Safe Reinforcing Steel: Built to Global Standards

by
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Introduction

Reinforced concrete is a composite material. By definition a material is composite if it is made of 2 different materials with highly divergent and even opposite properties. Manufactured concrete is excellent in compression and a lightweight material but brittle which make it useless in any member is subjected to tensile forces. To overcome this steel bars are placed in concrete member zones resisting tensile forces. Steel has excellent tensile properties and highly ductile compared to concrete. Therefore a combination of steel and concrete confers unique properties to RCC which retains the most desirable characteristics of both the materials.

As reinforced concrete is the mainstay of infrastructure and housing construction throughout the world, cement and reinforcing steel has emerged as major manufacturing industries in every country. This has led to codification of RCC construction practice throughout the world to simplify and streamline the design and construction process. This in turn has led to the standardization of material specifications for the construction industry. Reinforcing steel production is a major industrial segment in every country of the world. It is generally produced to national standards specification. As international trade has grown in volume and scope the demand for a material specification across major national standards has grown. The Geneva based International Standards Organization (ISO) under the tutelage of the World Trade Organization (WTO) played a pivotal role in the internationalization of material standards. Today the European Community nations follow common material specifications for thousands of items and reinforcing steel is no exception. Standardization of products to national and international specifications serves 3 useful purposes. First, it simplifies the exchange of goods as buyers and sellers have a common specification. Further, legal enforcement of contract specifications becomes easier and transparent. Most important the design profession can prescribe material specification as per well defined norms which are available in the area.

The international standard for reinforcing bar specification is ISO 6935. It has been adopted by the national reinforcing steel standards of the entire European Community of nations as well as Russia and all the CIS nation states. In Asia India, China and Japan along with the ASEAN nations has adopted the ISO based standards for steel and many other material standards as well. Bangladesh adopted the standard in 2006. The strongest motivation, for this move is to remain globally competitive, by making a product for both the domestic and international market. It is worth mentioning that many of the nations adopting the ISO based standard are in the high seismic category. Among them are Turkey, Italy, and New Zealand. China and India both have areas of intense seismic activity.

ASTM and ISO Compared

For a long time the U.S. national standard ASTM 615 reinforcing steel specification was most widely used in many parts of the world including Bangladesh. One of the reasons for the widespread use of ASTM 615 reinforcing steel was that it could be easily manufactured using simple and relatively inexpensive equipment and technology.

ASTM 615 is an open chemistry specification, the mechanical properties are defined, the test procedures are relatively straightforward but the chemical composition of the steel are not specified. The yield strength is derived by increasing the carbon content of the steel, but this increases brittleness as well. Practicing engineers will recall the common site experience of ASTM 615 Grade 60 bars breaking while bending. The open chemistry specification was a further reason for the widespread adoption of the ASTM 615 specification as raw material (billets) from a variety of sources could be used to manufacture ASTM 615 Grade 60 bars. This is reflected in the wide variation of the mechanical properties of the ASTM 615 Grade 60 steel. In our country old demolished structures, such as anchor chains and propeller shafts of ships and railway rails are used to make ASTM 615 Grade 60 reinforcement.

In stark contrast ISO 6935 standard has a highly restricted chemistry where the principal alloying elements such as carbon, manganese, silicon which affects the mechanical properties of steel and several other trace elements which have deleterious effects on steel property. The logical consequence of a restricted chemistry reinforcing steel means the raw material [billet] has to be custom made for the purpose. The chemistry of both the standards are compared below

Table.1 Chemistry of ASTM and ISO Standards

Chemical Composition	ASTM A 615 Grade 60	ISO 6935 Grade 500W
Carbon %	No limit	0.24% Max
Manganese %	No limit	1.65% Max
Silicon %	No limit	0.60% Max
Phosphorous%	0.06% Max.	0.06% Max
Sulphur %	No limit	0.06% Max
Carbon Eqv.	No limit	0.51% Max

The above comparison makes it amply clear that ISO 6935 Grade 500W reinforcing steel can be manufactured out of custom made billets only. As the chemistry of the billets is tightly controlled in the ISO standard the reinforcing bar mechanical properties are also controlled within a narrow band.

