DEVELOPMENT AND PROSPECT OF APPLICATIONS OF NIOBIUM MICROALLOYED STEELS TO BUILDING STRUCTURES IN CHINA

Mingxuan He[1], Yaohua Wu[2] and Houxin Wang[3]

[1]Baosteel Construction Co., Ltd. Shanghai 201900, China
[2]Central Research Institute of Building and Construction, MCC, Beijing 100088, China
[3]CITIC-CBMM Microalloying Technology Center, Beijing 100082, China

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Abstract

The Chinese steel industry has been developing at an amazing rate for over ten years, providing great quantities of steel materials to downstream industries and also stimulating the development of these industries. In recent years, with the further development of urbanization and modernization, many high-rise buildings and large span structures have been built in China, and a large amount of steel has been used in those buildings. Before giving some examples of the buildings in which niobium microalloyed steels have been used, Chinese steel standards are reviewed. The new version of the code for the design of steel structures allows more steel grades to be considered for building structures. There is no doubt that niobium microalloyed steels, with outstanding mechanical properties, will play a very important role in the booming era of high-rise buildings in China.

Present Situation and Development of Building Steel Structures in China

In recent years, China's economy has been growing continuously at high speed, and urbanization is similarly increasing. China has been the biggest steel producer in the world for over 15 years. To achieve light weight, high strength, better seismic performance, improved usable floor area, faster construction, energy conservation, environmental protection and other comprehensive economic advantages, more and more steel is used in building constructions. The development of steel structure buildings has become a principal engineering construction policy in China. The steel construction industry chain has been formed on the basis of the steel production, steel structure design, steel components production, installation and related industries. While the lower strength steel Q235 dominated in the past, Q345 and higher strength low alloy steels are now the major steel grades being used. The number of high-rise buildings and large span steel structure buildings in China will be the largest in the world in the next ten years, and accordingly niobium-bearing microalloyed high strength steel should be widely used.

China’s Steel Output and Steel in Building Structures

China’s steel output exceeded 100 million tons in 1996, becoming the world’s biggest steel producer. At present, within the domestic steel market, supply exceeds demand. According to the 2009 census, the steel consumption in segments was: building (including rebar and structural steel plates) 52%, industries 34%, transportation 6% and others 8%. Steel output and steel consumption in building structures in 2009 and 2010 are shown in Table I. From the table, the proportion of steel used in building steel structures to the total steel output is too low (accounting for only about 4%), while it is approximately 10% or more for developed countries and more than 30% for Japan and the United States. Therefore, there is much space and great potential for the development of building steel structures using niobium-bearing high strength steels.

Table I. Steel Output and Steel Consumption by Building Steel Structures

Year	Steel Output (million ton)	Steel Consumption by Building Steel Structures (million ton)	Proportion (%)
2009	565	23	4.1
2010	626	26	4.2
2011	683	30	4.4

Steel structures consist of buildings, railway and highway bridges, power plant construction, municipal construction, etc., according to China’s steel construction society statistics [1,2]. The usage distribution of steel structures is as follows.

Proportions according to the applications are shown in Table II and Figure 1.

Table II. Proportions According to Applications (%)

Year	Building	Bridge	Tower Mast	Others
2009	54	9	7	30
2010	66	11	6	17

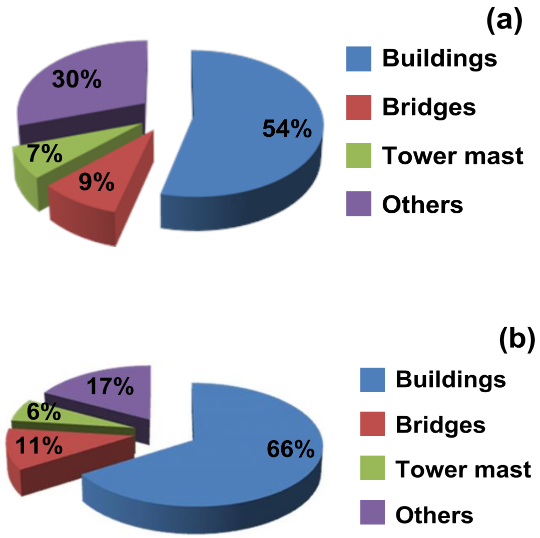


Figure 1. Steel construction proportions according to applications in (a) 2009 and (b) 2010.

Proportions according to steel grades are shown in Table III and Figure 2.

