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SURVEY OF STRUCTURAL STEEL USED IN MAJOR CONSTRUCTION PROJECTS

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Abstract

Beginning with a brief survey of the development of China's steel structure industry, this paper gives an account of the requirements for and features of the structural steel applied in large construction projects by taking the National Stadium (Bird Nest) and the new CCTV tower and the new Guangzhou TV tower as examples, and presents new requirements for production in steel mills in light of the status of materials used for steel structures both at home and abroad and ends with suggestions on the selection of materials in designing.

Fast Growth of China's Steel Structure

China's economy is enjoying sustained growth at a rate of over 10%. The construction industry has become a pillar of the national economy. In 2005, the added value of the construction industry accounted for some 5.5% of the GDP. The 2007 steel output was 467.19 million tons (excluding repetitive steel), and the per capita consumption of steel was over 300 kilograms. The amount, variety and quality of construction steel are capable of meeting the growth requirements of the steel structure industry.

Starting from zero, the output of hot-rolled H sections produced by Ma Gang, Lai Gang and Rizhao reached over 5 million tons in 2006. The yield of color-coated plates of 2006 reached over 5 million tons. The output of medium/thick plates has been increasing year over year, reaching 35 million tons in 2006 and even more this year. Other sections, tubular products, high-frequency welding H sections, cold-bent sections and coated plates used in steel structures have all witnessed marked growth.

Steel structure has witnessed fast growth, with the scope and amount of applications ever increasing.
There have appeared throughout China in recent years a number of steel structure design and research institutes, specializing in structural design and detail drawing design of steel structures as well as consultancy work. A lot of excellent steel structure designs, design software and R&D results have emerged. Revision has been done to the criteria for the design and check-and-acceptance quality control of steel structures. Over a hundred books of technical rules and design

drawings have been compiled. Institutes of higher education attach importance to the development of the steel structure discipline, augmenting the teaching force, increasing the number of MA and PhD students, closely integrating teaching with practice in projects, publishing textbooks, theses, monographs and handbooks and engaging in academic exchanges.

According to the criteria of China Steel Construction Society (CSCS), thirty-two Special Class (annual output exceeding 50,000 tons) steel structure manufacturers of high-quality members and excellent management are leading the industry, some of them having an annual capacity exceeding 300,000 tons. Most of their products are used in major domestic projects and some are exported. Their production technology and quality match up to advanced international standards. Forty-three first class steel structure manufacturers (annual capacity of 12,000-15,000 tons) are processing steel structures used in large and medium-sized projects, witnessing good progress both in output and quality. A large number (nearly a thousand) of small and medium-sized enterprises are playing unique roles of their own, meeting the demand in the domestic market. The steel structure processing industry is now in a good situation with manufacturers competing to continuously improve.

A great number of steel structure installers have undertaken the installation of steel structures in large projects in China. New technologies, new processes and new equipment keep emerging and their installation meets advanced international standards. There are adequate accessory products for steel structures (high-strength bolts, bolt pins, special welding materials, connecting parts as well as heat preservation and insulation materials). With manufacturers of processing equipment growing quickly, the needs of the steel structure industry have been met. Table 1 below shows China's total amount of structural steels and the forecast. (These statistics includes industrial and civilian buildings, railway and highway bridges, hydro- and fire-power projects, urban construction).

Table 1. Total amount of steel structure and forecast.

Year	2002	2004	2005	2006	2007	2010
Quantity (Million Ton)	8.50	14.00	15.80	17.38	20.00	26.00
Percentage of Steel Used in Reinforced Concrete Structure (%)	7.9	8.5	9.94	9.61		11.2
Percentage of Steel Output	4.3	4.8	4.26	4.12	4.28	5.5

The following classifications are defined within Table 1: (1) Classified by the products of 46 steel structure processors (2007 statistics) - Industrial workshops 34%, multi-storey (<7 storey) 8.7%, high rise 13.1%, public buildings 9.0%, bridges 8.5%, non-standard steel structure 17.2%, other buildings 9.5%; (2) Classified by the proportion of various steel used by steel structure processors - Medium/thick plates (including very thick plates) 70.9%, hot rolled H sections 15.5%, color coated (including galvanized plates) 3.8%, tubular products 6.4%, other sections and cold bent sections 3.4%; (3) Classified by the strength of steel used by steel structure processors - Q235 27.4%, Q345 66.4%, Q390 2.0%, Q420 3.0%, Q460 1.2% (not much of Q420

and Q460 high strength steel is used); (4) Classified by the location of steel structure processors - High concentration in Shanghai, Zhejiang, Jiangsu and the Yangzi River Delta areas, where steel structure output reached 4.50 million tons in 2004 accounting for 1/3 of the national total. Another 1/3 is in Hebei, Shandong, Beijing, Tianjin and the Bohai Bay area. And next come Guangzhou, Shenzhen, the Pearl River Delta region and the North-eastern and Midwestern regions.

