TB

PROFESSIONAL STANDARD OF

THE PEOPLE'S REPUBLIC OF CHINA

UDC

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TB 10091-2017

J 461-2017

Code for Design on Steel Structure of Railway Bridge

铁路桥梁钢结构设计规范

Issued on: February 02, 2017 **Implemented on: May 01, 2017**

Issued by: National Railway Administration of the People's Republic of China

Foreword

Since the issuing of TB 10002.2-2005 "Code for Design on Steel Structure of Railway Bridge", remarkable achievements have been made in China's railway construction, especially in the construction of high-speed railways. High-speed railways such as Beijing-Shanghai, Beijing-Guangzhou, Zhengzhou-Xi'an and Haerbin-Daqing, passenger-freight railways such as Yiwan, Taiyuan-Zhongwei-Yinchuan, heavy haul railways such as central-southern Shanxi corridor, Western Mongolian-Central China, inter-city railways such as Pearl River Delta and Wuhan city circle and have been opened to traffic in succession, improving the road network structure and increasing the effective supply of railway transportation services. After more than a decade of active exploration and innovative practice, China's railway bridge construction technology has made major breakthroughs and has been among the advanced ranks in the world. The successful construction of a number of deep-water, large-span, special-geological-condition, complex-structural-form bridges such as Nanjing Dashengguan Yangtze River Bridge, Wuhan Tianxingzhou Yangtze River Bridge, and the wide use of independently-researched large tonnage box girder complete sets of technology have accumulated rich experience and laid a solid foundation for further improvement of the technical standards of railway bridges.

This Code is completely revised according to the requirements of the National Railway Administration of the People's Republic of China for building railway engineering construction standard system, in order to meet the railway bridge construction and development needs, unify the design standards on steel structure of railway bridges, improve the design level of steel structure of railway bridges and ensure the safety and quality of steel structure of railway bridges, on the basis of the original code, summarizing the practical experiences and scientific research achievements of the steel structure construction and operation of high-speed, inter-city, passenger-freight and heavy haul railway bridges in recent years.

This Code implements the principle of safety first, strengthens the requirements of quality and safety, resource conservation and environmental protection, pays attention to the overall design and combines with China's national conditions, socio-economic development level, environmental conditions and other factors, to reasonably determine the main design standards for steel structures of railway bridges of different types of transportation and at different speed grades, further promote the scientific and technological economic rationality of the code. In recent years, a large number of new materials, new structures and new technologies have emerged in the field of design on railway steel bridges in China, including the adoption of Q500q steel, application of all-welded panel points and integral steel bridge floor plates, and construction of kilometric railway cable-stayed bridges and suspension bridges, etc., this Code is revised on the basis of summing up and absorbing the above advanced achievements and mature experiences.

Table of Contents

1 General provisions

1.0.1 This Code is formulated with a view to carry out relevant national laws and regulations and railway technology policies, unify the technical standards for the design on steel structure of railway bridges and make the design on steel structure of railway bridges comply with the requirements of safety and reliability, advance and mature, economy and usability, and environmental protection.

1.0.2 This Code is applicable to the design on steel structure of riveted, welded-and-high-strength-bolted and welded bridges for high-speed railways, inter-city railways, passenger-freight I and II level railways. The steel structure of bridges carrying both railway and highway which bear the highway load separately shall be designed according to the relevant standards of the current highway industry.

1.0.3 The steel structure of railway bridges shall have the specified strength, rigidity, stability and durability. The service life of the main structure shall be 100 years.

1.0.4 When adopting this Code, the design shall still comply with the provisions of the current “Code for Design on Railway Bridge and Culvert” (TB 10002).

1.0.5 The design on components of steel structures shall be standardized so that the same type of components can be interchangeable. The structure shall be easy to process, transport, install, inspect and maintain.

1.0.6 The bridge superstructure shall be provided with camber, and the camber curve should be basically the same with shape of the deflection curve generated by the dead load and half static live load, but with the opposite direction. When the vertical deflection caused by the dead load and static live load is not more than 1/1600 of the effective span of the bridge, the camber may not be provided.

1.0.7 For bridge superstructures, in the most unfavorable combination of calculated loads, the lateral tipping stability factor shall not be less than 1.3.

