INSTITUTE FOR STEEL DEVELOPMENT AND GROWTH

Seminar on

USE OF HIGH STRENGTH STEEL & SOLUTIONS FOR CONSTRUCTION

HIGH STRENGTH STEEL IN CONSTRUCTION AN OVERVIEW OF SUSTAINABILITY

N. Bandyopadhyay

22nd July, 2022

SUSTAINABILITY ISSUES IN CONSTRUCTION

Decarbonization is a challenge common to all sectors of the built environment.

This high-priority issue involves both operational carbon as well as embodied carbon; the latter includes carbon from the manufacture of materials and the transport and assembly of components used to produce a structure.

There are immense opportunities to reduce carbon emissions associated with steel structures in general (and steel bridges in particular).

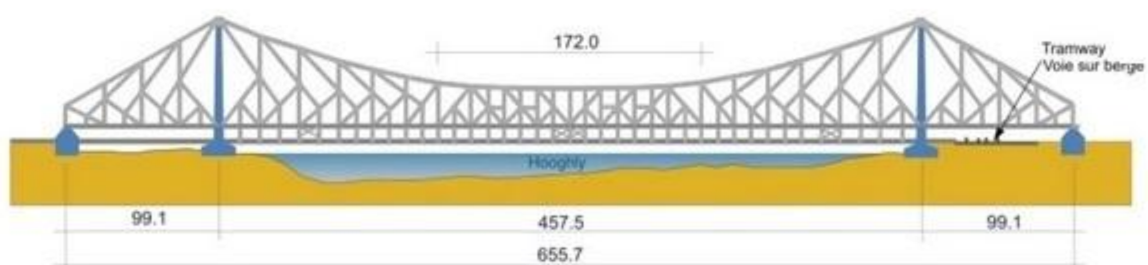
There is a need for all stakeholders to focus on material choices and approaches that support environmental sustainability.

Adoption of High Strength Steel in Structures will be a step towards it.

Adoption of High Tensile Steel

An 80 year old example - Howrah Bridge commissioned in 1943

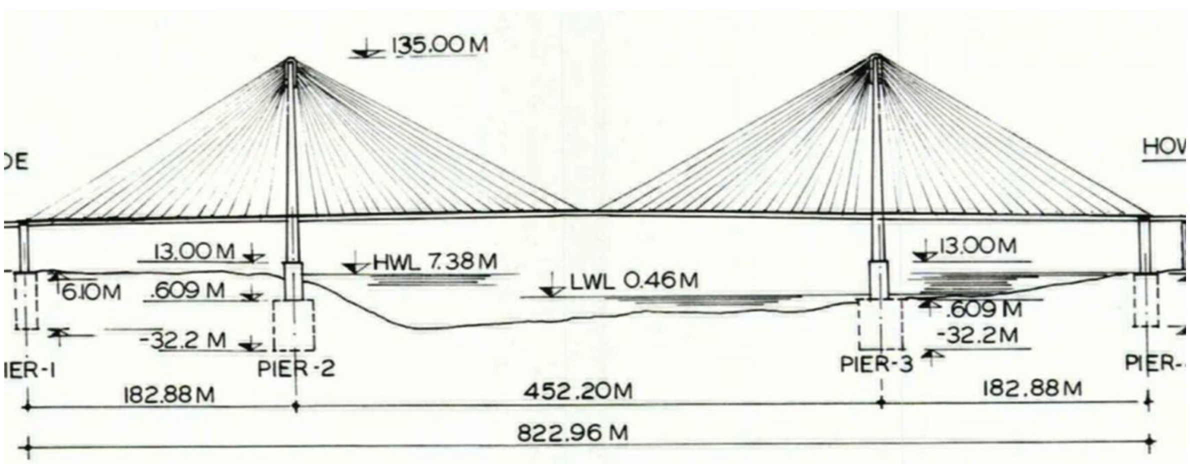
A 30m wide, 655m long Cantilever Bridge with Central Span of 457m. Initial design with Mild Steel had a tonnage of 36000t and made the bridge almost unviable. Later design was carried out with High Tensile Steel. It resulted in saving of 10,000t of steel making the bridge lighter. Steel Weight per Metre – 40t



Second Hooghly Bridge – designed in 1970s – Cable Stayed Bridge of total length 822 m, central span of 452m, a few kilometers downstream of Howrah Bridge

Steel Consumption approx 16,500 t including Cables.

