



中国建研院 建研科技股份有限公司

2019· Xichang

Seminar on the “Application of Vanadium Alloy in Steel Reinforcing Bar”

Application of High-Strength Rebar in Concrete Structures and Related Standards

Presented by: Zhu Aiping (Research Fellow)

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China Academy of Building Research



Outline

I.

Studies on the Application of High-strength Rebar

II.

Standards for Engineering Application of Rebar

III.

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Researches I Have Carried out as a responsible person:

- **Experimental Study on Application of 500MPa Grade Rebar**
(2004-2012, a project funded by China Academy of Building Research (CABR))
- **Study on Applications of 500MPa Grade Rebar in Concrete Structures**
(2008-2012, the “eleventh five-year-plan period”)
- **Study on Applications of High-strength PC Steel Bars in Concrete Structures**
(2008-2012, the “eleventh five-year-plan period”)
- **Study on Application and Promotion of HRB500 Rebar**
(2011-2013, a science and technology project planned by the Ministry of Housing and Urban-rural Development (MOHURD))
- **Study on Standardization of Applications of 500MPa and Higher-grade Rebar**
(2012-2013, a project implemented and monitored by MOHURD)
- **Experimental Study on Anchorage Performance of 500MPa Grade Rebar in High-strength Concrete and Under-side-pressure Concrete**
(2013-2017, funded by China Academy of Building Research (CABR))
- **Guidelines for Applications of 500MPa and Higher-grade High-strength Rebar** (2015-2016, a project implemented and monitored by MOHURD)
- **Study on the Adaptation of Combined Application of High-performance Concrete and High-strength Rebar in Architectural Structures**
(2015-2016, a project implemented and monitored by MOHURD)
- **Study on Centralized Processing and Distribution of High-strength Rebar and Related Standards**
(2016-2017, a project implemented and monitored by MOHURD)
- **Early Study on the Standard for Promoting Top-quality Steel (Stainless Steel Rebar) in Buildings** (2016-2017, a project implemented and monitored by MOHURD)



Researches I Have Participated in

- Study on Seismic Fire-resistant Steel for Buildings (2002-2005, a project under “863” program)
- Technical Specifications for Application of High-performance Steel Materials and Super-Steel (2004-2005, a project under “863” program)
- 400MPa Grade Fine Grain Size High-strength Low-alloy Anti-corrosion Rebar (2006-2009, a project under “863” program)
- Study on Standards and Specifications Associated with High-performance Cost-saving Steel for Buildings (2007-2010, a project under national science and technology support)
- Study on Applications of High-performance Cost-saving Steel for Buildings (2007-2010, a project under national science and technology support)
- Key Technology Study on Application of Fine-grain High-strength Rebar and Square Steel Tube in Buildings (2007-2011, a project under “863” program)
- Study on Applications of Reinforced Concrete for High-speed Railway (2008-2011, a project under “863” program)
- Study on Development and Applications of Stainless Steel Rebar for Marine Building Structures (2015-2018, a project under “863” program)



- **Carry out Experimental Test on 500MPa Reinforced Concrete Members under Load and Related Theoretical Analysis and Comparison**
- **Summarize Design Approaches for 500MPa Rebar**
- **Incorporate the Applications of 500MPa Grade Rebar into Related Standards and Specifications for Concrete Structures**
- **Carry out Pilot Engineering Applications**
- **Achieve the Goal of Fully Publicizing 400MPa, 500MPa, and Other Higher-grade High-strength Rebar**