1.0.8 The steel beam shall be able to be lifted by jacks. The lifting facilities and structures themselves shall be calculated as 1.3 times the lifting load.

1.0.9 For bridges with deviated line center on the curve and other bridges with eccentric load, the influence of eccentric load on the bridge superstructure shall be calculated.

1.0.10 For the design on steel structure of railway bridges, not only the requirements stipulated in this Code, but also those in the current relevant ones of the nation shall be complied with.

2 Terms and symbols

2.1 Terms

2.1.1 Simply supported beam

A beam supported in two ends, with one end of vertical expansion bearing and another end of vertical fixed bearing.

2.1.2 Continuous beam

A beam with two or more spans that are continuously supported by bearings.

2.1.3 Truss

A planar or spatial lattice structure or component composed of several members. Each member mainly bears the axial force generated by various actions and sometimes also bears the panel point bending moment and the shear-force.

2.1.4 Steel beam

A beam with steel as the main building material.

2.1.5 Strength

The ability of a material or component to withstand damage when stressed.

2.1.6 Stiffness; rigidity

The ability of a structure or component to resist deformation.

2.1.7 Deformation

The relative displacement between points in a structure or component, caused by actions.

2.1.8 Deflection

In the bending moment action plane, the linear displacement, caused by the deflection and perpendicular to the direction of the axis or the middle plane, of a point on the axis or the middle plane of the structural component.

2.1.9 Camber

The reserved correction amount in the opposite direction to the deflection, in order to counteract the deflection of the bridge superstructure caused under load.

2.1.19 Damage correction factor

The factor matched with allowable stress range for fatigue design, transforming the designed load effect into the service load fatigue accumulated damage effect during the designed service life of the bridge.

2.1.20 Ultrasonic hammering

The method of using ultrasonic equipment to reinforce the weld toe surface of component connections.

2.2 Symbols

2.2.1 External forces and internal forces

N - the axial force (kN)

M - the bending moment (kN • m)

V - the shear-force (kN)

P - the allowable anti-slip bearing capacity of high-strength bolts (kN)

2.2.2 Stresses

$[\sigma]$ - the axial allowable stress of steel (MPa)

$[\sigma_w]$ - the allowable bending stress of steel (MPa)

$[\sigma_o]$ - the allowable stress range for fatigue design of components or connections (MPa)

$[\tau]$ - the allowable shear stress of steel (MPa)

E - the elasticity modulus of steel (MPa)

G - the shear modulus of steel (MPa)

σ - the normal stress (MPa)

τ - the shear stress (MPa)

2.2.3 Geometrical characteristics

L_0 - the calculated length of components (m)

A - the cross-sectional area (m^2)

I - the moment of inertia of cross-section (m^4)

may and the longitudinal forces is assumed to be evenly distributed across the bolt (rivet) group.

3 When the splicing of plate girder web plate uses the bolt (rivet) connection, the strength of bolt (rivet) group shall not be less than the composite strength of the net section flexural strength of the spliced web plate and the maximum shear strength.

6.1.8 High-strength bolt or rivet connection joint of axial force members shall comply with the following provisions:

1 When the limbs of a member are eccentrically connected with the gusset plate and the limbs are not connected with a batten plate in the connection area or when the limbs of a member have splice plates on only one side, the total number of bolts (rivets) shall be increased by 10 % and the force of each bolt (rivet) shall be calculated.

2 The strength of the high-strength bolts or rivets between the splice plate and the spliced part of main truss members and plate girder flanges shall not be less than the strength of the splice plate calculated by the net cross-sectional area when spliced in accordance with the net section; when spliced in accordance with the gross section and effective section, the strength shall not be less than the strength of the splice plate calculated by the gross section and effective section.

3 For individual parts of the cross-section of riveted members that are not connected directly but through other parts of the cross-section, the number of rivets shall be increased by 10 % for each plate and by 20 % for every two or more plates, but the total number of rivets may not be increased.

4 When connecting with the filler plate in the middle, and there are rivets with an area equivalent to 1/4 the area of the filler plate outside the range of joints, the number of rivets may not be increased.

