beam cable-stayed bridge having a span more than 400 m, it is preferable to use the static level or hydraulic sensor to monitor the deck deflection through the connection pipe principles, the cable-stayed bridges having two-way 6 lanes and above shall be subjected to main beam torsional monitoring, AND it is preferable to use the rope-type displacement meter to monitor the longitudinal displacement at the end of the main beam.

3 It is preferable to use the pressure sensor or vibration sensor to monitor the cable tension of the stay cable. The pressure sensor shall be calibrated before installation AND the pressure sensor shall be installed before the stay cable is tensioned.

B.0.4 Suspension bridge post construction monitoring shall comply with the following requirements:

1 Load monitoring item may include wind load, temperature and humidity, earthquake and ship impact response, and dynamic traffic load; the structural response monitoring item may include the main beam deflection, the main beam horizontal displacement, structural dynamic characteristics, key cross-section stress, fatigue stress, stay cable tension, and suspension cable tension.

2 Structural spatial deformation monitoring shall be made by selecting appropriate monitoring equipment. It is preferable to use the GPS method to monitor the main cable deformation, it is preferable to use the

List of quoted standards

1 Code for engineering surveying GB 50026

2 Code for engineering design of generic cabling system GB 50311

3 Code for construction of mass concrete GB 50496

4 Technical code for monitoring of building excavation engineering GB 50497

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