The feature* presents a historical review of major developments in the sphere of reinforcing steel, especially in the Indian context. The major landmarks in the history covering square-twisted rebars, cold-twisted and hot-rolled rebars, thermomechanically treated rebars, Torkari bars, etc are described. The author has also touched upon special steels, coated rebars and sub-standard rebars.

The concept of reinforced concrete (RC) was first initiated by Jean Louis Lambot in 1850 through his rowboat. Subsequently, several engineers improvised this to bring about efficient RC members and structures of today’s standards.

The first RC roof built by Francois Coignet in 1853, the work of Wilkinson of New Castle in 1855, the work of W E Ward (USA) in 1874, the contribution of Hyatt in 1875 regarding provision of deformations on rebars through indentations or projections and development of the concept of stirrups by Francis Hennebique in 1898 are part of history.

By the end of the second world war, deformed high strength rebars started gaining momentum around the world. Cold twisted and hot rolled deformed rebars of proof stress about 420 N/mm² came out for wide usage. However, in the Indian context, till about 1965, the classical plain mild steel rebars of yield strength 250 N/mm² constituted the reinforcement for the concrete construction industry, Fig 1. Winds of change were seen in this domain only after 1965.

Introduction of square twisted rebars

For the first time in India, on a small scale, square twisted rebars with chamfered corners, Fig 2, were brought into market by IRC Steels, West Bengal with the collaboration of BRC, UK. Since production of such rebars was quite an involved process and since the rebars were not efficient enough, they were phased out from the Indian market in a very short period.

Production of cold twisted circular rebars

In 1967, Tor Isteg Steel Corporation of Luxumberg introduced, in India, ‘cold twisted deformed circular rebars’ of proof stress 420 N/mm², which subsequently became popular as Tor 40 rebars. The manufacturing process essentially comprised of three stages:

(i) production of quality billets

(ii) passing the reheated billets through stands, to get deformed rebars of desired diameters ; and

(iii) cold twisting the deformed rebars to the desired pitch.

Agarwal Hardwares, Kolkata; Mukund Steel, Mumbai, Rathi Steels, Delhi; ISRM, Chennai were the first to produce these rebars in the country in 1967. Hindustan Steels, (Presently SAIL) followed soon after. By about 1970, these Tor 40 rebars (grade Fe 415) replaced the classical plain mild steel rebars by about 50 percent in the country, Fig 3.
In view of the simplicity in production, significant savings in the consumption of rebars in constructions and aggressive technical marketing by the manufacturers and TOR ISTEG Steel Corporation, classical plain mild steel rebars were virtually replaced by these, by about 1975. Some of the brochures of the manufacturers depicting advantages of ribbed torsteel are shown in Fig 4.

**Production of hot rolled rebars**

During the period when cold-twisted rebars were being introduced, a few industrialists decided to produce hot-rolled alloy rebars as well in the country, which were popular in USA during that period, Fig 5. In this process, the enhancement of strength to about 420 N/mm$^2$ from 250 N/mm$^2$ is achieved essentially by incorporating alloys like nickel and vanadium in the molten metal, while producing the billets. The billets are subsequently passed through stands resulting in high strength deformed hot rolled rebars.

It was by about 1968, that for the first time these rebars were produced by Tata Steel and were branded as Tistrong rebars, Fig 6. However, the production of these rebars was discontinued within a short span, in view of the prohibitive cost of the alloying elements. Tata Steel, subsequently brought out cold twisted deformed rebars with indigenous technical back up, branding them Tiscon rebars, Fig 7.

**Scenario in the seventies**

In the beginning of seventies, the emphasis in marketing the cold-twisted rebars by the leaders in the industry, was essentially on the resulting high strength and reduction in consumption of steel in construction. Subsequently, the emphasis shifted to the inherent quality inputs in cold-twisted rebars.

It was at this juncture that Tor Isteg Steel Corporation handed over the mantle of ensuring production of quality rebars to Torsteel Research Foundation.

By about 1978, the industry decided to bring in Fe 500 cold-twisted rebars in consonance with the trend in Europe. As a result, Tor 50 and Tiscon 50 (grade Fe 500) were pushed in the market, Fig 8. Several major constructions came up around the country with these higher grade rebars.

In addition to Torsteel and Tiscon, several secondary steel units, in the unorganised sector, also started production of Fe-415 rebars, popularly termed as CTD rebars.

**Introduction of thermo processed (TMT) rebars**

Between 1980 and 1985, new type of rebars termed TMT rebars were developed around the world, for the benefit of RC constructions. Notable amongst them were Torsid from...
France, Tempcore from Belgium and Thermex from East Germany.