Table III. Proportions According to Steel Grades (%)

Year	Q235	Q345	Q390	Q420	Q460
2009	35	53	7	3	2
2010	31	62	4	2	1

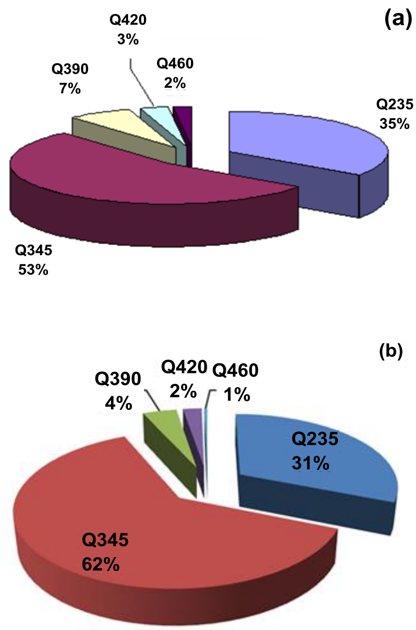
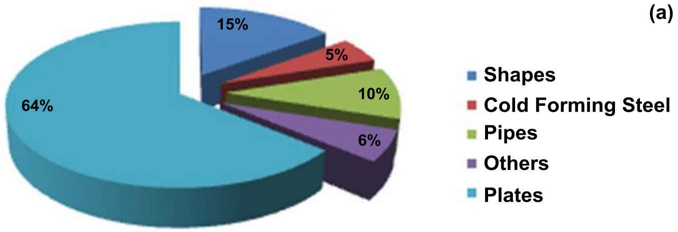


Figure 2. Steel construction proportion according to steel grade in (a) 2009 and (b) 2010.

Proportions according to the steel products are shown in Table IV and Figure 3.

Table IV. Proportions According to the Steel Products (%)

Year	Plates	Shapes	Cold Forming	Pipes	Others
2009	64	15	5	10	6
2010	60	15	6	15	4



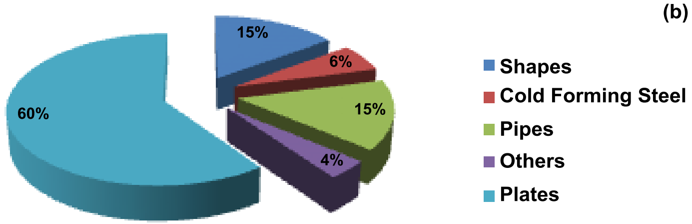


Figure 3. Steel construction proportions according to the steel products in (a) 2009 and (b) 2010.

In building structures, steel consumption can be divided by building types into public buildings, industrial plant, high-rise buildings, multistory buildings and so on. The steel distribution is thus shown in Table V and Figure 4.

Table V. Proportions of Steel Consumption According to Building Type (%)

Year	Public	High-rise	Multistory	Factory
2009	21	17	13	49
2010	21	14	12	53

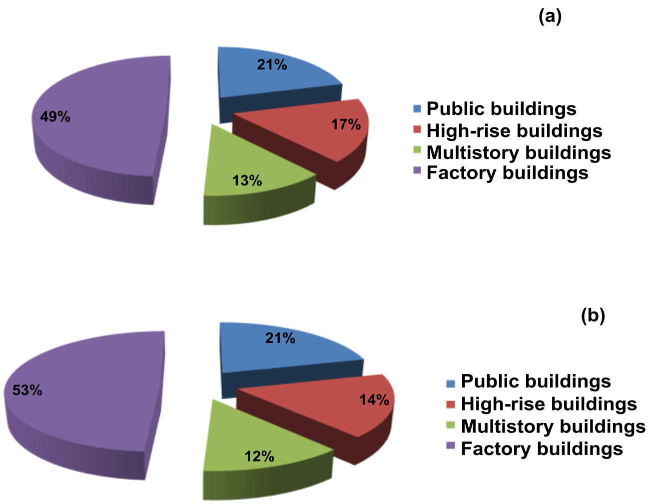


Figure 4. Steel consumption proportions according to building types in (a) 2009 and (b) 2010.

Building Structure Steel Standards

Ten years ago, the major steel used in building structures was Q235 carbon structural steel produced as per the national standard "Carbon Structural Steel" GB/T 700-88 [3] and a small amount of Q345 steel as per "High Strength Low Alloy Steels" GB/T 1591-94 [5]. Along with the continuous development of China's steel industry, the level of technology, processing, equipment and management for steel production has been constantly advancing. More high strength steel grades such as Q390 steel, Q420, Q460, Q345GJ, Q390GJ, Q420GJ and others are used in domestic large-scale projects, such as CCTV's new tower, the national swimming center (water cube), Beijing's international trade building and other large constructions. The leading position of Q235 in constructions has been replaced by Q345 steel in recent years. The quality and strength level of structural steels for buildings and construction has been improved. The current steel material standards for steel structures in China are introduced briefly as follows.