6.1.9 The maximum riveting thickness of rivets shall not be larger than 4.5 times the diameter of rivet holes. When using double rivet guns, impact-type or U-shaped riveting machines for riveting, the riveting thickness may be increased to 5.5 times the aperture. If it exceeds the above thickness, the number of rivets shall be increased by 1 % each thicker 2 mm.

6.1.10 The force of pin joints may be calculated as the internal force of the member to be connected, and the following requirements are met:

1 The pinned components, whether compression or tension, shall be calculated deducting the net area of the pin hole.

2 When the length of pins is twice larger than the diameter, the pins subjected to deflection may be approximately calculated by the simply supported beam, assuming that each concentrated force acts on the axis of each slat contacting the pin.

6.1.11 In pined joints, for tension members with pin holes, the dimension of pin holes shall meet the following requirements:

1 The net cross-sectional area in the direction of the vertical member axis and through the center of the pin hole shall be 40 % larger than the net area required for component calculation.

2 The cross-sectional area from the member end to the pin hole edge shall not be less than the calculated cross-sectional area of the component.

6.1.12 The difference between the diameter of pins and pin holes, if no special needs, should be as small as possible. The length of the fine processing portion of the pin body shall be 6 mm or more longer than the distance between the two outer sides of the member to be connected. Use either cap nuts or nuts with washers on both ends of pins.

6.1.13 When using threaded connection, the shear strength, bending strength of threads shall be calculated, and the tensile strength of thread members is calculated according to the minimum cross-section.

The material of real round steel suspension members shall adopt 35CrMo round steel. The fitting accuracy of threads shall meet the requirements of 8H/7e in GB/T 5796.4. The thread height increases gradually from the first row to the rear several rows, forming a gentle vertical slope. The shape and the surface process state of the thread shall be set to minimize the local stress. The back end of threads shall use backup nuts.

6.2 Welding connection

6.2.1 For main components, discontinuous welding, plug welding and slot welding shall not be used.

6.2.2 For butt welds, it shall ensure complete penetration of the weld root. In tension or tension and compression joints, the weld surface shall be machined along the direction of the stress. When butt welds are used for plates of unequal thickness or unequal width, slope shall be made on one or both sides of the thick (wide) plate, which is not steep 1: 8 for tension or tension and compression joints, and is not steep 1: 4 for compression joints. The weld surface shall be machined along the direction of the stress to have uniform transition. Do not use butt joints that have both of these transitions in thickness and width.

6.2.3 The calculated thickness of welds shall comply with the following provisions:

7 Bridge floor systems and bracing systems

7.1 Bridge floor systems

7.1.1 The steel bridge should adopt the overall bridge floor, and bridges for passenger-freight railways with a speed of 160 km/h and below and heavy haul railways may adopt the open steel gird floor. The center to center distance of stringers of the open steel gird floor shall not be less than 2 m. The bridge sleeper and the stringer (plate girder) shall adopt a reliable connection method and should not be connected with a hook bolt.

7.1.2 The bending moment, shear-force and reaction force of bolted, riveted stringers in the vertical plane may be calculated as the simply supported beam with a span equal to the middle distance of the cross-girder. The bending moment, shear-force and reaction force of bolted, riveted cross-girders in the vertical plane may be calculated as the simply supported beam with a span equal to the middle distance of the main beam (main truss).

7.1.3 When the connection between the web plates of the stringer and cross-girder uses angle steel, it shall meet the following requirements:

1 When there re fish-shaped plates, cow's legs or other structures capable of withstanding bending moment of the fulcrum, the connection between the stringer and the cross-girder shall be capable of withstanding the longitudinal force of the stringer and the fulcrum bending moment, which is 0.6 times the mid-span bending moment of the stringer. The number of bolts (rivets) on the vertical angle steel limb connected to the cross-girder's web plate shall be calculated as 10 % increase of the simple supported reaction force.

2 When there is no structure subjected to fulcrum bending moment, the number of bolts (rivets) on the vertical angle steel limb connected to the stringer shall be calculated as 20 % increase of the simple supported reaction force, and the number of bolts (rivets) on the vertical angle steel limb connected to the cross-girder shall be calculated as 40 % increase of the simple supported reaction force.

