

Review of Quality and Production of Seismic Rebars in China

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0 Introduction

After the catastrophic Wenchuan Earthquake in 2008, how to improve seismic performance of buildings has become a major focus of both the government and enterprises, hence seismic rebars have received more and more attention from public. Requirements for seismic performance have been officially provided in the Standards for Rebar Products (GB 1499.2-2007) in China. This paper gives a brief review on both the quality and production of seismic rebars in China.

1 Brief Introduction to Seismic Rebar

1.1 Seismic intensity mapping in China

Seismic activities in China features high frequency, high magnitude, wide distribution and shallow hypocenter, which make China one of the world's most earthquake-hit countries. As many countries have developed their own seismic intensity zoning maps, China began to develop such a map after the Tangshan Earthquake which was promulgated in 1990 (see Figure 1). The current map is the 2002 revised version. As the map shows, China is an earthquake-prone country. 60% of its land is categorized into zones with seismic intensity

of 6.0 or above. Regions with a basic seismic intensity of 7.0 or above cover an area of 312 000 square kilometers, accounting for 32% of China's total land area. Therefore, seismic protection should be required for buildings in most of the areas in China, which in turn places higher criteria for both seismic structural design and materials.

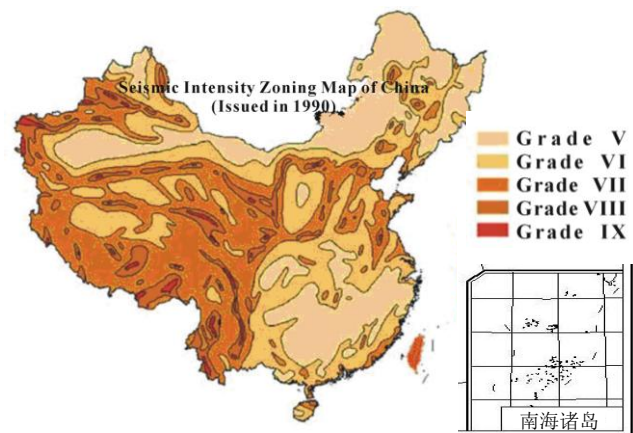


Figure 1 Seismic Intensity Zoning Map of China

1.2 Seismic performance of rebar required in product standards

Seismic rebar refers to rebar with seismic performance. Many countries have set forth provisions for the seismic performance of rebar in their product standards. The original national standard *Hot Rolled Ribbed Bars for the Reinforcement of Concrete* (GB 1499-1998) contains provisions for ratio of

actual tensile strength to actual yield point, ratio of actual yield point to minimum yield point and total elongation under the maximum stress. However, these requirements are only met when the purchaser requests so, and are not abided by in most deliveries.

In the new national standard *Rebar for the Reinforcement of Concrete-Part2: Hot Rolled Ribbed Bars (GB 1499.2-2007)*, not only provisions for seismic performance of rebar, but also the corresponding grades are clearly specified, which are as follows:

Structure having strict requirement for seismic function should use rebar with E as the suffix (for example: HRB400E, HRBF400E). Such rebar should not only meet the following requirements (see a, b, c), but also those corresponding to the specific grades.

- a) The ratio of R_m^0/R_{eL}^0 (R_m^0 stands for the actual tensile strength; R_{eL}^0 stands for the actual yield strength) should not be less than 1.25.
- b) The ratio of R_{eL}^0/R_{eL} (R_{eL}^0 stands for the actual yield strength; R_{eL} stands for the eigenvalue of yield strength as stated in Table 6) should not be greater than 1.30.
- c) A_{gt} (the total elongation at maximum force) should not be less than 9%.

The applicable grades include HRB335E, HRB400E, HRB500E, HRBF335E, HRBF400E, and HRBF500E.

As for foreign standards, Australia and New Zealand Standard AS / NZS / 4671:2001 gives a clear definition of seismic

rebar, under which three ductility levels are categorized so as to meet the seismic-resistance requirements. These three levels are: L (Low), N (Normal), and E (Earthquake). The 'E' refers to the code of the seismic rebar, and the standard contains two grades: 300E and 500E, providing requirements for the ratio of tensile strength to yield strength as well as the total elongation at maximum force. In addition to this standard, other countries also have made provisions for the seismic performance of rebar, although their specific standards may not give a clear definition of seismic rebar. Different countries have different requirements in terms of yield ratio and ratio of tensile strength to yield strength, for example: ISO6935-2: 2007 uses the scope of yield strength to limit yield ratio, keeping the latter less than 1.30; JIS G 3112-2004 uses the scope of tensile strength to limit the ratio of tensile strength to yield strength; BS 4449-2009 provides requirements for the ratio of tensile strength to yield strength; UNE36065-2000 places requirements for the ratio of tensile strength to yield strength, yield ratio and total elongation at maximum force.