<u>"Carbon Structural Steel" GB/T 700</u>

Q235 steel is the most widely used among the carbon structural steels listed in the national standard GB/T 700 "Carbon Structural Steels". The mechanical properties of Q235 in the 2006 edition almost remain as per the 1988 edition [4]. Table VI shows the mechanical properties of Q235 in the 2006 edition of GB/T 700.

Table VI. Mechanical Properties of Q235 Steel in GB/T 700-2006

Steel Grades	Quality Grades	Yield Strength R_{eH} (MPa)						Tensile Strength R_m (MPa)	Elongation A %, ≥					Impact Test (V-notch)		Cold Bending
		Thickness or Diameter (mm)							Thickness or Diameter (mm)					Temperature (°C)	Absorbed Impact Energy (J)	Thickness (mm)
		≤16	>16~40	>40~60	>60~100	>100~150	>150~200		≤40	>40~60	>60~100	>100~150	>150~200			≤60
Q235	A	235	225	215	215	195	185	370~500	26	25	24	22	21	—	—	Longitudinal/ (0.5a) Transverse/(a)
	B													20	≥27	
	C													0		
	D													-20		

"High Strength Low Alloy Steels" GB/T 1591

The mechanical properties and chemical composition of "High Strength Low Alloy Steels" (HSLA steels) are listed in Table VII and Table VIII respectively. Comparing the last version of "High Strength Low Alloy Steels" (GB/T 1591-94) [5] with the current edition (GB/T 1591-2008) [6] has changed in the following areas:

- Modified thickness classification;
- Increase in Q345's yield strength;
- The yield strength decrease with thickness has become smaller (the drop of typically 20 MPa reduced to 10 MPa), as seen in Figure 5;
- The absorbed impact energy of E grade steels increased from 27 Joules to 34 Joules;
- The CEV and Pcm requirement index added;
- Lower sulfur and phosphorus content required and increase in allowable niobium and vanadium contents.

Table VII. Mechanical Properties of HSLA Steels in GB/T 1591-2008

Steel Grades	Quality Grades	Yield Strength R_{eH} (MPa)						Tensile Strength R_m (MPa)	Elongation A (%), ≥					Impact Test (V-notch)	
		Thickness or Diameter (mm)							Thickness or Diameter (mm)					Temperature (°C)	Absorbed Impact Energy (J) ≥
		≤16	>16~40	>40~63	>63~80	>80~100	>100~150		≤16	>16~40	>40~63	>63~80	>80~100		
Q345	A	345	335	325	315	305	285	470~630	20	19	19	18	17	-	-
	B													+20	34
	C													0	
	D													-20	
	E													-40	
Q390	A	390	370	350	330	330	310	490~650	20	19	19	18	-	-	-
	B													+20	34
	C													0	
	D													-20	
	E													-40	
Q420	A	420	400	380	360	360	340	520~680	19	18	18	18	-	-	-
	B													+20	34
	C													0	
	D													-20	
	E													-40	
Q460	C	460	440	420	400	400	380	550~720	17	16	16	16	-	0	34
	D													-20	
	E													-40	