7.1.4 When the overall steel bridge floor structure is calculated, the bridge floor servers as the upper flange of the stringer (stiffener) and the cross-girder (stiffener), it shall take into account the effects of shear lag. The effective width of the steel bridge floor is b_e ($\lambda_1 + \lambda_2$), where λ_1 is the effective width of the extending part on one side and λ_2 is the effective width of half of the center line of the main beam. The value of λ_1, λ_2 shall meet the following requirements:

1 The value of λ_1, λ_2 of simply supported beams or continuous beams may be taken according to the following equations:

bolts (rivets) on the vertical angle steel limb connected to the cross-girder shall be calculated as 10 % increase of the simple supported reaction force, and the number of bolts (rivets) on the vertical angle steel limb connected to the main beam (main truss) shall be calculated as 20 % increase of the fulcrum reaction force. For double-track and composite beams, this shall be determined according to the calculation.

2 Where there is a structure capable of supporting the fulcrum moment, then all the bending moment is borne by the structure and the number of pegs on the vertical angle steel limb connecting the beam and the main girder (main girder) is still increased by the fulcrum reaction force 10 % Calculation.

7.1.6 When the cross-girder involves in the calculation of the lateral frame, it shall comply with the following provisions:

1 When the cross-girder servers as a part of the frame or half-frame, the fulcrum bending moment can be calculated in accordance with appendix B.

2 For cross-girders of half-through steel beams, the additional bending moment caused due to the horizontal resistance of the lateral half-frame shall be taken into account and shall be calculated as the main combination. This horizontal resistance acts on the cross-sectional center of gravity of the compression flange (or chord member) in the direction towards the half-frame; the size is 1 % of the longitudinal force of the compression flange (or compression chord member).

3 When the cross-girder is also serves as the support member at the lateral bracing system, it shall also consider the force it bears as the support member.

7.1.7 In the calculation of bridge floor system, in addition to having to calculate in the case of separate load of the stringer and the cross-girder, it shall also calculate the stringer’s axial force and the cross-girder’s bending moment caused by the joint force with the main truss chord member or the main beam flange, which shall comply with the following provisions:

1 When calculated in the case of joint force, the eccentricity of each component at the same elevation may not be taken into account, and it may be assumed that the stringer is hinged to the cross-girder, and the cross-girder is fixedly connected to the center of the panel point of the main beam (main girder).

2 The plane longitudinal bracing system pf the bridge span should not be directly connected with the stringer. When a single-track simply supported bridge-span is not directly connected with the stringer, it may be approximately calculated by the method listed in appendix C.

3 The allowable stress increase factor of the stringer may be 1.2; the allowable stress increase factor of the cross-girder may be 1.7.

4 When the bridge floor system and the main truss chord member adopt the same type of steel and the continuous length does not exceed 80 m, the influence of the joint effect of the bridge floor system and the main truss may be ignored.

7.1.8 When the allowable stress is increased by 20 %, the bridge floor system shall be basically the same with the carrying capacity of the main truss.

7.2 Setting of bracing systems

7.2.1 For steel beams, the longitudinal and lateral bracings shall be reinforced; for non-integral bridge floors, the upper the lower plane longitudinal bracing system shall be set. The main truss (main beam)'s longitudinal bracing system should not use triangular truss, and its member shall adopt I-shaped section.

7.2.2 The lateral bracing of steel beams shall be set according to the following provisions:

1 For deck plate girders, in addition to the reinforced lateral bracing system set at the, it shall also set the lateral bracing system between spans, with the spacing of not larger than 4 m.

2 For through truss girders, it shall set suitable lateral bracing systems and reinforced portal frame.

3 For half-through beams (trusses), it shall set half-frame on the vertical plane of each cross-girder. The calculation of lateral half-frame shall take into account the effects of horizontal resistance and may be in accordance with the provisions of Article 7.1.6.

4 The lateral bracing system of stringer shall be connected with the upper and lower flange of the stringer. When the lateral bracing system of the plate girder and the stringer is welded to the vertical stiffener, the stiffener shall be connected to the compression flange of the plate girder/stringer.

7.2.3 For the calculation the truss-type bracing system, it may determine the internal force assuming that the panel point is hinged. For longitudinal bracing system' members, it shall calculate the bending moment due to their own weight, and the bending moment shall be calculated as a simply supported beam of equal span length.