Contents of Experimental Studies	Quantity of Members finalized
Experimental Study on Anchorage Performance of 500MPa Grade Rebar	240pcs of 500MPa hot rolled bars; 75pcs of fine grain size bars; and 180pcs of mechanical anchorages (5 anchorage modes)
Study on Crack in 500MPa Reinforced Concrete Flexural Members; Study on Stiffness of 500MPa Reinforced Concrete Flexural Members	Finalized experimental studies on the flexural load-carrying properties, stiffness, and short-term cracks in 43pcs of 500MPa reinforced concrete beams; finalized experimental test on long-term cracks in 8pcs of 500MPa reinforced concrete beams.
Study on Shear Loading Performance of 500MPa Reinforced Concrete Flexural Members	finalized shear test on inclined section of 32pcs of 500MPa reinforced concrete beams
Experimental Test on 500MPa Reinforced Concrete Compressed Member under Load	finalized experimental test on 49pcs of 500MPa rebar compressed columns and eccentric-loaded beams
Study on Seismic Performance of 500MPa Rebar Coupling Beam of Small Span-depth Ratio	finalized repeated low cycle loading test on 10pcs of 500MPa rebar small span-depth shear wall coupling beams
Study on Seismic Performance of 500MPa Reinforced Concrete Column	finalized repeated low cycle loading test on 15pcs of 500MPa reinforced concrete columns; conducted repeated low cycle test on another 18pcs of 500MPa rebar-prefabricated grout sleeve connecting columns



Total quantity of test members exceeds 800pcs

Contents of Experimental Studies	Quantity of Members finalized
Study on Seismic Performance of 500MPa Reinforced Concrete Beam and Column Joints	finalized repeated low cycle loading test on 44 various 500MPa rebar frame-joint assemblies, including 20 intermediate joints in intermediate layer, 10 end-joints (include 4 joints anchored with anchorage plate) in intermediate layer, and 14 end-joints in top layer (including 8 joints lapped with anchorage plate rebar).
Study on Flexural Behavior of 500MPa Rebar Bonded Prestressed Concrete Beams	finalized tests on flexural behavior of 47pcs of 500MPa rebar bonded prestressed concrete beams
Study on Flexural Behavior of 500MPa Rebar Unbonded Prestressed Concrete Beams	finalized tests on flexural behavior of 8pcs of 500MPa rebar unbonded prestressed and 2pcs of non-prestressed (for comparison) concrete beams.
Other Tests	Mechanical properties and fatigue properties, etc.
Calculation and Analysis on Seismic Performance of Reinforced Concrete Frame Structures at Different Strengths	Carrying out necessary non-linear finite element analysis in conjunction with experimental studies, mainly the repeated low cycle loading test on frame columns, frame joints, and coupling beams; analyzing the reaction of typical frame structures of 400MPa, 500MPa and 600MPa rebar and the deformation of columns and beams, in big earthquakes.
Other Units	Production technology, weldability, mechanical connection properties, and fire resistance of rebars etc.



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■ Main U.S. Standards

- ✓ **Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement (ASTM A615) (Product)**
- ✓ **Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement (ASTM A706) (Product)**
- ✓ **Building Code Requirements for Structural Concrete and Commentary (ACI 318) (Application)**

■ Main Chinese Standards

- ✓ **Steel for the Reinforcement of Concrete --- Part I: Hot Rolled Plain Bars (GB1499.1)(Product)**
- ✓ **Steel for the Reinforcement of Concrete --- Part II: Hot Rolled Ribbed Bars (GB1499.2)(Product)**
- ✓ **Code for Design of Concrete Structures (GB50010) (Application)**
- ✓ **Code for Seismic Design of Buildings (GB50011) (Application)**
- ✓

■ Strength

- ✓ The stipulated strength grades are basically the same in the two countries
- ✓ **Grade 40, Grade 60, Grade 75, and Grade 80**

■ Rebar Application

- ✓ Main reinforcement — 400MPa (**Grade 60**)
- ✓ Auxiliary reinforcement — The U.S. standards are stricter, which is helpful to improve property of structures.
 - HPB300MPa rebar has extensive application in China
 - Generally only Grade 40 (280MPa) **ribbed** bars can be used; plain round bars are allowed to be used in steel mesh and spiral reinforcements only.

■ Seismic Property and Application

- ✓ The two countries have basically the same requirements on seismic property.
- ✓ The U.S. standards are stricter than Chinese standards in the control of rebar strength
- ✓ The low alloy ribbed rebar of the U.S. shows excellent performance.
- ✓ The U.S. has stricter requirements on elongation than China (9% in China; the U.S. standards differ)

■ Mechanical Connection and Mechanical Anchorage

- ✓ Connection — The U.S. and Chinese standards have similar lowest requirements while connection types are different.
- ✓ Anchorage — The requirements are basically the same; both encourage mechanical anchorage; China starts later in respect of the mechanical anchorage technology (GB 50010 and JGJ 256).