1.3 Requirements for rebar by seismic structure

Currently, most of China's building projects are built with the reinforced concrete structure, in which rebar plays a significant role. Seismic structure asks for the use of rebar with excellent seismic performance which could, in case of earthquakes, delay the cracking time of the buildings, thus avoiding instant collapse and

enhancing the seismic function of the buildings. Therefore, for better seismic structure, ideal rebar should have good performance in both yield and ductility; besides, the actual yield strength should not be too much higher than the standard value. For details, please refer to Figure 2.

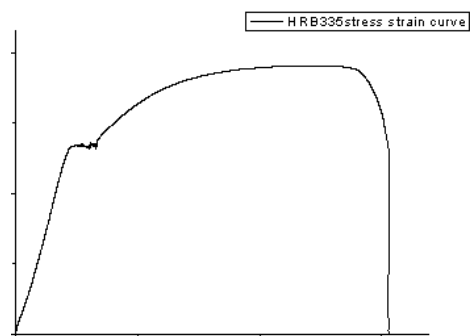


Figure 2 Stress - Strain Curve of Rebar

2 Quality of Seismic Rebar in China

2.1 Quality of China's rebar products

In the past three decades, the quality and production of hot-rolled ribbed rebar have witnessed synchronous progress with the industrial technologies. For most rebar manufacturing enterprises, their technique and equipment have been greatly improved, quality control further strengthened, quality consciousness gradually enhanced, product quality significantly improved based on quality assurance system; at the same time, the government have applied license management system and national product quality supervision & inspection system for rebar production. Under the legal effect of the administrative licensing and the guidance of industrial policy, backward technology and equipment have been eliminated, and quality of rebar products,

especially, hot-rolled ribbed rebar has been improved. In recent years, China's rebar products have been exported to South East Asia, South America, Africa and other regions.

In 1985, the rebar products were firstly included into the national product quality supervision & inspection program which still prevails today. The statistics are summarized in Figure 3 which provides an objective reflection of the quality and production status of hot-rolled ribbed Rebar in China. Previous inspections show that both physical and chemical properties of the rebar are at a higher level. Large and medium-sized enterprises constitute the major force in China's rebar production, and their output accounts for more than 80% of the nation's total. The acceptability of products in terms of physical and chemical properties inspected at large and medium-sized enterprises in recent years is shown in Figure 4, from which we can see that product quality is stable at large and medium-sized enterprises, and important product quality indicators, such as mechanical properties, bending properties and chemical composition have been recorded at an ideal level. Therefore, China's rebar production is under good control at large and medium-sized enterprises, and, on the whole, the country's rebar product quality is at a good level.

Besides, the State Quality Supervision and Inspection Center for Building Rebar has conducted similar statistics based on the tens of thousands of inspected rebar products in recent years. The mechanical

properties of rebar products with different grades are shown in Table 1. We can also find the corresponding R_{eL} distribution of each grade, for example, the R_{eL} distribution

diagram of HRB400 is shown in Figure 5. As Table 1 and Figure 5 show, for China's rebar products, the main indicators are stable, with a higher concentration and normal distribution.

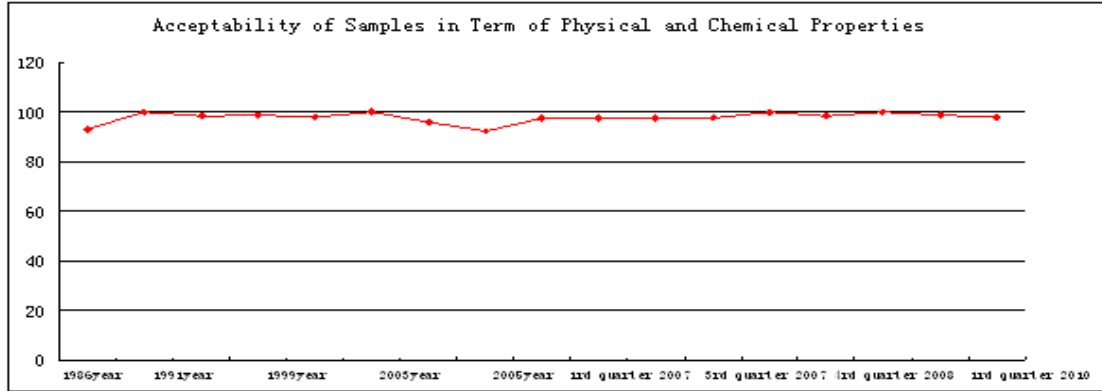


Figure 3 Acceptability of Hot-Rolled Ribbed Rebar in Terms of Physical and Chemical Properties Inspected under the National Product Quality Supervision & Inspection Program (1986-2008)

