CORROSION

FIRE PROTECTION

BY

GROUP 4B

WHAT IS CORROSION?

Corrosion is a process of formation of compound of pure metal by chemical reaction between metallic surface and its environment.

It is an oxidation process which results in loss of pure metal, thus metal forms its oxide.

Example:
Formation of rust on the surface of materials made up of iron like almirah, iron doors etc.

Equation:
$4Fe + 3O_2 + 6H_2O \rightarrow 4Fe(OH)_3$.

Factor responsible for corrosion:

01 Metal itself.

02 Environment conditions and chemicals.

03 Environmental temperature

04 Design of the structure

3 Major Theories of CORROSION

- **Acid Theory:**

  This suggest that the corrosion happens due to presence Acids around the metal surface. **Acids** basically increases the conductivity of moisture around metal, making **rust** happen more quickly. It can happen due to Acid Rain.

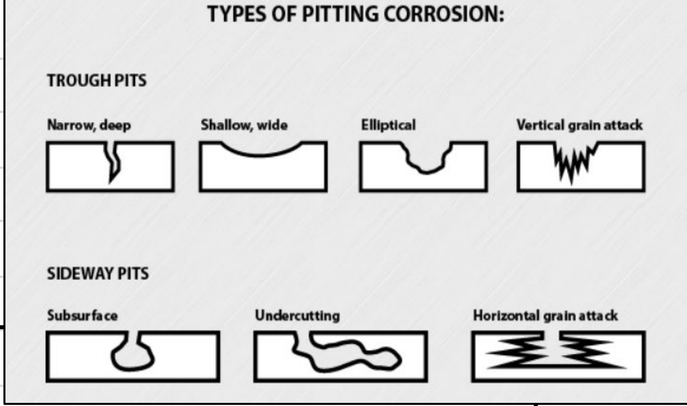
- **Chemical Theory:**

  According to this theory, Corrosion happens due to direct reaction of environmental gases like oxygen, halides, oxides of sulphur, etc. with metal. Oxygen is mainly responsible for corrosion as compared to other gases (oxidation corrosion).

- **Electrochemical Theory:**

  It's a corrosion type where corrosion happens when the metal comes in contact with the conducting liquid or when two dissimilar metal are dipped in electrochemical solution.

Types of CORROSION:



1. **UNIFORM CORROSION:**

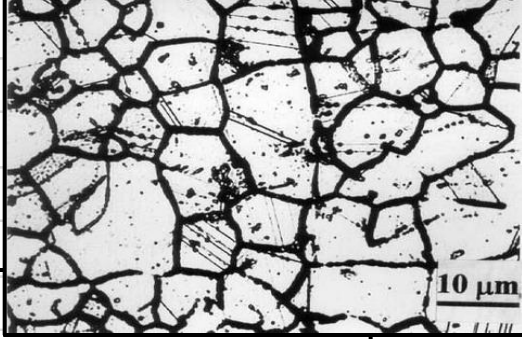
   Uniform corrosion means corrosion attack happens evenly across the surface of a material and is the most common type of corrosion. We can easily evaluate the resulting impact of corrosion over the material surface. It happens in large material surface.

2. **PITTING CORROSION:**

   It is the most dangerous type of corrosion because it is hard to predict or detect. It is localized form of corrosion where either a local anodic point or cathodic point forms a small corrosion cell with the surrounding normal surface. I grows into a hole or cavity and takes different shapes. It penetrates from the surface in a vertical downward direction.