Guidelines

- Technical Guidelines for Application of High Strength Hot Rolled Ribbed Bars in Concrete Structures (RISN-TG007-2009) was prepared before related standards are revised and prepared.
- Addressed key technical problems in the application of 500MPa and 400MPa bars.
- Some technical specifications revised in the *Code for Design of Concrete Structures* can be seen in the guidelines.
- Proposed the first time in China the **test and inspection methods to differentiate and identify bars of different grades** so that to regulate the use of high strength rebar.
- Put forth precautions to be taken during construction of high strength rebar by absorbing experiences learnt from pilot projects.

RISN-TG007-2009

热轧带肋高强钢筋在混凝土结构中应用技术导则

Technical guidelines for application of high strength hot rolled ribbed bars in concrete structure

住房和城乡建设部标准定额研究所 编

中国建筑工业出版社



Code for Design of Concrete Structures (2015) GB 50010-2010

- **Comply with the national requirements on the publicity and application of high strength rebar.**
- **Phase out the large-diameters (14mm or larger) HRB335 bars while keeping HRB335 with diameter ranging from 6mm to 14mm.**
- **Keep the size of bars HPB300 and HRB335 within 6mm-14mm (diameter).**
- **Rebar HRBF335 is not listed any longer.**
- **The code is included in **the plan 2019** for revision of standards and specifications for engineering construction.**



Code for Seismic Design of Buildings (2016) GB 50011-2010

■ Main basis for revision

- ✓ *The Seismic Ground Motion Parameters Zonation Map of China (GB18306-2015)*
- ✓ *The Brief Manual of Administrative Divisions of the People's Republic of China 2015*
- ✓ **100% of the national territory requires for fortification against earthquake**

■ Main Contents of Revision

- ✓ Seismic fortification intensity, design basic seismic acceleration, and design earthquake groups of major cities and towns of China



Code for Construction of Concrete Structures (GB 50666-2011)

- Rebar grades are the same with the Code for Design of Concrete Structures (GB 50010-2010), including the 500MPa rebar to encourage the use of high strength rebar.
- Explicitly propose “**fabricated rebar produced in a specialized manner is preferred for reinforcing engineering projects**” to publicize the use of specialized fabricated rebar.
- Ascertain the application of rebar with its grade containing “E”.
- Add technical specifications on the application of mechanical anchorage plate, so as to provide simple and reliable ways for the anchorage of high strength rebar.

- **Incorporate contents associated with 500MPa rebar.**
- **Add test items on the in-site weight deviation of rebar.**
- **Add specifications for the secondary test on mechanical property and weight deviation after cold-drawing and straightening.**
- **Add acceptance rules for new application technologies like fabricated steel.**
- **Improve the acceptance of in-site prefabricated members.**
- **The size of each test plot can be expanded by one time for certified rebar and prefabricated rebar.**



- **Partial safety factor for permanent action — 1.3**
- **Partial safety factor for variable action — 1.5**
- **Partial safety factor for prestressed force — 1.3**



Technical Specifications for Application of Fabricated Steel Bars of Concrete Structure JGJ 366-2015

- **The first standard of China covering the whole process of production and application of fabricated steel bars.**
- **Prepared with the participation of all the major distributors, manufacturers and users of fabricated steel bars of China.**
- **Coordinated many times with related specifications.**
- **Main technical contents:**
 - ✓ **Organizational requirements for processing and distribution;**
 - ✓ **Inspection and acceptance of raw materials for off-site processing of rebar and in-site fabricated rebar;**
 - ✓ **Quality control in processing and distribution process;**
 - ✓ **Requirements on production safety.**