Steel Weight -20t per M



Around the time when these two iconic bridges were constructed, Green House Gas (GHG) and sustainable development were not serious issues. Yet with the adoption of higher strength material resulted into contribution towards better environment.

A construction Engineer cannot control the embedded carbon in the adopted material of construction. But reduction of material usage will lead to lesser GHG effect.

Steel including Mild Steel is a sustainable material of construction. Unlike Concrete or Wood, it is 100% recyclable.

Normally in India we build bridges with 250 MPa grade steel although in many countries 350 MPa grade steel is the norm.

High Strength Steel for structural usage are manufactured 450 MPa grade to as high as 1000 MPa Yield Strength grade.

Development of TMCP Technology contributed towards production of such High Performance Steel.

Thermo-Mechanical Controlled Process (TMCP). It involves optimal control of Rolling Temperature and subsequently control of cooling at a rate faster than air cooling.

It results in a fine grained structure compared to conventional steel plate.

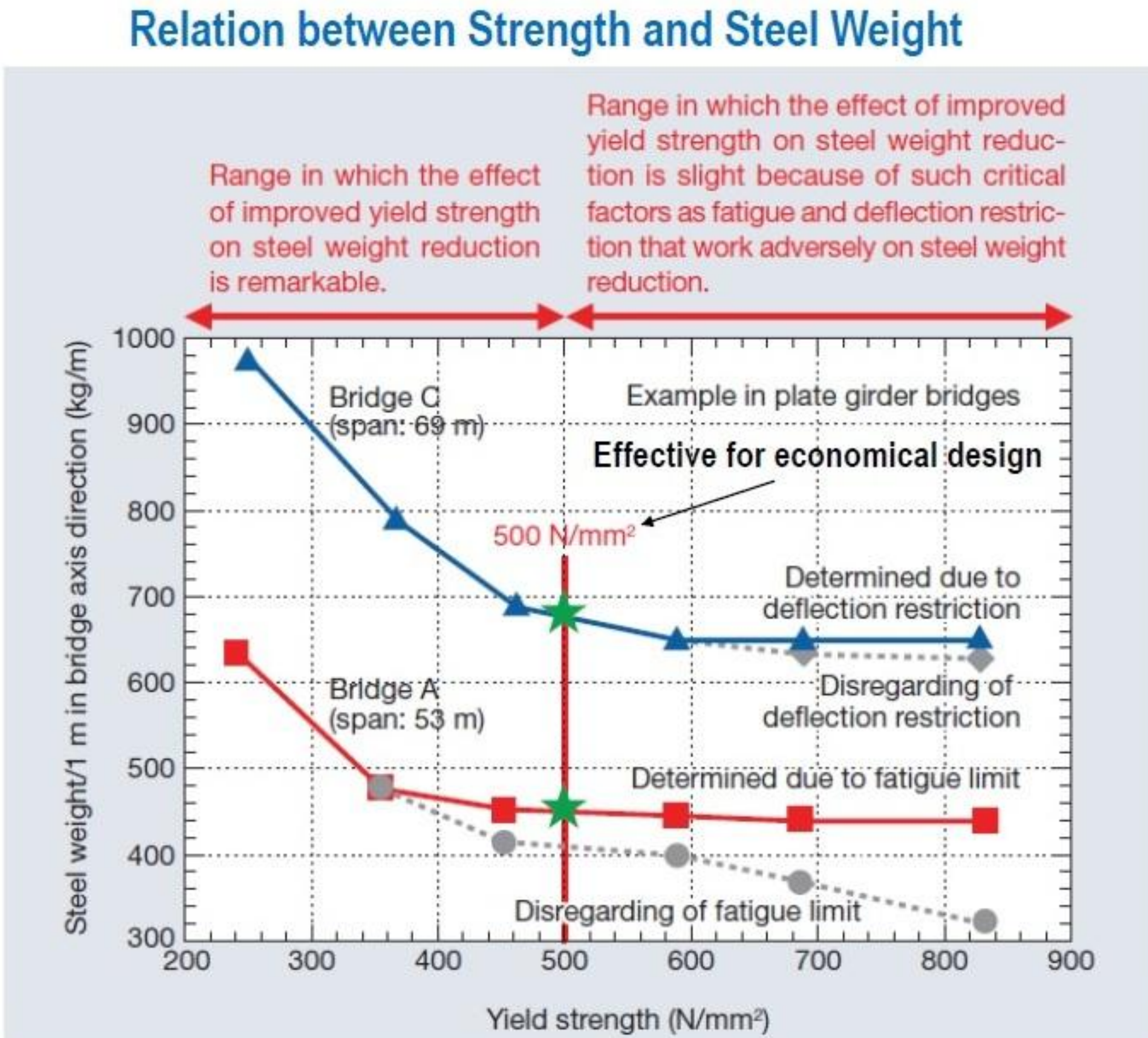
The resulting steel products display High Strength and Toughness.

