Overview of the Standard Weather-resistant Steel High-Strength Bolts for Steel Structures

《钢结构用耐候钢高强度螺栓连接副》标准简述

Brief Description of the Standard

With the development of bridge construction in China, many coastal and sea-crossing bridge projects are under construction. As the environment where the bridges are located is highly chloride corrosive, the use of conventional alloy steel is limited and the demand for atmospheric corrosion-resistant bridge steel continues to increase. Since the U.S. weather-resistant steel high-strength bolts cannot guarantee the torque coefficient, making them unable to meet the requirements of China's torque method of construction, and the alloy compositions of Japan's weather-resistant steel high-strength bolts mismatch with China's weather-resistant bridge steel, so it cannot be solved through purely importing bolts, which also implies the need for R&D. Nowadays, there is no domestic standard for "Weather-resistant Steel High Strength Bolts for Steel Structures", and many bridge designers and manufacturers are not clear about the performance indexes of this steel and how to use it. Therefore, **in order to meet the needs of the domestic and international market and production of bridge steel for corrosion-resistant atmospheric environments, and on the basis of domestic and foreign standards, technical data, actual product supply technical agreements and test results, the National Technical Committee for Standardization of Fasteners took the lead in preparation of the national standard " Weather-resistant Steel High-Strength Bolts for Steel Structures" in order to further standardize and improve the quality of the products in real terms.**

The standard is one of the projects proposed in the field of fasteners in the construction of the national standards system to further improve the existing national standards for fasteners and provide technical basis for the design and selection of weather-resistant steel fasteners and production. **The standard specifies types, dimensions, technical requirements, test methods, acceptance inspection, marking, quality certification, packaging, transportation and storage of weather-resistant steel high-strength bolts for steel structures with thread specifications from M12 to M36 and performance grades NH8.8S/NH8H and NH10.9S/NH10H; and establishes the requirements for the mechanical and physical properties of the weather-resistant steel fasteners, which are subject to long-term penetration by water, oxygen, salts and acids formed by ions such as H+, O2-, Cl-, and solves the problem of resistance to atmospheric corrosion and delayed fracture of high-strength fasteners.** Weather-resistant steel fasteners are mostly used in remote/uninhabited areas and maintenance-free application scenarios, and are required to be used with mated parts, which increase the reliability of fastener connection and meet the requirements for steel structural bridges, power towers, infrastructure facilities and many other industries.

Types

Currently, weather-resistant steel products are mostly used in remote/uninhabited areas and maintenance-free application scenarios, which are required to be used with the mating materials and mostly applied to infrastructure such as steel bridges and power towers, etc. Therefore, the product category has been limited to weather-resistant steel high-strength bolts for steel structures of the performance grades NH8.8S/NH8H and NH10.9S/NH10H. Weather-resistant steel high-strength bolts for steel structures consist of high-strength bolts, nuts and washers made of weather-resistant steel. Weather-resistant high-strength bolts for steel structures consist of one bolt, one nut and one/two washers, with dimensions according to GB/T 1228-1230, GB/T 3632, GB/T 32076.3- GB/T 32076.6, GB/T 32076.8, GB/T 32076.9 and other product standards.

Materials

In the national standards development process, Chinese Steel Industry Association, Steel Structure Association, the Federation of Power Enterprises and other organizations have released their weather-resistant steel and fasteners related group standards. Taking the wide range of standard applications into account, the differences of material systems adopted by standards, as well as the reliability of

material application practices and other factors, and reference to the requirements of ASTM F3125/F3125M-2022type3 for corrosion-resistant chemical compositions, weather-resistant steel high-strength bolts, nuts and washers should be used with the same chemical compositions of materials, and chemical compositions (melting analysis) limits should be in line with the provisions of **Table 1**, the permissible deviation of chemical compositions of finished products should be in line with the provisions of GB / T 222.

The material should have sufficient hardenability and about 90% martensite after quenching and before tempering. The corrosion resistance index "I" of the weather resistant steel for connecting parts calculated according to the chemical composition of the material in accordance with GB/T 4171 shall be not less than the corrosion resistance index of the component steel and shall be not less than 6.0. On the premise that the upper and lower limits of the C content comply with the basic requirements of GB/T 3098.1, and integrating the material requirements of weather-resistant steels in the standards of the organizations such as T/CISA193 and T/CEC305.4-2020, the information on the chemical compositions of other materials of weather-resistant high-strength bolts is given as an appendix.