Standards for Centralized processing and distribution- Main Problems

- **Some standards on production and processing equipment need to be revised urgently.**
- **Lack of standards on the management and evaluation of centralized processing and distribution.**
- **Few standards show significant effects on the publicity and application of centralized processing and distribution and there is no special standards on the production procedure control and ex-factory quality evaluation and certification.**
- **Failure to define the processing and distribution of “rebar” as a “commodity”; the *Code for Quality Acceptance of Concrete Structure Construction* (GB50204) sets up strict acceptance criteria for prefabricated rebar.**
- **Little supporting standards, especially, exclusive standards, for the high-stage products of steel processing and distribution, such as rebar welded mesh, integrated reinforced cage, and rebar trusses, which is no good for the popularization and application.**



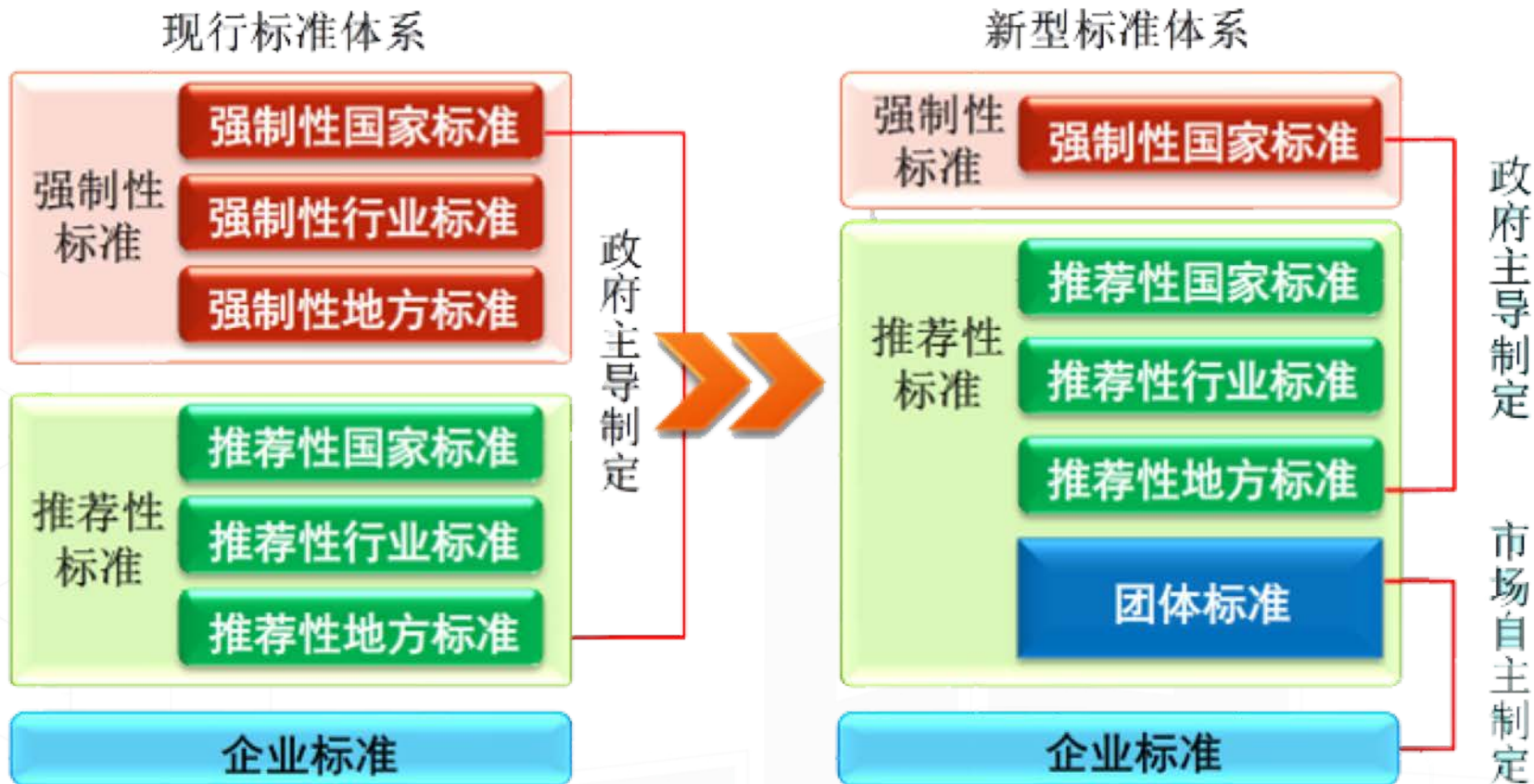
Proposals to Promote the Centralized Processing and Distribution of High Strength Rebar