If calculated according to the proportion of national economic growth and if the output of steel structure is calculated at 10% annual increase, it reached 20 million tons in 2007. In light of the current economic growth rate, the estimate of 26 million tons of steel structure output in 2010 will be exceeded.

Government Policy Guidance and Structural Steel Development Support

The government has improved policy guidance and support to structural steel development relevant national industry standards and codes concerning the steel, design, manufacturing and construction of steel structures have been compiled and revised. Standards have been developed such as System of Indicators for Assessment of Performance of Residential Buildings, Public Building Energy Conservation Design Standard and Technical Standards for Construction of Healthy Residential Buildings. The Ministry of Construction has developed a 2010 Policy Guide to Technology of Construction Undertakings and released it at the end of 2001 along with the Technical Guide to Industrialization of Construction of Steel Structure Residential Buildings.

The compliation of the “11.5” steel structure development goals is also very important. Active efforts have been taken to increase the variety of steel used in steel structures and improve product performance. R&D is in progress concerning high-performance steel product series used specially in construction, including quality welded steel structures, high strength quality thick plates, hot-moulded tubular products, quality weldable cast steel. The variety and specifications are being expanded with regard to cold bent sections and hot-rolled H sections, including large-section cold bent tubular products, large-section H sections and light H sections. Rational promotion is under way for the use of weathering steel, fire-proof steel, Z-direction steel and flux-cored electrode (welding rods). By 2010, we will achieve the objective that steel used in steel structures will be made in China.

Development of steel structures is being greatly promoted and applied technologies are being further improved. High-rise and super high-rise buildings will prefer the use of rational steel structure or steel-concrete structure systems. Large-span buildings will actively adopt space lattice structures, three-dimensional truss structures, cable-membrane structures and pre-stressed structure systems. The use of economical and applicable light steel structure systems is greatly encouraged in low rise buildings. Building on pilot experience and in light of market demand, we shall take active measures to develop steel structure residential building systems and gradually commercialize them.

By 2010, the amount of steel used in steel structures will be encouraged to increase to 6% of the total national steel output. And the comprehensive technological level concerning steel structures shall catch up with or exceed the advanced international level.

General Consensus

A consensus has emerged to emphasize and develop steel structure buildings. Steel structure buildings are a new construction system that is energy conserving and environment-friendly, which is promoted as one of the "green building" systems of the 21st century. This type of building has a structure that can be recycled in use, which is in accordance with the requirement for buildings that save land and energy and contribute to sustainable economic growth.

The advantages of steel structures are better demonstrated in high-rise buildings, large-scale factory works, large span space structures, communications and energy projects, as well as residential buildings. The investigation done after the Wenchuan earthquake in China has once again proved that steel structures have better seismic performance. Therefore, we may well say that a consensus has emerged to encourage the development of steel structure buildings.

Steel Used in the National Stadium (Bird Nest)

The steel structure of the house roofing of the National Stadium (Bird Nest) is in the form of a hyperboloid saddle, with the highest point being 68.5m, and the lowest point 40.1m; the plane figure appears in oval shape, with the long axis being 332.3m and the short 297.3m; the inner ring of the opening in the middle of the roof is in oval shape, with the long axis being 185.3m and the short 127.5m; the long-span roof is supported by 24 column trusses that are 38.0m apart from each other. There are 24 portal steel frames circling around the concrete spectators bowl inside the stadium. The steel structure, shown in Figure 1 below, uses a large number of box-section members of welded steel plates, and the intercrossing primary and the secondary structures of the house roofing and elevation intertwine with each other, woven into the appearance of a "bird nest".

Figure 1. National stadium (Bird Nest).