Strength Categories

Both the ISO and ASTM standards steel have various strength categories. These enable structural engineers to use steel as per design and service requirement. The strength categories ASTM and ISO standards are compared below for easy reference.

The ASTM standard follows the traditional U.S. customary units for stress which is pounds per square inch or psi. The ISO standard follows the Systeme International or SI units for stress which is indicated in Pascal. One million Pascal is abbreviated to MPa. For easy conversion 1 MPa = 145 psi.

Table. 2 Strength comparisons of steel standards

ASTM 615	ISO 6935
Grade 40 [40,000 psi = 275 MPa]	Grade 300 [300 MPa = 43,500 psi]
Grade 60 [60,000 psi = 415 MPa]	Grade 400 [400 MPa = 58,000 psi]
Grade 75 [75,000 psi = 520 MPa]	Grade 500 [500 MPa = 72,500 psi]

As the demand for economy and cost control in the construction industry has raised world wide the demand for high strength steel reinforcement and high strength concrete. All buildings and structures in the developed world and in the Middle East and in the ASEAN region are designed and built on Grade 500 steel only. The reason is not only economy but better performance of the structure under conditions of earthquakes and storms.

Ductile Grades of Steel

Within the umbrella of the ISO 6935 standard a new generation of high strength reinforcing steels has been developed which is used in all high grade construction with safety and performance under adverse conditions of prime concern. The distinguishing feature of these steels is both the yield strength and ultimate strength have a minimum lower limit and maximum upper limit. This is clearly shown in the table below. In contrast the earlier ASTM 615 bars had only minimum yield and ultimate strength requirements with no specified upper limits. The leading ductile or earthquake bar standards of several countries are compared below:

Table.3 Earthquake grades of reinforcing steel.

Attribute	**ASTM 706 Grade 60**	**AS/NZS 4671 Grade500E**	**BS4449 Grade 500C**	**JIS G3112 SD 490**
ORIGIN	**U.S.A.**	**Australia-New Zealand**	**U.K.**	**Japan**
Yield strength, Fy,Mpa	**540≥Fy≥420**	**600≥ Fy ≥500**	**650≥ Fy ≥ 485**	**625≥Fy≥490**
Ultimate strength Ts, Mpa	**550 Min ≥1.25Fy**	**1.40Fy ≥Ts≥1.15Fy**	**1.38Fy≥Ts≥1.13Fy**	**620 Min**
Elongation Gauge	**200 mm**	**5d**	**5d**	**5d**
Elongation: Fracture	**10% – 14%**	**--**	**--**	**12% Min.**
Elongation: Max. Force	**--**	**≥10%**	**6% Min.**	**-**

The 3 Measures of Ductility

The % elongation to a defined gauge length is the most commonly reported measure of ductility. ASTM standards have a fixed gauge length of 8 in. or 203mm for all bar sizes. ISO standard have a variable gauge length of 5D, the gauge length varies with the bar diameter. The variable gauge length takes in to account the tri-cyclic nature of the post elastic strain after the yield point.

Design Consideration

Performance based RCC design dictates that structural elements form a plastic hinge under overload conditions. Further, the plastic hinge must be capable of undergoing large inelastic deformation with no significant reduction in load carrying ability. Structural designers would like to know the maximum strength of a plastic hinge zone so that other elements of a structure can be designed to remain elastic. For example, designers of RCC buildings would want the beam to 'fail' by forming plastic overload hinges, in dissipating earthquake forces but not the columns. This is known as 'strong column weak beam' design to minimize loss of life in an earthquake. For such design the design engineers must know the minimum and maximum yield strength and the minimum and maximum tensile strengths of the reinforcing steels. Further, the use of higher strength steel relieves bar congestion in beam and column intersections, which is the most critical zone for safety from earthquakes. As the above ISO based bar standards place a definite lower and upper limit to the yield and tensile strength of the bar, probable over strength capacity of a plastic hinge can be inferred from test properties of the reinforcing steel manufactured to ISO standards.