Table VIII. Chemical Composition of HSLA Steel in GB/T 1591-2008

<table>
<tr><th rowspan="3">Steel Grades</th><th rowspan="3">Level</th><th colspan="15">Chemical Composition (wt.%)</th></tr>
<tr><th rowspan="2">C ≤</th><th rowspan="2">Si ≤</th><th rowspan="2">Mn ≤</th><th>P</th><th>S</th><th>Nb</th><th>V</th><th>Ti</th><th>Cr</th><th>Ni</th><th>Cu</th><th>N</th><th>Mo</th><th>B</th><th>Als</th></tr>
<tr><th colspan="2">≤</th><th colspan="10">≤ (x10^{-2})</th><th>≥</th></tr>
<tr><td rowspan="5">Q345</td><td>A</td><td rowspan="3">0.20</td><td rowspan="5">0.50</td><td rowspan="5">1.70</td><td>0.035</td><td>0.035</td><td rowspan="5">7</td><td rowspan="5">15</td><td rowspan="5">20</td><td rowspan="5">30</td><td rowspan="5">50</td><td rowspan="5">30</td><td rowspan="5">1.2</td><td rowspan="5">10</td><td rowspan="5">-</td><td rowspan="2">-</td></tr>
<tr><td>B</td><td>0.035</td><td>0.035</td></tr>
<tr><td>C</td><td>0.030</td><td>0.030</td><td rowspan="3">.015</td></tr>
<tr><td>D</td><td rowspan="2">0.18</td><td>0.030</td><td>0.025</td></tr>
<tr><td>E</td><td>0.025</td><td>0.020</td></tr>
<tr><td rowspan="5">Q390</td><td>A</td><td rowspan="5">0.20</td><td rowspan="5">0.50</td><td rowspan="5">1.70</td><td>0.035</td><td>0.035</td><td rowspan="5">7</td><td rowspan="5">20</td><td rowspan="5">20</td><td rowspan="5">30</td><td rowspan="5">50</td><td rowspan="5">30</td><td rowspan="5">1.5</td><td rowspan="5">10</td><td rowspan="5">-</td><td rowspan="2">-</td></tr>
<tr><td>B</td><td>0.035</td><td>0.035</td></tr>
<tr><td>C</td><td>0.030</td><td>0.030</td><td rowspan="3">.015</td></tr>
<tr><td>D</td><td>0.030</td><td>0.025</td></tr>
<tr><td>E</td><td>0.025</td><td>0.020</td></tr>
<tr><td rowspan="5">Q420</td><td>A</td><td rowspan="5">0.20</td><td rowspan="5">0.50</td><td rowspan="5">1.70</td><td>0.035</td><td>0.035</td><td rowspan="5">7</td><td rowspan="5">20</td><td rowspan="5">20</td><td rowspan="5">30</td><td rowspan="5">80</td><td rowspan="5">30</td><td rowspan="5">1.5</td><td rowspan="5">20</td><td rowspan="5">-</td><td rowspan="2">-</td></tr>
<tr><td>B</td><td>0.035</td><td>0.035</td></tr>
<tr><td>C</td><td>0.030</td><td>0.030</td><td rowspan="3">.015</td></tr>
<tr><td>D</td><td>0.030</td><td>0.025</td></tr>
<tr><td>E</td><td>0.025</td><td>0.020</td></tr>
<tr><td rowspan="3">Q460</td><td>C</td><td rowspan="3">0.20</td><td rowspan="3">0.60</td><td rowspan="3">1.80</td><td>0.030</td><td>0.030</td><td rowspan="3">11</td><td rowspan="3">20</td><td rowspan="3">20</td><td rowspan="3">30</td><td rowspan="3">80</td><td rowspan="3">55</td><td rowspan="3">1.5</td><td rowspan="3">20</td><td rowspan="3">0.4</td><td rowspan="3">.015</td></tr>
<tr><td>D</td><td>0.030</td><td>0.025</td></tr>
<tr><td>E</td><td>0.025</td><td>0.020</td></tr>
<tr><td rowspan="3">Q500</td><td>C</td><td rowspan="3">0.18</td><td rowspan="3">0.60</td><td rowspan="3">1.80</td><td>0.030</td><td>0.030</td><td rowspan="3">11</td><td rowspan="3">12</td><td rowspan="3">20</td><td rowspan="3">60</td><td rowspan="3">80</td><td rowspan="3">55</td><td rowspan="3">1.5</td><td rowspan="3">20</td><td rowspan="3">0.4</td><td rowspan="3">.015</td></tr>
<tr><td>D</td><td>0.030</td><td>0.025</td></tr>
<tr><td>E</td><td>0.025</td><td>0.020</td></tr>
<tr><td rowspan="3">Q550</td><td>C</td><td rowspan="3">0.18</td><td rowspan="3">0.60</td><td rowspan="3">2.00</td><td>0.030</td><td>0.030</td><td rowspan="3">11</td><td rowspan="3">12</td><td rowspan="3">20</td><td rowspan="3">80</td><td rowspan="3">80</td><td rowspan="3">80</td><td rowspan="3">1.5</td><td rowspan="3">30</td><td rowspan="3">0.4</td><td rowspan="3">.015</td></tr>
<tr><td>D</td><td>0.030</td><td>0.025</td></tr>
<tr><td>E</td><td>0.025</td><td>0.020</td></tr>
</table>