Greatly improved Weldability adds to ease of Fabrication effort.

Very small amount of Chromium, Nickel are added in the manufacture of steel in the higher strength bracket.

Besides TMCP technology, Q&T (Quenched and Tempered) process is also adopted to manufacture High Strength Steel.

Economy in Design by adopting High Strength Steel



In the last slide we came across two constraints namely **deflection** criteria and **fatigue** consideration, that restricted weight reduction beyond a certain level. These are based on established design rules.

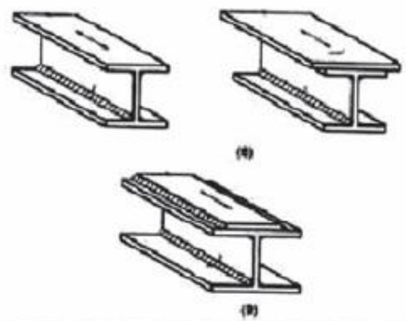
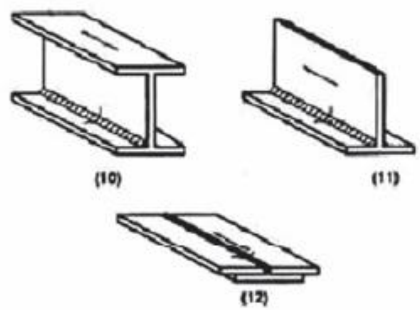
For functional Serviceability requirement, the **deflection** of the whole structure cannot be allowed to exceed certain limits (L/800 for Indian Highway bridges). Deflection under a given set of loads depends on the stiffness of the structure and stiffness is determined from cross-section of relevant components. Thus as a structure under a set of loading becomes lighter, its deflection is increased and reaches the limiting value at some point. Often, with better design approach e.g. replacing Plate Girder configuration with Box Girder, it is possible to extend the deflection limit.

Fatigue is the damage caused by repeated fluctuation of stress, leading to progressive cracking and failure of a structural element. Established Design Procedure is followed to verify all members are safe against fatigue failure.

Essentially, the variable stress range is estimated and is compared with the permissible stress range based on the **Detail category** of the member and its connections. The permissible stress is independent of strength of steel. Thus design for Fatigue often puts a restriction on optimization using High Grade Steel.

Next slide shows some example of Detail Category

Part of the Table specifying detail categories

Sl No. (1)	Detail Category (2)	Constructional Details: Illustration (*see* Note) (3)	Constructional Details: Description (4)
i)	92		**Welded plate I-section and box girders with continuous longitudinal welds** (8) & (9) : Zones of continuous automatic longitudinal fillet or butt welds carried out from both sides and all welds not having un-repaired stop-start positions.
ii)	83		**Welded plate I-section and box girders with continuous longitudinal welds** (10) & (11) : Zones of continuous automatic butt welds made from one side only with a continuous backing bar and all welds not having un-repaired stop-start postitions. (12) : Zones of continuous longitudinal fillet or butt welds carried out from both sides but containing stop-start positions. For continuous manual longitudinal fillet or but welds carried out from both sides, use Detail Category 92.
iii)	66		**Welded plate I-section and box girders with continuous longitudinal welds** (13) : Zones of continuous longitudinal welds carried out from one side only, with or without stop-start positions.
			Intermittent longitudinal welds

In a Bridge structure, some members are designed on the basis of the fluctuating load (Live Load) and they remain practically stress free in absence of Live Load – (e.g. Slippers in a Railway bridge). Design of these members are actually guided by Fatigue Design clauses. These may be fabricated with conventional 250 MPa grade steel.