   Cause: Local break or damage to the protective oxide film or a protective coating

Types of CORROSION:



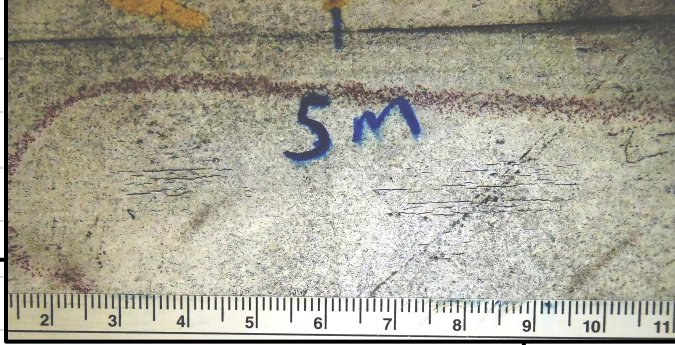
3. CREVICE CORROSION:

Crevice corrosion is a form of corrosion which results from a stagnant microenvironment in which there is a difference in the concentration of ions between two areas of a metal. It mostly occurs under bolt heads, gaskets, etc where circulation of oxygen is restricted. Due to this restriction pH of the material shifts away from neutral thus growing imbalance between the crevice (microenvironment) and the external surface (bulk environment) contributes to higher rates of corrosion. Crevice corrosion can often occur at lower temperatures than pitting. Proper joint design helps to minimize crevice corrosion.

4. INTERGRANULAR CORROSION:

During the solidification process, grains are formed on the metal body which results in Intergranular corrosion, which is caused by impurities present at these grain boundaries or by the depletion or enrichment of an alloying element at the grain boundaries.

Types of CORROSION:



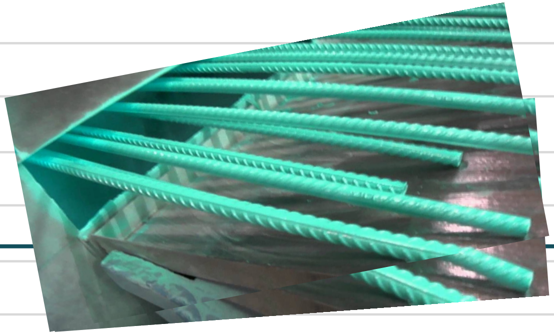
4. STRESS CORROSION CRACKING:

Stress corrosion results from external stress i.e. expansion/contraction due to rapid temperature changes. It may also result from residual stress imparted during the manufacturing process such as from welding, machining, etc. The fine cracks appear in the microstructure, making the corrosion hard to detect.

5. GALVANIC CORROSION:

Galvanic corrosion is the degradation of one metal near a joint or junction which occurs when two electrochemically dissimilar metals are in electrical contact in an electrolytic environment i.e. dipped in electrochemical solution.

Corrosion preventive methods:



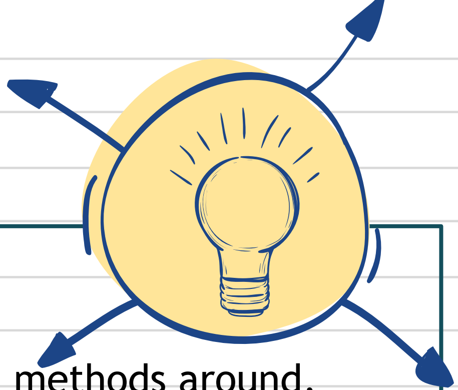
- **Barrier Coatings**

  One of the easiest and cheapest ways to prevent corrosion is to use barrier coatings like paint, plastic, or powder. Powders, including epoxy, nylon, and urethane, are heated to the metal surface to create a thin film. Paint acts as a coating to protect the metal surface from the electrochemical charge that comes from corrosive compounds. The biggest drawback with coatings is that if these aren't applied properly can quickly fail and lead to even increased levels of corrosion.

- **Hot-Dip Galvanization**

  This corrosion prevention method involves dipping steel into molten zinc. The iron in the steel reacts with the zinc to create a tightly-bonded alloy coating which serves as protection. Compared to other corrosion prevention methods, galvanization is known for lower initial costs, sustainability, and versatility, with disadvantage being it can't be done on site.