Table 1. Chemical Compositions of Weather-resistant Steel for Bolts/Nuts/Washers

Chemical Compositions（Quality Scores）%								Lowest Tempering Temp./℃
C	Mn	P	S	Cu	Ni	Cr	Mo	
0.30～0.52	≥0.60	≤0.025	≤0.025	0.20～0.60	≥0.20	≥0.45	≥0.10	425

Mechanical Performance

Considering the use of weather-resistant high-strength bolts for steel structures, the mechanical properties are harmonized with the product standards GB/T 1231, GB/T 3632, GB/T 32076.3 to 32076.6, GB/T 32076.8 and GB/T 32076.9. Mechanical properties of bolts are shown in **Table 2**, With reference to ASTM F3125/F3125M-2022, the tensile strength of NH10.9S grade ranges from 1040 to 1190 MPa, and the upper limit value of 1240 MPa in GB/T 1231-2006 is not used; the section shrinkage rate is according to GB/T 3098.1, and the others are according to GB/T 3632; the Rockwell hardness and Vickers hardness are in line with GB/T 1231-2006. Rockwell hardness and Vickers hardness are basically consistent with GB/T 1231-2006.

Table 2. Mechanical Properties of Bolts

Performance Levels	Tensile Strength Rm / MPa	RP0.2 / MPa min	Elongation at Break of Machined Test Piece A/ % min	Section Shrinkage of Machined Test Piece Z / % min	Energy Absorption KV2 / J —20℃ min	Hardness	
						HV30	HRC
NH8.8S	830～1030	660	12	52	27	249～296	23～31
NH10.9S	1040～1190	940	10	48	27	312～367	32～38

The decarburized layer is required to comply with GB/T 3098.1 (Gr.10.9), and the height of the non-decarburized layer of the thread of the bolt made of weather-resistant steel is E ≥ 2/3H1 (H1 - the height of external threads under the maximum physical conditions); the depth of the fully decarburized layer of the thread is G ≤ 0.015 mm. The torque coefficient of the connecting part of the weather-resistant high-strength large-hexagon bolts used for steel structures is according to GB/T1231, the average value of torque coefficients of the connecting part of the same batch is 0.110～0.150, and the standard deviation of the torque coefficient should be not more than 0.0100. The tightening axis force of high strength weather-resistant torsion-shear bolts for steel structures is in line with GB/T 32076.8, which is calculated by taking the nominal value of tensile strength (1000 Mpa) for grade 10.9 in GB/T 3098.1 as Rm, and the coefficient of variation of the tightening axis force should be less than or equal to 0.10 (coefficient of variation= standard deviation/ average value). Adopting the coefficient of variation of the tightening axis force to determine its dispersion avoids the influence of the specification on the standard deviation.

History of Standards

Weather-resistant steel is created based on ordinary low alloy steel and is added with appropriate amounts of Cu, Cr, Ni and other alloying elements to form a dense and stable surface layer to prevent it from rust and the penetration of H+, O2-, Cl- and other ions formed by oxygen, water, salts and acids in the atmosphere, significantly improving the corrosion resistance of weather-resistant steel. **Weather-resistant steel can be used "without painting" in certain environments such as "good ventilation and drainage, alternating wet and dry conditions, low salinity, and weak acidity". Compared with the traditional "ordinary steel structure + painting" solution, the "weather-resistant steel structure + paint-free" solution has the advantages of lower composite cost, shorter construction cycle, and obvious green and environmental protection**, with significant economic and social benefits. As the development direction of high-performance steel, weather-resistant steel has been widely used overseas. The U.S. has more than 10,000 paint-free weather-resistant steel bridges, and most of the nearly 30 steel bridges added each year are made of weather-resistant steel, which has formed systematic weather-resistant steel, welding materials, high-strength bolts, design, material selection, manufacturing, maintenance and other mature

technologies and standards. Japan, Canada and W. Europe have also widely developed and applied similar technologies.

The development of the standard " Weather-resistant High-Strength Bolts for Steel Structures" plays an active role in improving and optimizing the system of fastener standards, leading the professional production of fasteners, improving the product grade and meeting the market demand, filling in the gaps in the field of technical specification of weather-resistant steel high-strength fasteners and driving the technological progress of the relevant industries, improving the safety of bridges and high-speed trains, and boosting the bridge construction of high-speed rail, railways, and highways.