There are other members, where fluctuating load forms a small part of the total stress. High Tensile Steel can be adopted in those members.

In long span Truss Bridges often the Floor Elements are made with conventional Mild Steel whereas the Truss elements are made with High Tensile Steel. This method is also called 'Hybrid Construction'.

Corrosion in Steel

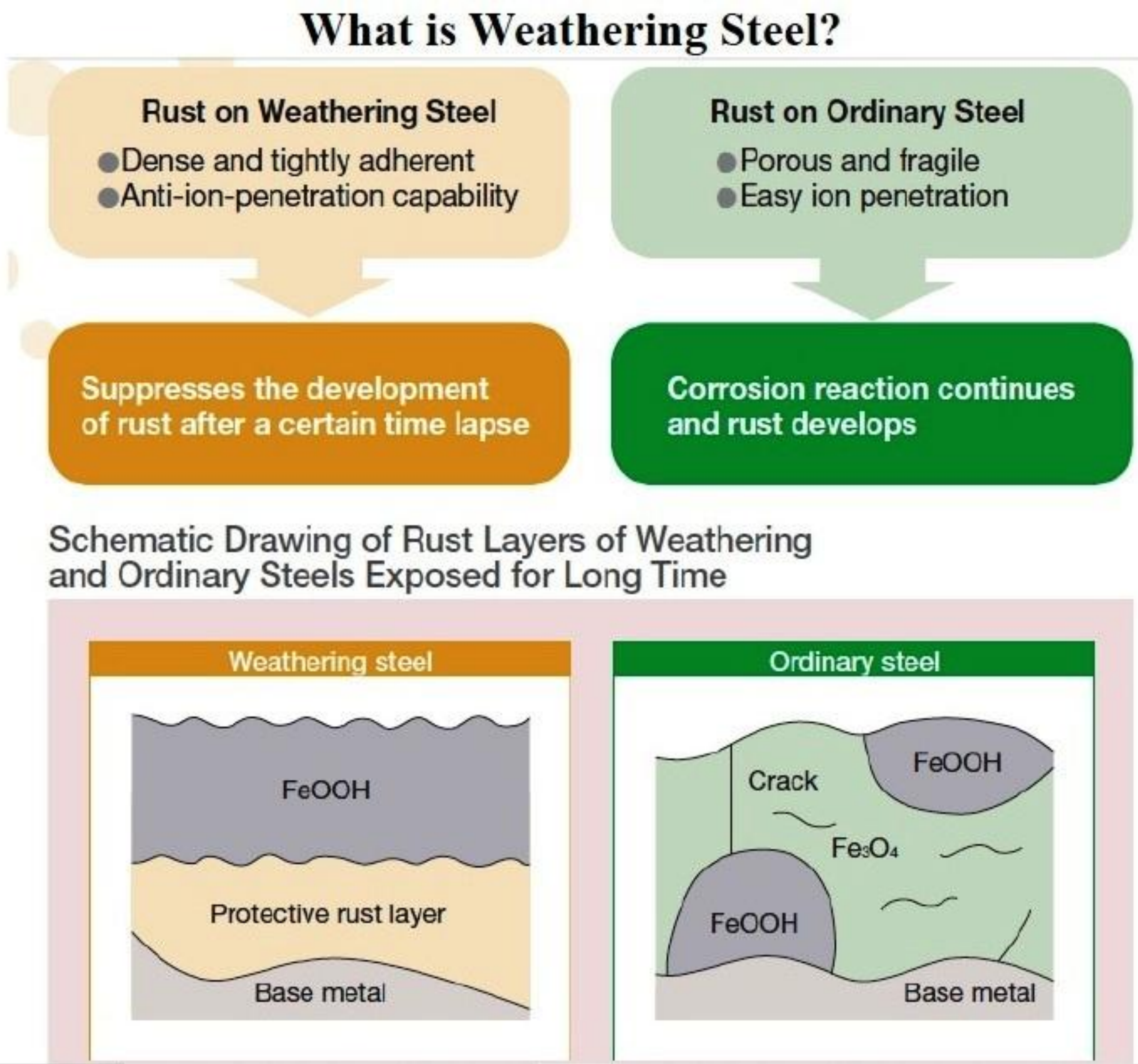
Corrosion of outdoor steel structure is a major source of concern. It is mitigated by regular inspection and periodic painting. There are paint systems that provide upto 20 yrs protection.