Corrosion preventive methods:



- **Alloyed Steel (Stainless)**

  Alloyed steel is one of the most effective corrosion prevention methods around, combining the properties of various metals to provide added strength and resistance to the resulting product. For example corrosion-resistant nickel combined with oxidation-resistant chromium results in an alloy that can be used in oxidized and reduced chemical environments.

- **Cathodic Protection**

  Cathodic protection protects against galvanic corrosion, which occurs when two different metals are put together and exposed to a corrosive electrolyte. cathodic protection connects the base metal at risk (steel) to a sacrificial metal that corrodes in lieu of the base metal. The technique of providing cathodic protection to steel preserves the metal by providing a highly active metal that can act as an anode and provide free electrons.

Corrosion prevention
(In context of concrete):

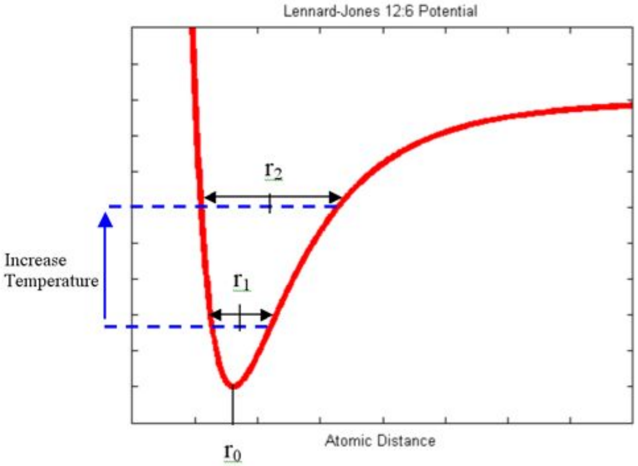
- Using SCM(Supplementary cementing materials like silica fume) and permeability reducing admixtures which leads to good particle packing, reduces permeability of concrete, and thus ingression of harmful agents to reinforcement steel.
- Making more width of cover concrete
- Using corrosion inhibitors in concrete mix designing, retarding corrosion rate
- Using crystalline waterproofing admixtures
- Ensuring good quality of cement, low w/c ratio, proper compaction and curing to get a good quality durable and less permeable concrete.

CHANGES IN MECHANICAL PROPERTIES OF STEEL AT HIGH TEMPERATURES

Expansion of steel

Mechanical properties of steel include elongation, toughness, yield strength etc,.

So when the temperature rises in a steel structure the atoms start to vibrate more and more. This thermal agitation, in turn, leads to an increase in interatomic distances and thus causes an **expansion** in the material. The density of steel decreases with temperature as volume increases



Yield and ultimate strength

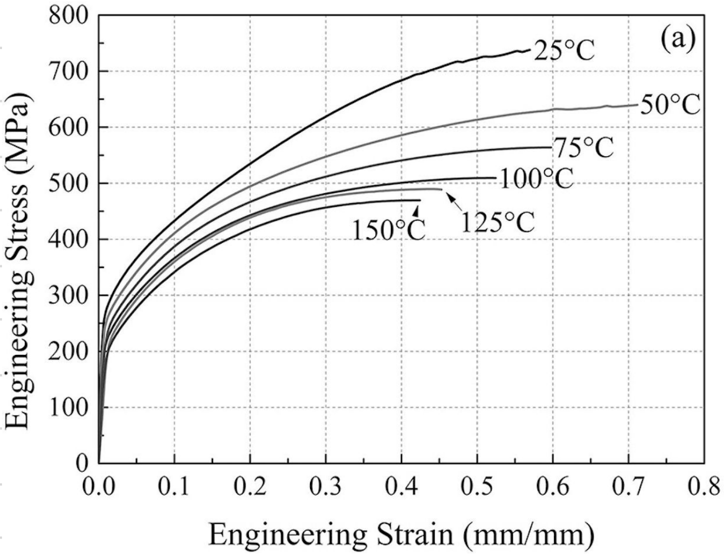
The yield strength and ultimate stress decrease for most of the steel members with increase in temperature. In some experiments the yield strength of the steel member decreased by 20% of the yield strength at room temperature.