The requirements of this standard are similar to other international standards. For example, the U.S., Japan and other countries have mandatory requirements for the use of weather-resistant high-strength bolts in weather-resistant steel bridges, and have formulated corresponding material and use specifications. Weather-resistant high-strength bolts commonly used in weather-resistant steel bridges in the U.S., with strength grades equivalent to Chinese standards 8.8S and 10.9S, should comply with ASTM F3125/F3125M-2020 "Heat-treated high strength bolts made of steels and alloy steels with minimum tensile strengths of 120ksi (830MPa) and 150ksi (1040MPa) in both inch and metric dimensions." The standard requires that the steel used for weather-resistant high-strength bolts should be added with sufficient amount of Cu (0.17%-0.63wt%), Cr (0.42%-1.05wt%), and Ni (0.17%-0.83wt%), in order to make the weather resistance conform to the provisions of ASTM A709 for high-performance weather-resistant steel (HPS 50/70W) for bridges. The installation and construction method of the weather-resistant high-strength bolts should also comply with the "Specification for Structural Joints Using ASTM A325 or A490 Bolts" formulated by the Structural Connections Council of the American Institute of Steel Construction. In addition, for the use of weather-resistant bolts in different environments, the following surface treatment programs are recommended: weather-resistant bolts without surface treatment can be used in areas with mild and dry climate; **weather-resistant bolts with blackening treatment are permitted for unpainted weather-resistant steel bridges; weather-resistant bolts with surface treatment, Dacromet or polymer coating are recommended for areas with complicated climate conditions.**

Although there is no national standard for steel structure weather-resistant bolts in Japan, some local major steel companies have developed a steel structure with weather-resistant bolts. The composition and performance requirements for weather resistant high strength bolts commonly used in steel bridges are comparable to ASTM F3125/F3125M-2020. The R&D of Japan's weather-resistant bolts is mainly based on the JIS B 1186 standard "High-strength Hexagonal Bolts, Hexagonal Nuts and Flat Washers." In recent years, it has also developed high-strength bolts with weather resistance and anti-delayed fracture features. Among these bolts, the ones with excellent weather resistance include New Nippon Steel's NWB110, Kobe Steel's KHB10W and JFE's weather-resistant steel for high-strength bolts, while the ones with good anti-delayed fracture resistance include Sumitomo Metal's ADS series and Kobe Steel's KNDS series, whose strength grade is 10.9S. The U.S. and Japan, with years of experience in the construction of weather-resistant steel bridges, have established a sound standard system. However, the relevant technical data and info about weather resistant steel high-strength bolts are still stuck in the 1990s. At present, China often refers to U.S. standards when it comes to weather-resistant steel bridges and relevant technology, such as design details, corrosion resistance index and so on.

Conclusion

The "Weather-resistant Steel High Strength Bolts for Steel Structures" standard is one of the projects proposed in the field of fasteners in the construction of the national standards system to further improve the existing national standards for fasteners and to provide a technical basis for the design, selection and production of weather-resistant steel fasteners. The standard specifies the mechanical and physical property requirements of weather-resistant steel fasteners and solves the problems of atmospheric corrosion resistance and delayed fracture for high-strength fasteners that have been subjected to long-term penetration of H+, O2-, Cl-, and other ions formed in the environment by water, oxygen, salts, and acids, and increases the reliability of the fastener connection to satisfy the requirements for the use in the steel structure of bridges, power towers, and other infrastructural facilities in the industry. The construction of weather-resistant steel bridges in China started relatively late; however, with the rapid development of national economy and the deepening of foreign technical exchanges, the application of high-performance weather-resistant steel to steel bridges has attracted the attention of relevant departments in China, but there are some technical problems that need to be solved. With standardization and improvement of the technology for the construction of weather-resistant steel bridges, relevant scientific research institutions in China should strengthen the basic research and start long time exposure corrosion test according to the climate characteristics of different regions in order to accumulate more basic information to determine what type of weather-resistant steel bridges best fits Chinese climate and formulate application guidelines for high-strength bolts. The construction of uncoated weather-resistant steel bridges in suitable areas shows environmentally friendly and lower life-cycle cost advantages, which has a broad development prospect. ◘