All of the primary structures of the roof are of box sections, with the sections of the upper chords being basically 1000mmX1000mm, those of the lower chords 800mmX800mm and those of web

members 600mmX600mm; the web members and the upper and lower chords are linked and pass through each other, with the span height of the roof trusses being 12.0m. Vertically there are 24 composite steel structure columns supporting the roof; each of the composite steel structure columns consists of two 1200mmX1200mm external box-section columns and one internal diamond-shaped column; there is a T shaped steel column base for each of the column trusses, through which the load is transferred to the foundation. The section of the elevation secondary structure is basically 1200mmX1200mm and that of the roof surface secondary structure is basically 1000mmX1000mm.

The designed total amount of steel was some 42,000 tons. See Table 2 for details. The maximum thickness of the steel plates is 110mm. Q345 steel is used when the thickness of the steel plate is ≤34mm; Q345GJ steel when steel plate is ≥36mm; Q345GJ and Q460 steel when100mm thick; Q460 steel when110mm thick. All of the above lines of steel are low-alloy and high-strength niobium steels, with excellent mechanical properties and weldability. In addition, GS-20Mn5V cast steel members are used at the place where the internal column of the column trusses transfers from its diamond section to rectangular section (except C19 column trusses). The maximum thickness of the cast steel members is 140mm. The design has put forward explicit requirements for the anti-tear performance and impact toughness of the steel to be used.

Table 2. Bird Nest steel details.

Strength	Plate thickness (mm)	Weight (t)	Strength	Plate thickness (mm)	Weight (t、)
Q345C Q345D	10	6749	Q345GJ	42-Z15	1584
	12	1638		50-Z15	1329
	14	2136		60-Z25	647
	16	5435		70-Z25	538
	18	1940		80-Z35	330
	20	9920		90-Z35	558
	25	4023	Q460 E	110-Z35	350
	30	1929	Total		About 42000
	36	2181		Cast steel GS-20Mn5V	

This project is the first to use high-strength high-performance Q460 E-Z35 steel produced by domestic-manufacturers. Due to the box-section crankle members and the multi-directional micro crankle nodes, there occurred more waste of the steel and therefore, the actual total amount of steel used is 48,000 tons. In the National Stadium project, high-strength and high-

performance Q460E-Z35 steel produced by domestic manufacturers is used and the steelmaking technology is up to advanced international steel producing levels.

Due to the lack of data and experience in applying Q460E-Z35 thick plates in stadiums both at home and abroad, there were some key technical problems to be tackled in light of the National Stadium design requirements. Wuyang Iron and Steel produced Q460E-Z35 thick plate industrial trial heats that satisfied engineering requirements for the steel structures of the National Stadium. The manufacturers and construction contractors developed a set of practical techniques for heat processing and welding of the Q460E-Z35 thick plates, which ensured the smooth construction of the National Stadium steel structures. The following work was done: 1) trial production of Q460E-Z35 thick plate; 2) test research into the heat processing and weldability of Q460E-Z35 thick plate; 3) assessment test of the welding processes of Q460E-Z35 thick plate; 4) applied research into the welding of Q460E-Z35 thick plates used in the National Stadium steel structure.

In addition, large complex cast steel nodes are used in the design of the steel structures of the National Stadium. High-strength cast steel members as thick as 110mm are used at the juncture where diamond columns are joined to the box-section column foot to achieve the transfer of different sections. These cast steel members need to be welded to Q345 steel or Q460 pole members. Based on previous experience, cast steel GS20Mn5V, which is of high toughness, low sulphur and phosphorous and good weldability, was used. But pre-heating is still necessary before welding. The use of low hydrogen welding material for multi-layer and multi-welding will need post-heat preserving slow cooling when the plate is over 40mm thick. This is one of the difficulties of the project. With tests and research and engineering practices, the tie-in performance of the welding of GS20Mn5V cast steel and Q460 and Q345 steels satisfied the design requirements. The precision of the measurement of the nodes met the requirements of the check and acceptance criteria. These technologies have reached advanced international level.

Steel Used in the Main Building of New CCTV Station

The main building of the new CCTV station consists of two towers, a podium and the pedestal, plus a basement of three floors. Figure 2 below shows the CCTV structure.