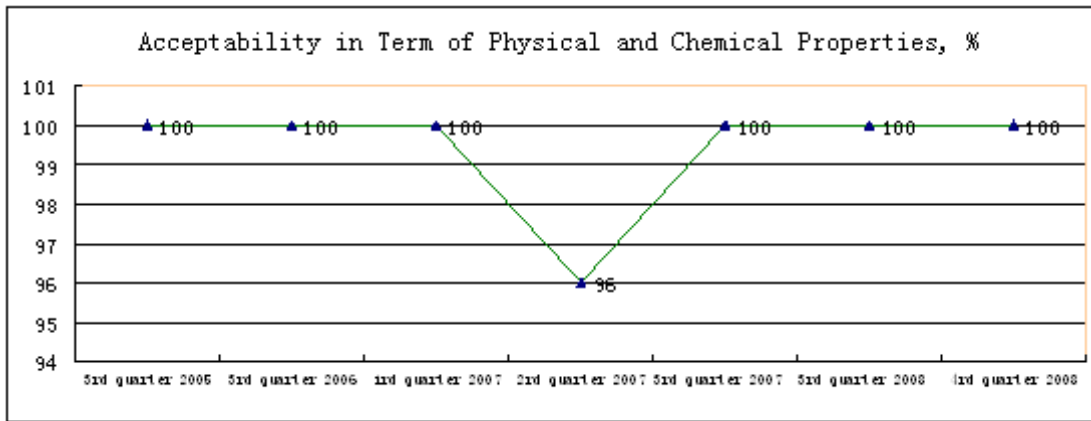


Figure 4 Acceptability of Rebar in Terms of Physical and Chemical Properties Inspected at Large and Medium-Sized Enterprises under the National Product Quality Supervision & Inspection Program (2005-2008)

Table 1 Mechanical Property Statistics of Hot-Rolled Ribbed Rebar (Average)

Grade	R_{eL}/MPa	R_m/MPa	R_m^0/R_{eL}^0	R_{eL}^0/R_{eL}	$A/\%$
HRB335	389	549	1.41	1.16	25.5
HRB400	465	629	1.32	1.16	24.1
HRB500	543	703	1.30	1.09	23.1

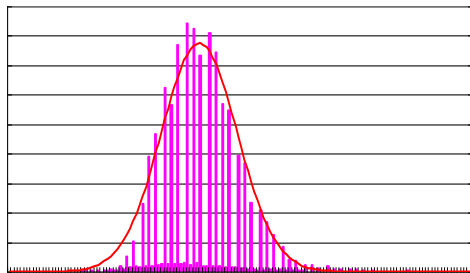


Figure 5 Statistical Distribution Histogram of R_{eL} of HRB400 Rebar

2.2 Quality of China's seismic rebar

Since issuance of GB 1499.2-2007, based on equipment modification, process improvement, technological innovation, China's metallurgical enterprises have made great progress in carrying out technical research, upgrading product quality and enhancing development of seismic rebars.

The State Quality Supervision and Inspection Center for Building Rebars have made statistics of thousands of recently tested seismic rebar products, which are shown in Table 2. As Table 2 and Figure 6 (the R_{eL} distribution diagram of HRB335

rebar) show, major quality indicators of China's seismic rebars are kept at a stable level, fully meeting the requirements of the relevant standard, and the finished products have a high quality.

Table 2 Mechanical Property Statistics of Seismic Rebar

Grade	R_{eL}/MPa	R_m/MPa	R_m^0/R_{eL}^0	R_{eL}^0/R_{eL}	$A_{gt}/\%$
HRB335E	389	557	1.44	1.15	17.5
HRB400E	470	619	1.31	1.12	14.2
HRB500E	580	710	1.32	1.07	13.1