Steel Grades	Level	Chemical Composition (wt.%)														
		C	Si	Mn	P	S	Nb	V	Ti	Cr	Ni	Cu	N	Mo	B	Als
		≤	≤	≤	≤		≤ (x10^{-2})									≥
Q620	C	0.18	0.60	2.00	0.030	0.030	11	12	20	100	80	80	1.5	30	0.4	.015
	D				0.030	0.025										
	E				0.025	0.020										
Q690	C	0.18	0.60	2.00	0.030	0.030	11	12	20	100	80	80	1.5	30	0.4	.015
	D				0.030	0.025										
	E				0.025	0.020										

Als = Soluble Aluminum

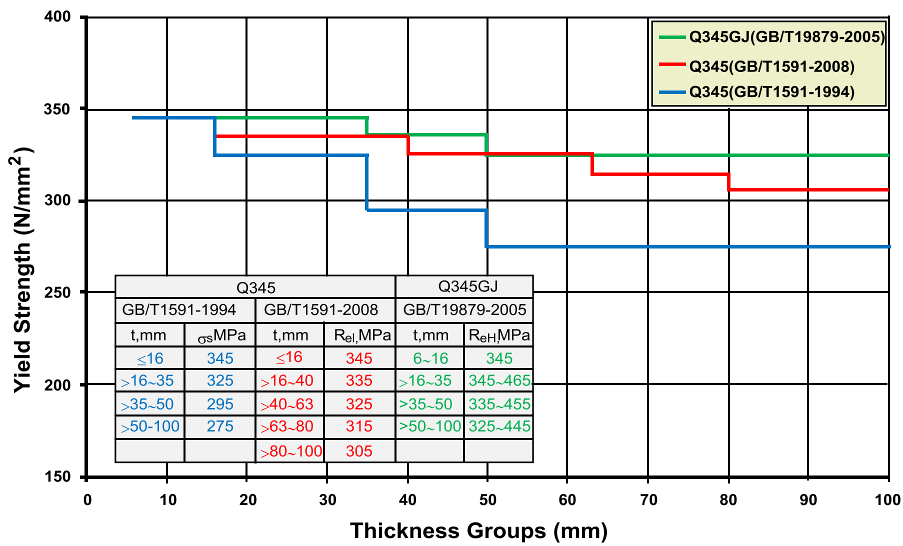


Figure 5. Increase in yield strength of Q345 steel. Comparison of standards.

"Steel Plates for Building Structure" GB/T 19879

The national standard "Steel Plate for Building Structure" GB/T 19879-2005 [7] is mainly for thick plate and seismic requirements of high-performance steel plates (GJ steels). In comparison with the high strength low alloy steel standard GB/T 1591-2008 [6], GJ steels have the following advantages: lower sulfur and phosphorus contents; smaller yield strength variation range and hence a tighter f_y/f_u ratio; higher elongation; stricter thickness tolerance (<- 0.3 mm), as seen in Table IX.

Table IX. Comparisons Between HSLA Steels (GB/T 1591-2008) and GJ Steels (GB/T 19879-2005)

Grade	f_y (MPa) Nominal Thickness (mm)				f_u (MPa)	d (%) ≥	f_y/f_u ≤	P (%)* ≤	S (%)* ≤
	≤16	>16~35	>35~50	>50-100					
Q460GJ	≥460	460~600	450~590	440~580	550~720	17	0.85	0.025~0.020	0.020
Q460	≥460	≥440	≥420	≥400	550~720	16		0.030~0.020	0.030~0.020
Q345GJ	≥345	345~465	335~455	325~445	490~610	22	0.83	0.025~0.020	0.015
Q345	≥345	≥335	≥325	≥305	470~630	21		0.035~0.025	0.035~0.020

* Different sub-grades of this specification have different maxima.

Present Development Situation of High-rise Buildings in China

According to the statistics [8], China has already built 470 skyscrapers over 500 feet high (>152 meters), while the United States has 533 skyscrapers. There are ten big cities in China constructing super high-rise buildings which are higher than the 541.3 meters new One World Trade Center in New York city, the highest in the USA (Figure 6 and Table X), and the construction height of the tallest buildings in eight Chinese cities will be more than New York's building 432 Park Avenue, of 420 meters.