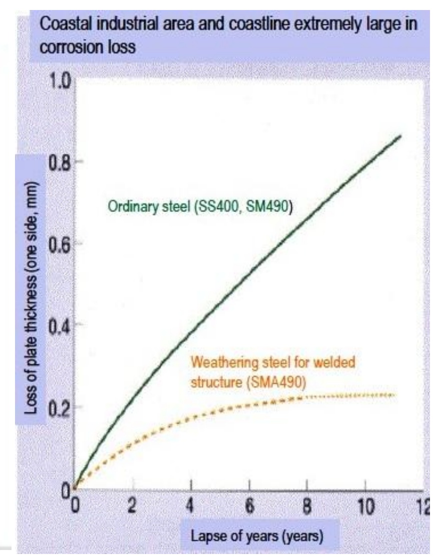
High Strength Steel also have been developed that does not require painting.

There is of course Stainless Steel containing 10-25% Chromium.

Another grade of high strength corrosion resistant steel, normally referred as **Weathering Steel**, has been developed by alloying with Nickel and Copper.

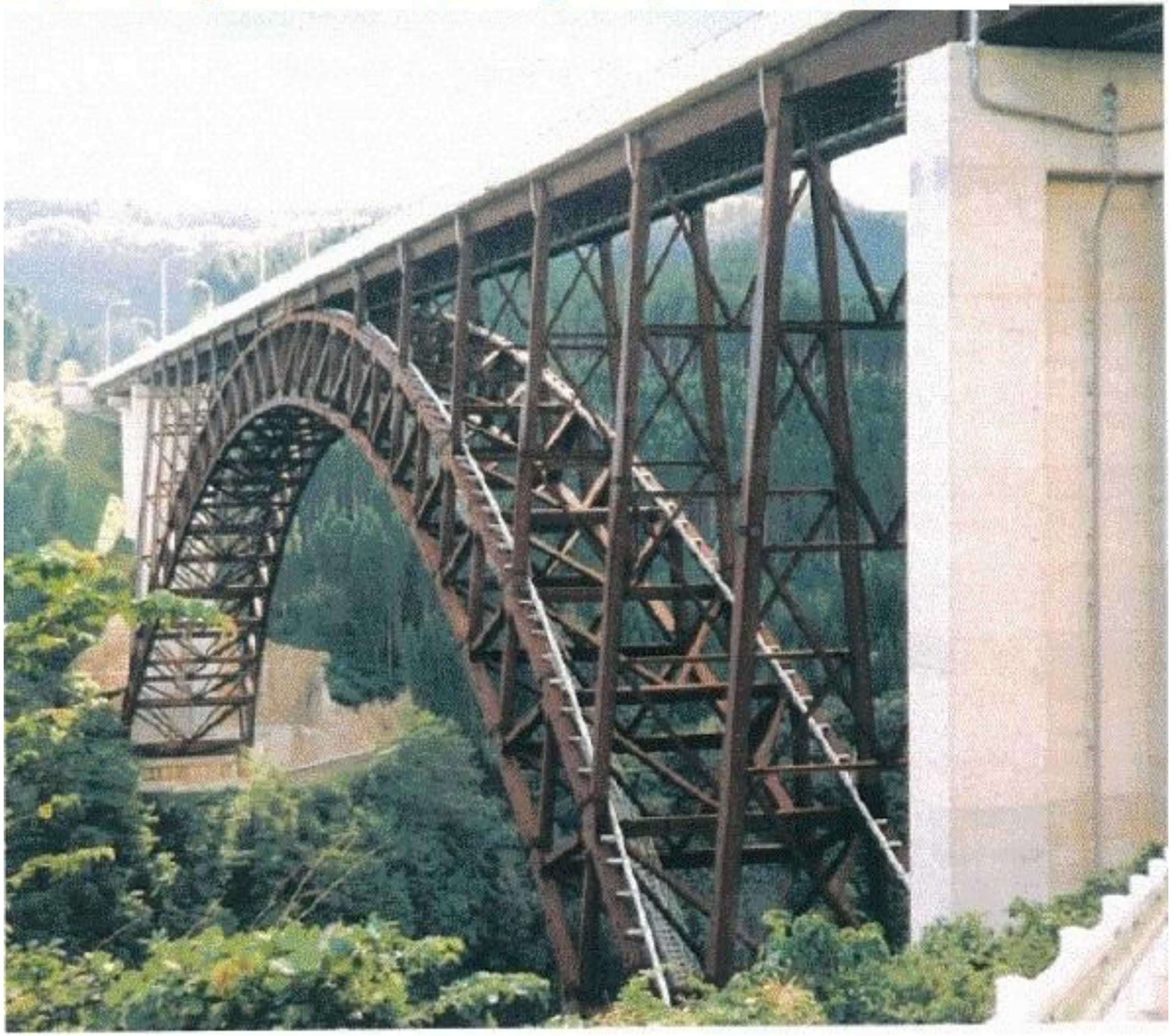
Weathering Steel





Weathering Steel

Unpainted application of weathering steel (Okuaso Bridge)



To SUMMARISE THE FEATURES AND PROPERTIES OF HIGH TENSILE STEEL

The properties are specified in Codes & Standards of different countries.

- European – EN 10025
- US – ASTM A709-01, AASHTO M270-02
- Japanese – JIS Z2201, JIS G3106

Besides strength and fracture toughness, all steel have good ductility of minimum 15%.

Primary Strength controlling chemical element in all steel is Carbon equivalence. In comparison to conventional Mild Steel (0.18<C<0.25), carbon content has been reduced to values between 0.11 and 0.16.

Improved Weldability and Toughness has been achieved through low sulfur content of 0.006% maximum.

FEATURES AND PROPERTIES OF HIGH TENSILE STEEL

Weldability : TMCP steels exhibit low carbon equivalence in combination with high toughness and hence provide best performance for welding. They can be easily welded to all ordinary steel allowing high heat input and in many cases preheating can be eliminated or has to be done at lower temperature. Roughly preheating of plates upto 50mm thickness can be eliminated. Favourable welding properties in combination with reduced welding volume because of reduced plate thickness compared to ordinary steel , significantly reduces fabrication and welding costs.

The High Tensile Steel are now mostly referred as High Performance Steel (HPS) as compared to ordinary steel a number of properties including UTS are improved.