7.2.4 The longitudinal bracing system shall be calculated with lateral horizontal force. When setting the upper and lower longitudinal bracing systems, the distribution factors of the lateral horizontal force shall be in accordance with Table 7.2.4.

8 Steel plate girders

8.0.1 The lateral width of the simply supported steel plate girder (the center distance of two main girders) shall not be less than 1/15 of the span and shall not be less than 2.2 m.

8.0.2 The riveted plate girder supporting the bridge sleeper shall have at least a layer of cover plate to cover the entire length of the upper flange. If the rest of the cover plate is interrupted within the span, the actual cut-off point shall extend beyond the theoretical cut-off point and the rivets arranged within this length shall not be less than three rows.

8.0.3 When the outer cover plate of the welded plate girder is interrupted, it shall extend beyond the theoretical cut-off point, and the length of its extension shall be determined by calculation. After the outer cover plate is interrupted, the plate end shall be processed along the width direction of the plate into a slope not steep 1: 4, and processed along the thickness direction into a slope not steep 1: 8; the width of its end should not be less than 20 mm, and the thickness may be 2 mm higher than the weld leg.

8.0.4 For the riveted or welded plate girder supporting the bridge sleeper, the width of the upper flange should not be less than 240 mm. The ratio of the extension length to the thickness of the flange plate of the welded plate girder (from the center of the web plate) shall not exceed 10.

8.0.5 For the plate girder, paired vertical stiffeners shall be set at the end support and at where delivery and concentrate external forces. The extension limbs of stiffeners shall be polished tightly with the supporting flange of the girder. The setting of stiffeners shall also comply with the following provisions:

1 The ratio of the width and the thickness of the extension limb of the supporting stiffener shall not exceed 12.

2 The supporting stiffener shall be designed according to the compression member. The cross section of the stiffener shall be stiffener plus the web plate with a thickness of not more than 15 times the thickness of the web plate on each side. The calculated length shall be 0.7 times the spacing between the two upper and lower panel points of the lateral coupling system at the support.

3 For the supporting stiffener, it shall calculate the supporting pressure of the tight part of its extension limbs and wings.

8.0.6 The setting of middle vertical stiffeners and horizontal stiffeners of web plates of simply supported plate girders shall comply with the following provisions:

9 Steel truss beams

9.0.1 For the side span of simply supported truss beam and continuous truss beam, the ratio of the width to the span should not be less than 1/20. For the span of continuous truss beam, the ratio of the width to the span should not be less than 1/25.

9.0.2 The center line of truss members shall meet at the panel point center at each panel point, otherwise eccentricity influence shall be considered. When the bearing hinge point and the center line of chord member is not at the same height, eccentricity influence of longitudinal force to the panel point shall be considered.

9.0.3 The axial force of truss members can be calculated assuming that the panel points are hinged. When the ratio of the section height to the section length of main truss members is larger than 1/15 in continuous truss beams and larger than 1/10 in simply supported truss beams, the secondary stress due to panel point rigidity shall be calculated.

9.0.4 In trusses, the axial force and bending moment, generated when the cross-girder is subject to vertical load, of the suspension member or column which forms the closed frame with the cross-girder, sway bracing or buttress bracing, shall be calculated. The bending moment may be calculated according to appendix B.

9.0.5 For the main truss diagonal or vertical members used as portal frame leg member, it shall calculate the axial force and bending moment when the portal frame is subject to the lateral force. The calculation assumption and the position of the bending moment zero point on the leg member may be determined in accordance with 7.2.11. When the portal frame leg member is the main truss diagonal strut, for the main truss chord member, it shall calculate the axial force of the leg member produced when the portal frame is subject to the lateral force.

9.0.6 In design, the basic allowable stress shall be increased by 20 %. The ability of all the main members in the bridge superstructure to bear excessive live load shall be basically the same. The internal force of these members generated by the live load are multiplied by the live load development coefficient η or calculated according to the test load of the corresponding bridge span when calculating the main force combination. η may be calculated as follows:

$$\eta = 1 + \frac{1}{6}(\alpha_m - \alpha) \qquad (9.0.6)$$

where

α - the ratio of the dead load internal force of members to the live load internal force including the impact force;

------ The End ------