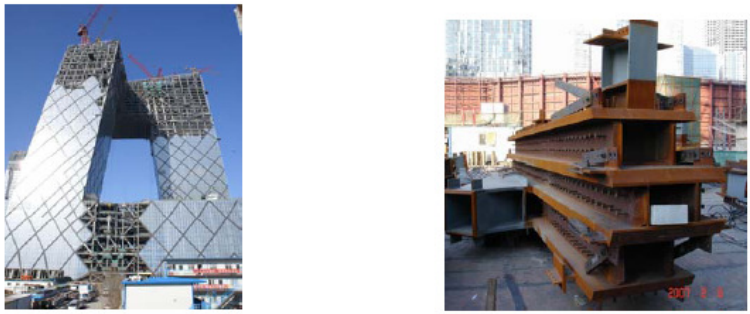

Figure 2. New CCTV Station.

The total floor area above ground is 400,000m^2. The two towers are tilted with 51 and 54 floors respectively. They are connected into one body at the top by a cantilever of 14 floors. The maximum height is 234 meters. The podium is of 9 floors and is connected to the towers. The steel used in the steel structure of the CCTV main building is large in amount, varied in specifications and types, and great in strength. The total amount of steel used in the steel structure is as much as 130,000 tons and the number of members totaled 41,500 pieces (Table 3). The main types of steel include: Q235C, Q345C, 390D (only for the 13 underground built-in columns), Q345GJ, Q420, and Q460, of which steel plates over 40mm amounted to 75,274 tons, accounting for 61.8% of the total volume. The thickness of Q420 and Q460 plates is 110mm, 100mm and 80mm. 4,900 tons of Q420 steel is used and 3,600 tons of Q460. In addition, there are also 296,000m² of profiling steel plates (t=0.9mm galvanized steel plate, the galvanized thickness being 275g/m²), 1,150,000 sets of high-strength bolts, 2,275,000 sets of bolt pins, 567,000m² of fire-retardant paint and about 100 tons of pre-stressed anchor bolts (M75).

Table 3. Structural steel tonnage.

S/N	Specifications and texture	Quantity (unit: t)
1	Section Q345C	16880
2	Plate Q345C	34730
3	Plate Q345GJC	69869
4	Plate Q420D	4900
5	Plate Q460D	3600
6	Total	129979

Considering the importance of this project, the seismic performance and super high-rise architecture factors are critical. The design exerts the following requirements on the structural steel.

1) The quality of Q345, Q390 and Q420 steel shall respectively conform to the provisions of current national standards "Carbon Structural Steel" GB /T700-2004 and "Low-alloy and High-strength Structural Steel" GB/T1591-1994 and shall also be qualified in terms of tensile strength, elongation ratio, yield strength, yield point, content of sulphur and phosphorous and carbon, cold bending test, as well as impact ductility.

2) The ratio of the measured value of tensile strength to that of yield strength of the steel shall not be less than 1.2 and the steel shall have an obvious yield plateau with the elongation being greater than 20%.

3) The carbon equivalent Ceq, welding crack sensitivity index Pcm and yield strength variation range shall conform to the provisions of “Steel Plate Used for Building Structures” (GB/T19987-2005).

4) Weld joint nodes are adopted. When the steel plate is ≥40mm in thickness and withstands the

through-thickness tension, there shall be an additional requirement for through-thickness area reduction in accordance with the provisions of the current national standards "Through-thickness Property Steel Plate" (GB/T5313-1995). Relevant steel product standards have prescriptions for the Z-direction performance level.

5) The delivery state of Q235 and Q345 steel is normalized or hot rolled. For Q345, the Z-direction property is additionally required and Q420 steel shall adopt TMCP (Thermo Mechanical Control Process state of delivery.

6) The special column of the outer cylinder structure requires Q460. As for steel plates that are ≥15mm in thickness, Z25 through-thickness property shall be additionally required to meet the current national standards "Through-thickness Property Steel Plate" (GB/T5313-1995) and the steel plate is delivered in the TMCP or accelerated cooling state.
7) For forged steel joint node, at some parts of the structure, a number of structural members intersect at the same joint node. So, solid forged steel members shall be used for connecting these joint nodes. The strength and performance of the forged steel members shall meet the highest strength level of the steel members that are connected.

8) Hot-rolled steel sections shall conform to the provisions of "Hot-rolled H Sections and Some T Sections" (GB/T 11263-1998); angle steel shall conform to GB/T9787-1998 and steel tubes to GB/T8162-99.