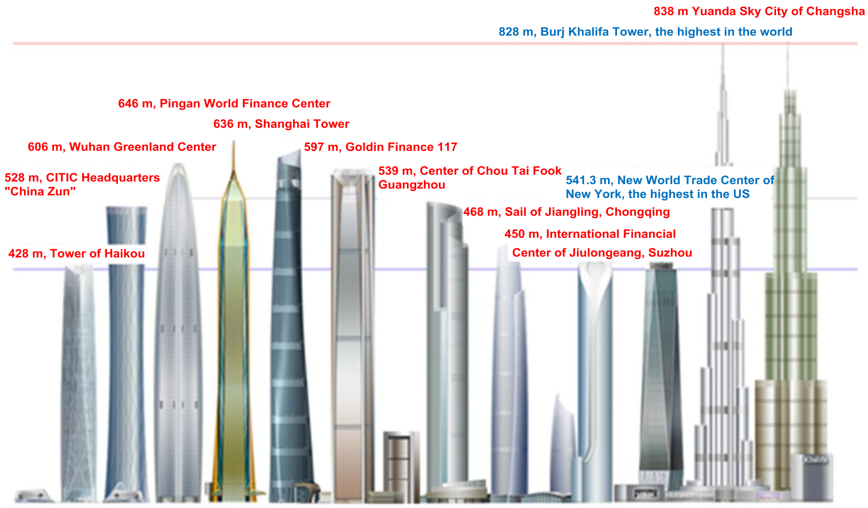


Figure 6. The highest buildings under construction or in planning in China (mainland), compared with the New World Trade Center (USA) and Burj Khalifa (Dubai).

Table X. The Highest Buildings under Construction or in Planning in Chinese Cities (Mainland)

No.	City	Highest Building	Total Height (including antenna)/meters	Status
1	Changsha	Yuanda Sky City	838	PEIA*
2	Qingdao	777 Tower	777	Enterprise intention
3	Zhuhai	Shizimen CBD landmark	680	Planning
4	Shenzhen	Pingan World Finance Center	646	Construction
5	Shanghai	Shanghai Tower	632	Construction
6	Nanning	Tianlong Wealth Center	628	Planning
7	Wuhan	Wuhan Greenland Center	606	Design
8	Guangzhou	Beltan CBD landmark	600	Planning
9	Tianjin	Goldin Finance 117	597	Construction
10	Jinan	Jinan Hengda Real Estate	560	Land leasing

*PEIA: Planning – Environmental Impact Assessment

Examples of Steel High-rise or Large Span Buildings in China in Recent Years

The National Stadium (Bird's Nest)

The National Stadium (Bird's Nest) steel structure roofing is a hyperbolic saddle, elliptic plane, 332 m long axis and 297 m short axis; roof peak of 68.5 m, the lowest part of 40.1 m; a large span roof supported on 24 latticed columns, the column bays being about 38 m. The whole roof structure is composed of 24 primary trusses which are arranged around the middle ring in the radial direction. Together with the façade and cross layout secondary trusses, the trusses are woven into the "Bird's nest" (Figure 7). The ETFE (ethylene tetrafluoroethylene) membrane structure and PTFE (polytetrafluoroethylene) membrane structure are inlayed areas within the steel grid. The ETFE membrane is located in the top chord of the roof truss, and the PTFE membrane is located in the lower chord, the total covering membrane area is about 90,000 m^2.

Steel box sections are welded using four plates, the primary truss upper chord section is 1000 x 1000 mm, the lower chord primarily 800 x 800 mm, the web member section 600 x 600 mm, and the roof truss is 12.0 meters high. The 24 façade steel columns are composed of two 1200 x 1200 mm box columns and an inner diamond column, and three-limb lattice columns. The roof secondary member section is 1000 x 1000 mm and the façade secondary member section is 1200 x 1000 mm.

The total steel quantity for the stadium was about 42,000 tons (Table XI). The maximum thickness of steel plate is 110 mm. Steel plate thicknesses less than or equal to 34 mm use Q345 steel. For thicknesses of steel plate in the range of 36 ~ 90 mm, Q345GJ steel was adopted. For thickness of steel plate in the range 100 ~ 110 mm, Q460 steel was used.

Table XI. Steel Tonnages of the National Stadium (Bird's Nest)

Plate Thickness (mm)	**10, 12, …34**	**36**	**42, 50**	**60, 70**	**80, 90**	**100, 110**
Steel Grades	Q345C, Q345D	Q345GJ	Q345GJC/Z15	Q345GJC/Z25	Q345GJD/Z35	Q460E/Z35
Weight (t)	33,770	2,181	2,913	1,185	888	500

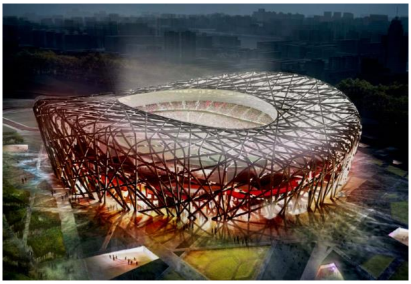


Figure 7. The National Stadium (Bird's Nest).