- ✓ **Encourage the application of:**
 - *Fabricated Rebar for Concrete Structure JG/T 226*
 - *Fabricated Steel Bar for Concrete Structures GB/T29733*
 - *Technical Specification for Application of Fabricated Steel Bars for Concrete Structures JGJ366*
- ✓ **Intensify studies on key technologies and revision of standards**
 - *Code for Design of Concrete Structures GB50010*
 - *Code for Construction of Concrete Structures GB50666*
 - *Code for Quality Acceptance of Concrete Structure Construction GB50204*
 - *Technical Specification for Steel Bar Welded Mesh Concrete Structures JGJ114*
 - *Technical Specification for Mechanical Splicing of Steel Reinforcing Bars JGJ107*
- ✓ **Improve technical standard of equipment and improve existing standards**



- ✓ **Improvement and Revision of Important Standards**
 - **Speed up technical studies on the application of high strength rebar. Improve studies on the seismic resistance of high strength rebar structural members; optimize the production technology of 500MPa grade high strength rebar; carry out R & D on the production technology of and the fundamental studies on the application technology of steel bars of higher strength and higher grade.**
 - **Guide and push forward the centralized processing and distribution of rebar.**
 - **Improve standards of steel bars, optimize the grading of steel bars; improve service performance of buildings, optimize production capacity and promote the structural upgrading of rebar production and consumption; establish building rebar grade systems keeping pace with the world and showing Chinese characteristics.**
 - **Revise main standards on the application of steel bars, including *the Code for Design of Concrete Structures* and *the Technical Specifications for Concrete Structure of High-rise Buildings*.**
 - **Clearly define the cycle for preparation and revision of related standards and specifications, continuously collect and analyze industry data; launch the “small revision version” to satisfy the needs of development**
 - **Make the standards more open, more compatible and more harmonious.**
- ✓ **Play the role of associations, federations, and societies to intensify technical exchange and popularization of rebar for reinforced structures**

标准体系的演变



政府主导制定的标准侧重于保基本，市场自主制定的标准侧重于提高竞争力。同时建立完善与新型标准体系配套的标准化管理体制。

■ Opinions on Deepening the Reform in Standardization Work for Engineering Construction

- **In the future, a new standard system will be set up with mandatory standards as the core, recommended standards as the auxiliary, group standards as the support, and enterprise standards as the supplement.**
 - ✓ Full-text national mandatory standards (as technical guidelines, quantity limited)
 - ✓ Recommended national standards and trade standards (critical trade-wide issues, quantity limited)
 - ✓ Group standards (to be used upon free will, sufficiently supply; all the groups are in the competition with each other)
- A great number of special standards (including national standards and trade standards) in the existing engineering construction standard system can be combined or removed in the future so as to be converted or split into group standards and play a role.

■ Current Management Status of Engineering Construction Standards

- mandatory standards for engineering construction are prepared and approved in recent years.
- No more recommended national standards and trade standards are prepared.
- List of existing recommended standards to be converted into group standards is released.
 - ✓ Societies, associations, commerce chambers, federations, and other social groups will perfect, improve, supplement and refine such standards.
 - ✓ After completion of the preparation, information such as the released files and the text of new standards will be reported to the Ministry of Housing and Urban-Rural Development who shall make arrangement for abolishment of existing standards accordingly.

mandatory specifications for engineering construction

Engineering projects
Take the engineering construction project as a whole to define the scale, layout, function, and mandatory technical measures during the construction period.

Universal technologies
Take professional technologies as the object and take the planning, reconnaissance, design, construction, and other universal technical requirements as main contents.