9) When other types of steel are used in substitution, it has to be ratified by the design unit and meet the requirements of relevant standards. Considering weldability and working temperature requirements, Q345GJC may substitute Q390D (plate thickness >50mm). The design strength of Q345GJC shall be validated by expert feasibility study before it is used in construction.

Apart from strict requirements for steel, there are also explicit requirements for welding materials used in the steel structure of the CCTV building. The strength of the weld metal shall match that of the steel of the main body. When steels of different strengths are welded, the strength of the welding material shall suit the low strength steel. The mechanical properties of the welding seam formed by welding material and welding processes shall be no lower than the grade of the original member. The quality of the welding rod used for manual welding shall conform to the provisions of "Carbon Steel Covered Electrode" (GB/T5117-1995) or "Low-Alloy Steel Covered Arc Welding Electrode" (GB/T5118-1995). E43 welding rod is suitable for Q235 steel and E50 for Q345 steel. Low-alloy E55 series of welding rods shall be chosen for Q420 steel to directly withstand the dynamic load or vibrating load. As to welded structures of thick plates, low-hydrogen alkaline welding rods or ultra-low hydrogen welding rods shall be used. The quality of the welding wire or solder used for automatic welding or semi-automatic welding shall conform to the provisions of "Steel Wires for Melt Welding" (GB/T14957-1994) or "Carbon Steel and Low-alloy Steel Welding Wire Used for Gas Shielded Arc Welding" (GB/T8110-1995), "Carbon Steel Flux-Cored Wire" (GB/T10045-2001), "Low-Alloy Steel Flux-Cored Wire" (GB/T17493), "Carbon Steel Welding Wire and Solder Used for Submerged Arc Welding" (GB/T5293), "Solder Used for Low-alloy Steel Submerged Arc Welding" (GB/T12470-1990). The argon gas or carbon dioxide gas used for shielded arc welding shall

respectively meet the current standards "Argon Gas" (GB/T4842) and "Carbon Dioxide for Welding" (HG /T2537).

In the steel structure of CCTV main building, a large amount of Q345, Q420 and S460 high-strength steel is used. The maximum thickness is 130mm. And meanwhile, there are very high requirements for the strength, ductility, seismic performance and weldability. Proper selection of steel products and their performance requirements is of great significance to the quality of the project.

After careful deliberation, it was concluded at the feasibility study hearings for this project that:

1) The performance and technical index of the Q390 steel chosen for this project satisfy the design specifications. But as this is the first time for large quantities of Q390 steel, especially large quantities of thick plates, to be used in great and important construction projects in China, there is a lack of application experience. Meanwhile, Q390 steel is general-purpose low-alloy steel. In light of the application in this particular project, it is necessary to provide an additional number of complementary technical requirements such as yield-strength-to-tensile-strength ratio (Y/T ratio), upper limit of yield strength, and carbon equivalent. In addition, Q390 steel plates require high welding standards, which do not fit in with the schedule of construction progress.

2) The Q345GJ thick plates produced in accordance with the current metallurgical industry standard YB-4104 "Steel Plate for High-Rise Buildings" possess better ductility, impact toughness and welding performance than Q390 steel and have already been successfully applied in several large major projects in China (the National Stadium and the Wukesong Cultural and Sports Center). It is concluded from analysis and comparison that the strength of Q345GJ thick plates (50mm -100mm) is equivalent to that of Q390 steel while their over-all properties are superior to those of Q390 steel. Therefore, this project may use Q345GJ in the place of Q390D. The manufacturer shall be required to guarantee a stable range of yield strength and properly increase inspection lots and frequency.

3) In light of the actual demand of the project, it is recommended that multiple channels be used for the procurement of steel products. For instance, A572-Gr50 materials can be purchased for plates over 35mm thick. However, the relevant properties and technical specifications must meet the design requirements.

(4) In selecting Q420 or Q460 (S460M) steel for this project, reference may be made to the experience of the National Stadium project.

Steel Used in Guangzhou TV New Tower (GZTV)

The GZTV new tower has 37 floors above ground and 3 floors underground. With a height of 610m (tower body 454m plus antenna pole 156m), it is so far the highest in the world. See Figure 3.