<u>CCTV New Tower</u>

China Central Television's (CCTV) new tower is composed of two linked sub-towers which are 6° inclined two ways. The 14 stories of the cantilever link structure is 163 m up the sub-towers as shown in Figure 8. The two sub-towers are 52 stories and 44 stories respectively, with additional features of a three story basement and nine story podiums. The maximum height of the building is 234 m and the total floor area is about 590,000 m^2.

Considering the importance of the project, potential high seismic intensity and the seriously irregular shape of the structure, a complicated construction process with a high proportion of high performance steels was used. The maximum thickness of steel plate is 135 mm and the total steel consumption is about 120,000 tons comprising 41,500 members. The main steel grades used in this project were Q345C, Q390D, Q345GJC, Q420 and Q460, Table XII. Of the plates employed, those of 40 mm or thicker comprised more than 75,000 tons, accounting for 62% of the total amount.

Table XII. Steel Tonnage of CCTV New Tower

Steel Grades	Q345C	Q345GJC	Q420D	Q460D
Weight (t)	51,610	69,869	4,900	3,600

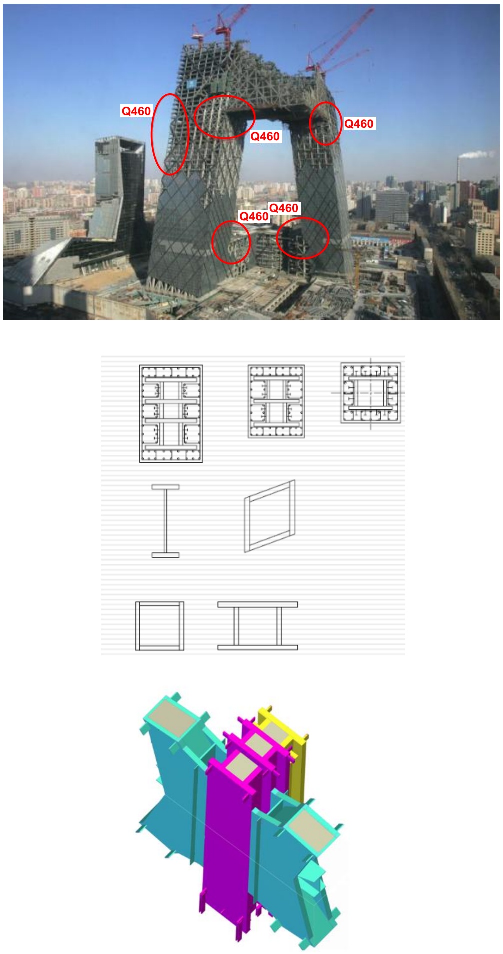


Figure 8. CCTV New Tower: the steel structure, cross section and frame node.

Shanghai World Financial Center

Shanghai's World Financial Center, Figure 9, is a super high-rise building of 492 m height. The building consists of three stories underground and 101 stories above ground. The total floor area of the building is 350,000 m^2. The building uses the structural system: "Inner core + Mega frame + Outrigger trusses." The inner core is made of reinforced concrete up to floor 79, and a steel braced frame core above floor 79. The giant columns and giant diagonal braces use steel reinforced concrete (SRC) box sections. The total steel tonnage is 60,000 tons and the maximum thickness of steel plate is 90 mm. It was constructed from 2005 to 2008 and the steels which were used in this building were A572 Gr50, S460 and SN490.

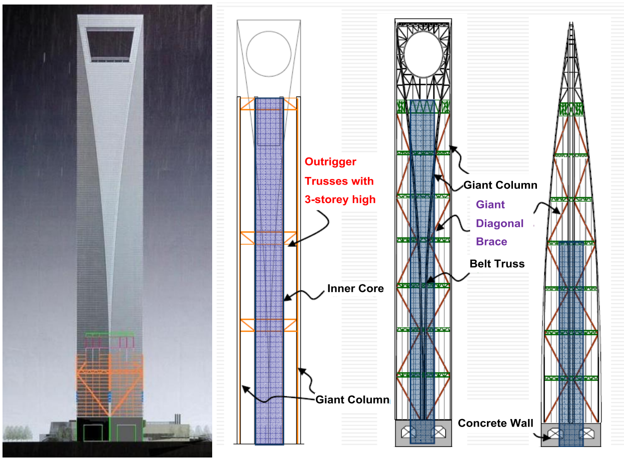


Figure 9. Shanghai World Financial Center.