The Grade 500 Manufacturing Process

The mechanical properties of the new generation ductile grade high strength reinforcing bar are derived from the restricted chemistry steel billets and by an unique in-line heat treatment in the bar rolling mill.

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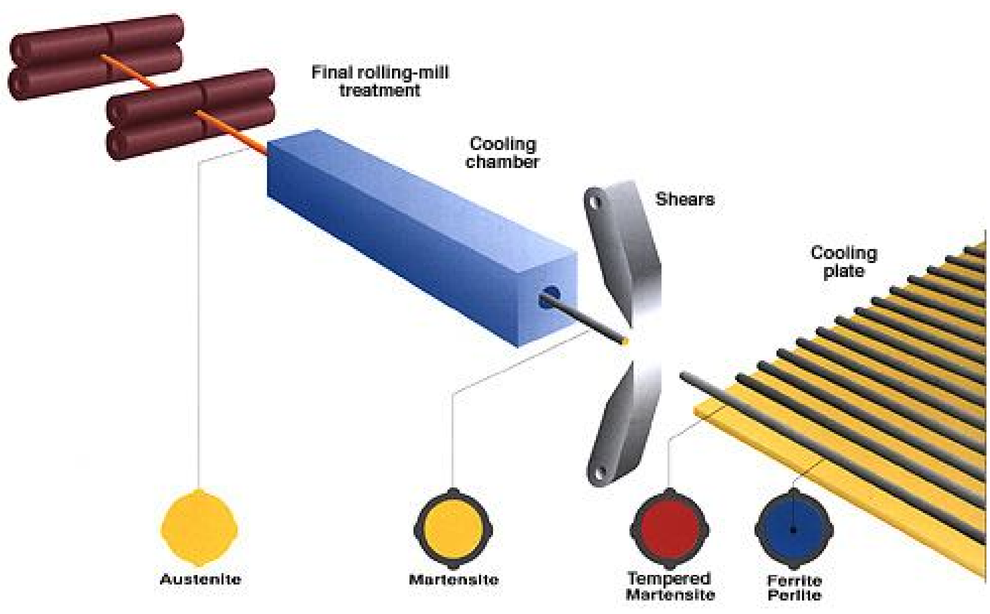

The above schematic diagram illustrates the **Quench & Temper** process which converts low carbon steel into 500 MPa high strength bars with a guaranteed yield strength of 500 MPa.

It consists in subjecting the hot rolled steel to an in-line heat treatment in 3 successive stages:

- As soon as it leaves the final mill stand, the product is rapidly and energetically cooled through a short cooling installation, where it undergoes surface hardening (martensite layer)
- As soon as this quenching operation is stopped, the surface layer is TEMpered by using the residual heat left in the CORE of the bar (self tempering of the martensite layer).
- The third stage takes place while the product lies on the cooling bed where the bar is subjected to normal cooling down to ambient temperature (transformation of the residual austenite in the core)

The above process requires precise process control in the rolling mill as the quench process is time and temperature sensitive. The Quench and Temper process has clearly emerged as the preferred manufacturing route for reinforcing steel throughout the world due to the excellent combination of high strength and ductility of the steel which is obtained through this process.

In Bangladesh BSRM Steels Ltd. is the first and only producer to introduce the high strength ductile grade 500 MPa yield strength steel reinforcement. The Grade 500 steel produced by BSRM is of the ductile or earthquake variety with controlled lower and upper limit yield strengths and the lower and upper limits in tensile strengths as well. It fully conforms to the internationally accepted U.K. bar standard B.S. 4449 Gr.500 and the Australia-New Zealand AS-ANZ 4671 Grade 500E and meets the major requirements of both the U.S. standard ASTM 706 and the Japanese standard JIS G3112 SD 490

Economic Consideration

Traditionally construction in Bangladesh has relied on Grade 60 strength steel for all types of construction. The scenario changed rapidly with the introduction of Grade 500 steel last year by BSRM Steels Ltd. As the use of Grade 500 steel reduces steel consumption by up to 15% compared to Grade 60 steel the introduction was an instant success. Many of the country's top developers and designers of high rise buildings switched to Grade 500 for the inherent economy in the use of this grade of steel.

Comments on this article
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