Figure 3. Guangzhou TV New Tower (GZTV)

Q345, Q345GJ and Q390GJ steel products are used for the structural members of this project, such as columns, slanted struts, ring beams, floor primary and secondary girders, beam trusses and antenna. Their quality meets the requirements of the current national standards "Low-Alloy High-strength Structural Steel" (GB/T1591-94), "Steel Plates Used for Building Structures" (GB/T19879-2005) and the materials shall be qualified in terms of tensile strength, elongation ratio, yield point, cold bending test and impact toughness. Where there are through-thickness property requirements, the requirements of "Through-thickness Property Steel Plates" (GB/T5313-85) shall be met. The Ceq and Pcm indexes of the Q345GJ and Q390GJ steel plates shall be guaranteed. The steel products shall meet the requirements of "Seismic Design Code for Buildings" (GB 50011): The ratio of the measured value of yield strength to that of tensile strength shall not be greater than 0.83 for Q345 steel and Q345GJ steel and not greater than 0.85 for Q390 steel and Q390GJ steel. The steel products shall possess an apparent yield plateau with the elongation ratio being greater than 20%. At the same time, the steel products shall have good weldability and be qualified in impact toughness and in cold bending test. The impact toughness requirements: Q345, Q345GJ and Q390GJ are all grade-C steel, which means the impact work at 0°C is not less than 34J. The through-thickness property requirements where there are through-thickness property requirements for the steel plates for thicknesses of 40mm $\leq$ t$\leq$ 60mm, the through-thickness reduction of area and content of impurity such as sulphur and phosphorus shall satisfy the value of Z15 grade specified in the national standard "Through-thickness Property Steel Plates" (GB/T5313). For round tubes and rectangle tubes, the material for round steel tubes is Q345C, Q345GJC and Q390GJC. The steel tubes are mostly straight welded pipes, while some are hot-rolled and hot-expanded seamless steel pipes. The material for rectangle steel tubes is Q345C and Q345GJC. Table 4 is the specifications and properties of the main steel members of the tower body.

Table 4. Specifications and types of main steel members of the tower body.

Description	Sectional dimension (mm)	Sectional form	Type	Weight (t)
Column	2000×50～1200×30	Round tube	Q345GJ	16940
Ring beam	CHS800×25 (30)	Round tube	Q345	1690 (544)
	CHS700×25	Round tube	Q345	416
Slanted strut	CHS850 (800)×40	Round tube	Q345GJ	2003 (2527)
	CHS850 (800)×40	Round tube	Q390GJ	1924 (674)
	CHS700×30 (40)	Round tube	Q345	1060 (697)
Joint Node	CHS1000×50	Round tube	Q345GJ	1907
Floor primary girder	H1500×500×25×50～ H600×200×11×17	H section	Q345	3708
	UC356×406×393	Section	Q345	100
	CHS600×30～ CHS400×25	Round tube	Q345	78
	RHS250×255×14×14～ RHS200×204×12×12	Rectangular tube	Q345	15
Secondary girder	HN350×175×7×11～ HN450×150×9×14	H section	Q345	520
Antenna connecting truss	RHS1500×1200×50×50～ RHS1000×500×50×50	Rectangular tube	Q345	981
Antenna	CHS1000×50～ CHS300×15	Round tube	Q345GJ	1003
	RHS 2500×2500×30×30～ RHS 1000×1000×30×30	Rectangular tube	Q345GJ	114

Features of Steel Used in Large Steel Structures

Steel structure buildings and future projects are tending towards wide span, super high-rise, high speed and heavy load, and capacity to withstand the trial of big earthquakes and all kinds of harsh environments (fire, wind, serious erosion, etc). Therefore, new requirements are put forward for the performance of steel products. The development of micro-alloyed niobium steel and its application to high-strength structures will satisfy the need for steel structures in buildings. At present, steel products used in large steel structure buildings are mostly medium/thick plates, ultra-thick plates, hot-rolled H sections, welded H sections (high frequency

welding, welding), square and rectangular tubes, round tubes (seamless, welded), galvanized sheets, color-coated plates, stranded wires and cast steel.