Shanghai Tower

Shanghai Tower is a super high-rise building of 580 m height and is nearing completion. The building consists of five stories underground and 124 stories above ground. It is the tallest building in China. The underground floor area of the building is 140,000 m^2 and the above ground floor area is 380,000 m^2. The "Core + Mega frame + Outrigger trusses" structure system is used in this building. Eight mega columns use steel reinforced concrete (SRC column) sections, and the reinforcing steel is composed of three H sections welded through two pieces of web connection, forming "mesh font" sections (Figure 10). The total steel tonnage is about 100,000 tons and the main steel grades are: Q345B, Q345GJC, Q390GJC and Q460GJC; the maximum thickness is 130 mm.

Figure 10. Shanghai Tower.

Bright Prospect for High-rise Buildings in China

Market Potential of High-rise Building and its Steel Demand

In China, there are 332 skyscrapers under construction, and another 516 have completed land sale, design bidding or have already established the foundation, while the United States only has 30 skyscrapers under construction and planning. This means that, in ten years' time, China will have a total number of 1,318 skyscrapers, far more than the United States, with 563 high-rise buildings. The total investment in China's skyscrapers that are under construction or planned will be more than 1.7 trillion yuan RMB. The high-rise buildings are normally constructed by using steel structures or steel and concrete composite structures. The average consumption of steel is estimated to be 60,000 tons for a skyscraper, the total construction will need 50.88 million tons of structural steel.

According to the China Steel Construction Society (CSCS), the steels consumed by steel structures in 2010 were composed of 62% Q345 steel, 31% Q235 steel and 7% Q390 or higher grades. In other words, Q345 and above grade steel accounts for 69%, 4% higher than in 2009, so high strength and high performance steels are being used more and more while carbon steels are used less and less. Due to intensive stress and seismic design, steels with high strength, low f_y/f_u ratio, good plasticity and toughness are essential for high-rise buildings and large span steel structures. Niobium microalloyed steels will be used increasingly for these applications.

Update to "Code for Design of Steel Structures" (GB 50017),
Essential Support for the Development of Building Steel Structures

The specification of "Code for Design of Steel Structures" GB 50017 is the principal code for Chinese steel structures designers. Only when there are numerous material options in the code, can high performance steel structures be designed and applied to the booming high-rise buildings, meeting the demand from this market. The highest strength steel grade specified in this code is only Q420 (with minimum yield strength of 420 MPa) listed in GB/T 1591, and the steel grades listed in GB/T 19879 which are special for building structures have not been quoted in GB 50017 yet. Obviously, updating the design code is a crucial step for the development of building structures.

In 2010, CBMM-CITIC Microalloying Technology Center, Central Research Institute of Building and Construction of MCC, and the China Steel Industry Association (CISA) initiated a working group. The objectives were:

- Building a bridge to understanding each other on both improvement in steel grades and their quality and requirements from designers and end users;
- Promoting applications of steels in steel structures and so forth, which has been considered as a long-term industry supply-chain cooperation platform;
- Strengthening the exchange and cooperation between the steel industry and the steel construction industry in the course of time.

The work to revise the code for the design of steel structures became the first key mission for the joint working group consisting of ten major steel mills including Wuyang Steel, Anshan Steel, WISCO, Baosteel, Shougang, Jinan Steel, and 11 top steel structure manufacturers such as Huning Mechanism, Holu Steel Structures, Hangxiao Steel Structures, Baosteel Steel Structure, China 22MCC Group, and four universities and research institutes like Tsinghua University. Through great efforts over two years by analyzing tens of thousands of data and a large number of tests, a completely new chapter on material options was added into the design code and higher steel grades like Q460 (with minimum yield strength of 460 MPa) and the steel standard of GB/T 19879 were specified in this code for the first time. The update helps avoid strict special regulations when applying the materials beyond the design code, like Q460 which has already been applied to some high-rise buildings, so it should create more opportunities for designers for their design masterpieces.

Conclusions

A lot of high-rise buildings and large span steel structures will be built in China in the next ten years, and vast amounts of structural steel will be needed. The current percentage of steel structures in China is very low, so there is a very big development opportunity and great potential for the use of structural steels. Structural steel supply exceeds demand at present and it is the right time to use more steel structures at low cost to obtain the benefits brought about by the use of high performance steels. Q345 and other high performance steels are leading the way in the application of structural steel in recent years and the new version of the code for design of steel structures provides more steel options which are required for optimizing building structures. The steel quality and standards in China are continuously advancing and as a result, more niobium microalloyed high performance steel will be used.

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