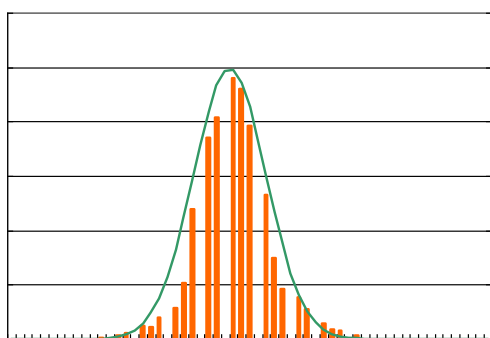


Figure 6 Statistical Distribution Histogram of R_{eL} of HRB335E Rebar

3 Status of China's Rebar Production

3.1 Output

In reinforced concrete structures, rebar consumption of per square meter of floor area varies with different functions and sizes of buildings, ranging from 30~100kg/m²,

some special structures have bigger rebar consumption. In recent years, with continuous and rapid economic growth, China's rebar consumption has also increased year by year. Figure 7 shows the output of hot-rolled ribbed Rebar (HRB400, HRB500) in recent years, from which we can find that China's rebar production keeps increasing year by year. Generally speaking, ribbed bars, HRB400 and HRB500 account for about 25%, 30% and less than 0.5% of China's total rebar production respectively. Therefore, HRB335 is the leading product of China's rebars, but the consumption of high-strength rebars has been on increase year by year.

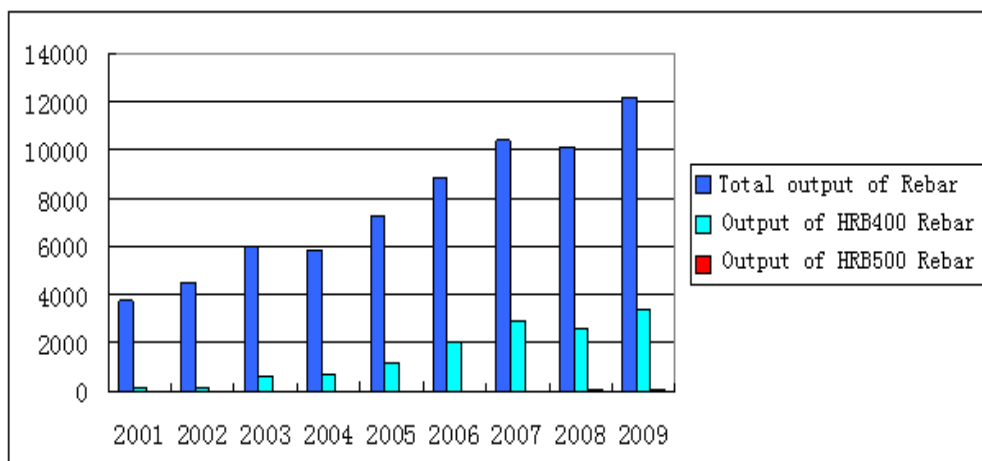


Figure 7 Output of Hot-Rolled Ribbed Rebar (2001-2009)

3.2 Statistics of China's rebar producers, product types, production licensing

Rebar production plays an important role in China's metallurgical industry and the national economy, and the product quality has a direct influence on both construction safety and personal and property safety. In the middle of 1980s, hot-rolled ribbed rebar products were firstly included into the catalog of important industrial products which were produced under the licensing management system. Practice shows that production licensing system plays a positive role in implementing national industrial and technological policies, promoting technological progress, enhancing business management, improving product quality, upgrading industrial restructuring, regulating market access, standardizing marketing behaviors, guaranteeing safety, as well as boosting production and application of rebar products.

According to statistics, more than 300 production plants have been licensed in hot-rolled rebar production in China, of which the integrated steelmaking and rolling plants account for about 46%, and the remainder are rolling plants. China has about 350 ribbed rebar rolling lines equipped with tandem or semi-tandem rolling mills, totaling a capacity of about 150 million tons. Those licensed for

production of seismic rebar HRB335E, HRB400E, HRB500E are large and medium enterprises, which accounts for 15%, 17% and 9% of the total number of licensed enterprises as shown in Figure 8. With the promulgation of the new design standards, the demand for seismic rebars will gradually increase, and more and more producers will apply for the license for production of such products. From the perspective of equipment, most enterprises in China can produce seismic rebar with high acceptability.

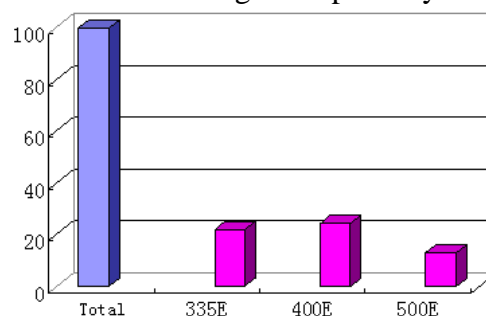


Figure 8

Generally speaking, rebar product standards are mandatory in China; therefore, producers should strictly abide by the standards and control the quality of products. At present, China's rebar products, with stable and world-class quality, are exported to various regions. Furthermore, in terms of production equipment, management and technology, metallurgical enterprises in China are able to produce seismic rebars in line with relevant standards.