The standards governing these steel products are: Carbon Structural Steel (GB/T700-2004); Low-alloy High-strength Structural Steel (GB/T1591-2000); Steel Plates Used in Building Structures (GB/T19879-2005), which has replaced Steel Plate Used in High-Rise Building Structures (YB 4104-2000); Hot-Rolled H section and Cut T Section (GB/T11236-2004); High-Frequency Welded H Section with Thin Wall (JG/T137-2001); Welded H Section (YB -3301-2004); Seamless Steel Pipes Used For Structure (GB/T8162-87); Straight Electric Welded Steel Pipe (GB/T13793-92); Welded Steel Pipe Used For Low-Pressure Fluid Transport (GB/T3092-93); Cold-bent Section (GB/T6725-2002); Dimensions, Profile, Weight and Allowable Deviation of Cold-Bent Hollow Section Used for Structure (GB/T6728-2002); Cold-Bent Square Steel Tube Used for Building Structure (JG/T178-2005).

In the last few years, for the steel products used in steel structures of major building projects, it is discovered that structural steel is showing following new trends:

1) Thickness as well as strength of steel plates is continuously increasing and welding performance requirements are much more improved. In some projects, high-strength steel plates of Q345 and above account for 92.6% of the total steel used and even 100% in some particular projects. The thickness of plates has increased from 40mm to 100mm and some particular projects used 130mm-thick plates. Where fabrication and on-site installation occur in winter, welding under low temperature conditions poses a challenge to the performance of steel products.

2) The variety of steel sections and the range of their application have been expanded. As there is a lack of hot-rolled H sections of large specifications (H>900mm and large wide wing edge H sections), quite a few projects could only use welded H sections instead.

3) The design has posed higher requirements on the performance of cold-formed tubular products (round tubes and square and rectangular tubes). At present, some of these products cannot satisfy design and fabrication requirements. For instance, the performance of the material at the angles of the square and rectangular tubes and the welding seams is not as good as that of the parent metal.

4) The performance and dimensional precision of cast steel used in building projects need to be further improved. Cast steel joints are used in many large public buildings. These joints or nodes are large in number and heavy in weight. Yet, the quality and dimensions as well as angle precision of the cast steel cannot satisfy design requirements.

5) There is a lack of high-grade house roofing and external wall panels such as stainless steel and titanium alloy. Major steel structure projects will frequently adopt high-grade roofing and external walling panels. However, there is not much to choose from in China.

Suggestions

Steel manufacturers should provide more steel products and increase their variety of steel grades and specifications as described in the following list:

1) Increase the output of over-50mm-thick plates with strength of Q345, Q420 and Q460; and if used in seismic areas, there will be higher requirements for the Y/T ratio and elongation ratio.

2) Increase the product variety and specifications of cold bent sections and hot rolled H sections, including big-section cold-bent tubular products, big-section H sections.

3) Provide for large cold bent square and rectangular tubes (500mmx 500mm, over 25mm thick).

4) Provide stainless steel plates, titanium alloy plates used for architectural decoration, with some of them having the surface processed into various ornamental patterns for external wall panels.

5) Develop weathering steel, fire-proof steel, high-quality weldable cast steel and flux-cored electrodes.

Manufacturers should develop and produce high-performance steel products to meet the requirements of steel structure buildings.

1) These steel developments involve thick steel plate grades that do not need preheated welding or need only low preheating temperatures.

2) R&D of thickening steel plates, which can be used in crane beam lower flange and bridge crossbeam soleplate.

The team in charge of compiling codes should give timely revision to the chapters relating to steel products in the Code of Design for Steel Structures (GB 50017-2003) so that design engineers will have a standard to follow. And the requirements for steel products in various structural design codes should be uniform.

Rational selection of steel products is the objective of each and every steel structure design, fabrication and installation engineer.

1) Purchasing steel products is the key first step in steel structure projects, because it accounts for more than 70% of the total cost value. Saving steel resources is a requirement that is in agreement with China's economic development.

2) The Z-direction requirements for thick steel plates: Since thick plates ($t \geq 40$mm) have tensile stress in Z direction at beam-column joints, higher requirements are imposed on steel products to prevent lamination crack in thick steel plates. For other types of connection, it is not necessary to impose Z-direction requirements on steel products.

(3) Adequate attention should be paid to the welding performance of steel products, which will influence the degree of difficulty in fabrication and installation, the progress of the construction schedule as well as increasing the cost of steel structure projects. Where the strength and the welding performance do not agree, the later shall be given full consideration.

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