■ Some mandatory Specifications for Urban-rural Construction

Technical Specifications for Engineering Projects (14 items)	Technical Specifications for General Technologies (24 items)	
Outdoor water supply engineering	Urban-rural planning	Building energy conservation and utilization of renewable energy sources
Outdoor drainage engineering	Engineering investigation	Building electrical and intelligent
Outdoor gas engineering	Urban-rural measurement	Building water supply and drainage and water saving
Outdoor heat supply engineering	Bases for design of structures	Municipal pipeline
Road and traffic engineering	Accessible	Construction scaffold
Urban rail transit engineering	Building and municipal foundations	Construction quality control of buildings and municipal projects
Landscape engineering	Concrete structures	Construction safety, hygiene and occupational health
City appearance and environmental sanitation engineering	Masonry structures	Identification and reinforcement of existing buildings
Treatment and disposal of building and municipal waste solids	Steel structures	Maintenance and restructuring of existing buildings
Residential buildings	Wood structures	Safety protection
Public buildings	Combined structures	
Special buildings (judicial buildings, civil affair buildings, parking lots)	Seismic resistance of buildings and municipal works	
Special facilities (comprehensive pipe racks and emergency shelters included)	Fire resistance of buildings	
Technical specification for the protection and utilization of natural and historical culture preservation areas.	Architectural environment	

CABR presided over the preparation of 7 items, participated in the preparation of 10 items, and participated in the management of 38 items

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■ Face Group Standards Correctly

- **Group (association) standard organizational management is a service job**
 - ✓ Service the society, serve all the trades, serve enterprises for a win-win future
- **Market-oriented, market-targeted, subject to contract agreement**
- **Implementation and quality are key elements.**
- **Free competition exists among different groups**
- **Implementation results need to be checked through engineering practices.**



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➤ **The promotion of rebar HRB500 is similar to that of rebar HRB400 while the situation is better when compared to those years**

- **The promotion of high strength rebar is pushed forward to different extents in different places.**
- **Designers in some regions haven't developed the habit of using high strength rebar yet.**
- **No significant economic benefits can be seen in the application in some structure types and members according to the requirements of related design codes (the quantity of bars used in some places are determined according to a fixed reinforcement ratio)**
- **Make-to-order is a habit of many manufacturers**
- **Quality and management of steel bars need to be improved.**



- **No clear technological process is determined for bulk production of rebar 500MPa and the quality is inconsistent.**
- **Comprehensive economic analysis, optimal structural design**
 - **Determine the economic cost for the application of high strength bars of different grades in view of the price of bars and the production cost and environment cost of related materials.**
 - **Define the concrete strength range applicable for the application of 500MPa rebar through comprehensive economic comparison.**
 - **Put forward advices on the grade and diameter of high strength bars to be used at different places of concrete structures in different conditions, so as to bring forward policy-oriented advices for the further promotion of high strength bars; prepare supporting and directive technical manuals for the application.**



- **Further push forward product certification**
- **Cope with problems related to the new applications of bars and the market competition**
 - **Demand declines and the existing supply-buyer mode unveils its disadvantages.**
 - **Powerful enterprises can start the distribution of fabricated bars or the processing of various bars to realize differentiated product and explore new spaces.**



➤ Promotion Outlook

- Consumption of prestressed wire rod
- Special-purpose bar and wire in conjunction with new technology development
- To develop enterprise ribbed bars
- Bar coils applicable for centralized processing and distribution
- Increasing consumption of welded mesh and steel bar trusses
- Increasing demand for processing of plain round bars
- Further promotion of cold-processing bars of medium-to-small diameter (CRB600H)
- Stainless steel bars and corrosion-resistant bars (corrosion resistance under different conditions)
- Improving quality, enhancing fundamental researches and going global



- **Closely follow the needs of the country, seize hot spots of the trade, and try to take diversified approaches to win support.**
- **Assist the competent government authority in work and establish communication channels.**
- **Establish good partnership with steel and building related enterprises; to promote new steel products, the manufacturer shall really come down to the building industry.**
- **Specifications and studies always enrich each other; the status of specifications determines the direction of studies; the study on the application of high strength rebar provides scientific and technological basis for the preparation and revision of specifications for concrete structures and correspondingly improves the strength of specifications.**
- **High quality, strict requirements**
- **The research teams shall “get together, do practices, learn more, and grow up”, so that the “person” can be a part of the “fruit”.**

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谢谢 Thanks