The basic process of manufacturing totally differed from that of cold-twisted and hot-rolled rebars. The manufacturing process essentially comprised of controlled quenching of rebars. The rebars heated up to a temperature of about 900°C, when passed through quenching tubes — wherein the volume and temperature of cooling water is controlled — get quenched to a temperature of about 450°C in a few seconds, Fig 9. This process results in enhancement of the strength level of rebars, subject to precise control of all parameters. These are essentially ‘dual phase rebars’, with tempered martensite periphery and ferrite-pearlite core.

The first to produce TMT rebars in India were Tata Steel, by about 1992, through Tempcore technology, Fig 10. Later Vizag Steel came on line followed by SAIL through Thermex technology, Figs 11. In the initial years, the production was restricted to rebars having diameter higher than about 16 mm. With experience and with the advent of refinements in technology, smaller diameters could be produced.

The production in the initial stages, however, was restricted to grade Fe 415 and restricted to major steel plants.

Soon after this, secondary sector plants also entered the arena. The first plant in the secondary sector to produce these rebars was Keshari Steels from Madhya Pradesh. Further, to cater to the secondary sector in the country, modified versions of Tempcore and Thermex processes were developed indigenously. To mention a few: RA-TMT (Fig 12), EVACON-TMT, PP ENGINEERING-TMT etc.

Table 1 presents a comparison of the properties of cold-twisted and thermo-processed rebars.

**Torkari rebars**

In contrast to the cold twisting and thermo processing, a new procedure for manufacturing high strength deformed rebars was developed by Germans, branded as Torkari rebars. The manufacturing procedure essentially comprises of simultaneous cold reduction and cold ribbing of wire rods. This process results in production of rebars of proof strength upto 550 N/mm². However, the process is restricted to diameters up to 11 mm.

Table 1: Comparison between cold-twisted and thermo-processed rebars

<table>
<thead>
<tr>
<th>Property</th>
<th>Cold-twisted rebars</th>
<th>Thermo-processed rebars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter, mm</td>
<td>6 to 45</td>
<td>8 to 45</td>
</tr>
<tr>
<td>Proof and ultimate strength</td>
<td>Minimum levels as specified by Indian Standards IS 1786</td>
<td></td>
</tr>
<tr>
<td>Percentage of elongation (measure of ductility)</td>
<td>About 15 percent for Fe-415 and 13 percent for Fe-500 rebars over a gauge length of 5d</td>
<td>Over 20 percent for Fe-415 and Fe-500 rebars over a gauge length of 5d</td>
</tr>
<tr>
<td>Stress strain diagram</td>
<td>Yield point not ‘well defined’</td>
<td>Yield point ‘well defined’</td>
</tr>
<tr>
<td>Rebar grade</td>
<td>Mainly Fe 415*</td>
<td>Fe 415 and Fe 500</td>
</tr>
<tr>
<td>Production centres</td>
<td>Restricted to secondary sector</td>
<td>Mainly from major steel plants and to some extent from secondary sector</td>
</tr>
</tbody>
</table>

* In the beginning of the nineties, since power tariff became expensive in the country, almost all the arc furnaces in the secondary sector closed down, resulting in non-availability of quality Fe-500 grade billets. As a consequence to this, the production of Fe-500 rebars got discontinued in the secondary sector.
Several small units around the country, started production of these rebars during the beginning of nineties, under the guidance of Torsteel Research Foundation. In order to exploit the full potential of these rebars, the production in this sector is trying to diversify from individual rebars to rebar meshes, Fig. 13.

The regime of special reinforcing bars

The life/durability of RC members depends on the corrosion resistance or otherwise of the rebars. In the Indian context, during seventies and eighties, collapses of some structures occurred due to severe corrosion of rebars. This triggered the production of special rebars to effectively combat corrosion problems in structures.

The first to come in the market was corrosion resistant rebars (CRS) from Tata Steel, Fig. 14. The desired properties, intended to be achieved, were through modifications in chemical composition of the billets. This was followed by similar corrosion-resistant rebars, from Vizag Steel and SAIL. Along with the popular usage of these rebars in many structures around the country, differences of opinion amongst the engineers also surfaced regarding the effectiveness of these rebars in combating corrosion.

In several countries around the world, austenitic and ferritic stainless steel rebars have been introduced as yet another effective step in regions prone for severe corrosion.