FEATURES AND PROPERTIES OF HIGH TENSILE STEEL

Fatigue : When High Strength Steel are used for Bridges in particular, high Fatigue resistance is required. In welded structures the fatigue strength does not depend on the strength of the steel material. Thus it is important to increase the Fatigue strength properties in order to exploit the high strength properties of steel.

Fatigue strength can be improved by

- New or Modified detailing
- Improved Welding Procedure
- Post-weld improvement methods

Among the Post-Weld Improvement methods, following are popular in European Union

- Grinding
- TIG (Tungsten Inert Gas) dressing of Weld toe
- Needle Peening

APPLICATION OF HIGH TENSILE STEEL IN BRIDGES AND OTHER MAJOR STRUCTURES

The major benefits of adopting High Strength Steel can be summarized as under:

- Reduced Weight & Cost
- Reduced Fabrication cost in welding because of thinner plates
- Easier handling and transportation due to lower weight
- Lower Painting and Maintenance Cost
- Reduction of Cantilever Bending Moment during launching
- Lower Life Cycle Cost

Besides Bridge Structures, there are many other application of HTS.

OPTIMIZED UTILIZATION OF HIGH TENSILE STEEL

An optimized use of High Strength Steel is often in combination with other grades of steel, by using hybrid combination with mild steel. That means it is specially advantageous to use HTS at certain location of the structure where stresses are high or there are specific requirement concerning safety, redundancy etc. For example, welded plate girders with mild steel web and HTS flange.

And herein lies the key to sustainable development. Intelligently select materials of construction and the method of construction without any prejudice in order to reduce the Carbon Footprint of the structure.

Recycle, Repair, Reuse to the maximum extent to reduce GHG effects.

Thank you for your kind attention