As a follow up, austenitic stainless steel rebars were produced in India, to start with. But productions were phased out, due to prohibitive cost of such rebars. Very recently, Sunflag Steel and others have brought out ferritic stainless steel rebars, (Fig 15) which are both cost effective and corrosion resistant.

It is being predicted that these ferritic stainless steel rebars, with a chromium content of 11 to 12 percent, will gain popularity.

Further developments in the field of corrosion resistant rebars, consist of a total change-over from conventional rebars to FRP rebars. Germany, France, Holland and Japan have already been in the forefront with glass, aramid and carbon fibre reinforced plastic rebars. A few constructions have come up in India with imported rebars and attempts are already on to introduce them in the Indian market in a big way.

Coated reinforcing bars

Simultaneously, developments have taken place in the production of coated rebars, as a parallel to corrosion-resistant rebars. The main two categories of factory produced rebars in the Indian market: are galvanised and epoxy coated rebars.

The first classical structure in the country, wherein galvanised rebars were used in toto, is the Bahai’s Temple at New Delhi, Fig. 16. Since then, several buildings and bridges have come up with these rebars.

In addition, fusion bonded epoxy coated rebars are very much in constructions, being produced by PSL Holdings and others, Fig. 17. Electrostatic precipitation process is generally used, Fig 18. A large number of bridge structures in the coastal belt around the country have come up with these epoxy coated rebars, Fig 19.
Of late, opinions are often being expressed, in several forums, for and against coated rebars with reference to their effectiveness.

**Provisions in standards**

Several national and international standards adequately cover the requirements of rebars. Since the role of present-day design/construction engineer is global in nature, these standards are helpful. By and large, the requirements regarding proof and ultimate strengths, percent elongation and chemical composition are amply covered.

A few prominent standards which cover the requirements are:

- **Indian Standards** – IS 1786
- **British Standards** – BS 4449
- **American Standards** – ASTM A615M and ASTM A706M
- **Euro norms** – EN10080
- and **Asian Model Code 1999**.

Only in case of percent elongation, the indicated gauge length differs from standard to standard.

<table>
<thead>
<tr>
<th>Type of rebar</th>
<th>Present status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-twisted rebars</td>
<td></td>
</tr>
<tr>
<td>Torsteel-40 (Fe-415)</td>
<td>Presently prevalent</td>
</tr>
<tr>
<td>Torsteel-50 (Fe-500)</td>
<td>Production hampered</td>
</tr>
<tr>
<td>CTD-40 (Fe-415)</td>
<td>Presently prevalent</td>
</tr>
<tr>
<td>Tiscon-40 (Fe-415)</td>
<td>Almost phased out</td>
</tr>
<tr>
<td>Tiscon-50 (Fe-500)</td>
<td>Almost phased out</td>
</tr>
<tr>
<td>Thermo processed rebars (TMT)</td>
<td></td>
</tr>
<tr>
<td>Tiscon - 40 (Fe-415)</td>
<td>Presently prevalent</td>
</tr>
<tr>
<td>Tiscon - 50 (Fe-500)</td>
<td>Presently prevalent</td>
</tr>
<tr>
<td>SAIL - 40 (Fe-415)</td>
<td>Presently prevalent</td>
</tr>
<tr>
<td>SAIL - 50 (Fe-500)</td>
<td>Presently prevalent</td>
</tr>
<tr>
<td>VIZAG - 40 (Fe-415)</td>
<td>Presently prevalent</td>
</tr>
<tr>
<td>VIZAG - 50 (Fe-500)</td>
<td>Presently prevalent</td>
</tr>
<tr>
<td>Secondary Sector-40 (Fe-415)</td>
<td>Presently prevalent</td>
</tr>
</tbody>
</table>

**Sub-standard reinforcing bars**

Inspite of the overall developments in the reinforcement field, the construction industry is faced with the problem of sub-standard reinforcements in the market which exhibit the following lacunae:

1. brittle rebars with high carbon content,
2. low strength rebars with low carbon content,
3. bars marketed as TMT rebars, not being quenched at all; and
4. bars with inadequate quenching resulting in lower strength

**The present scenario**

The present scenario regarding cold twisted rebars and thermo processed rebars (TMT) is summarised in Table 2.

In several plants, production of grade Fe 550 rebars with adequate ductility has commenced. Production of small diameter rebar meshes is also gaining importance. Attempts are also on to produce FRP rebars by a few industrialists.

In essence, phenomenal growth is witnessed in the domain of reinforcing bars. Despite a few problems concerning substandard rebars, the horizon of Indian reinforcing bars is bright enough.

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