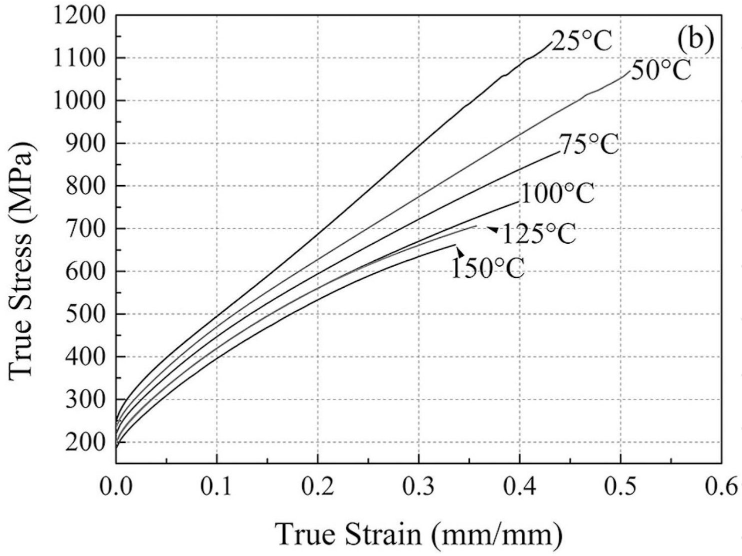
It is rather attributed to the fact that, as observed in the microstructure pictures, above 350 °C, the carbide particles continue to coarsen or become more plastic leading to lower thermal stability, which further deteriorates the strength properties.

As we can see from the experimental data, the shear strength of the bolts decreases rapidly with increase in temperature because the shear strength depends directly on the ultimate strength of the bolts.

Yield and ultimate strength

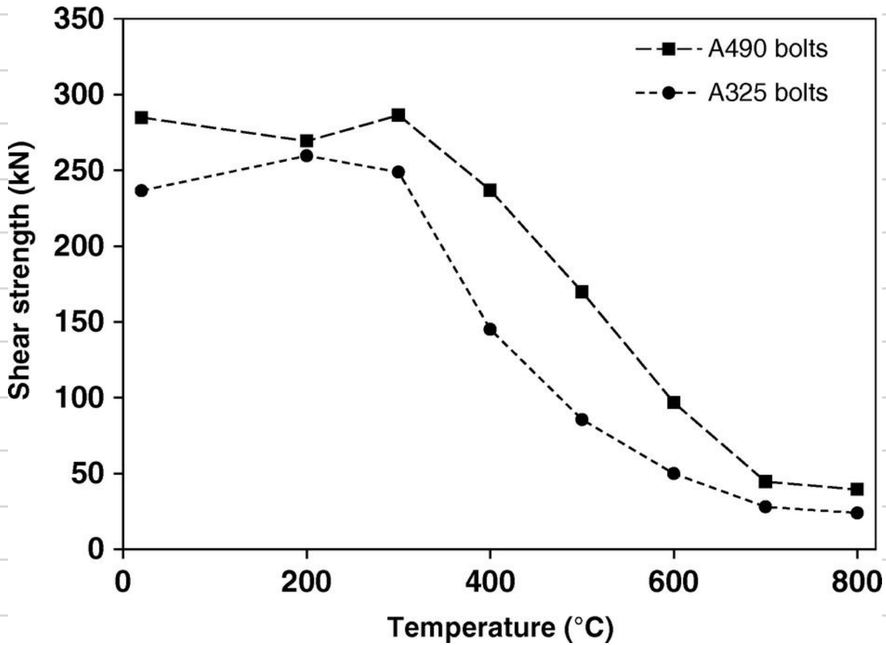
Experimental data shows the tensile strength of stainless AISI 304 steel at different temperatures

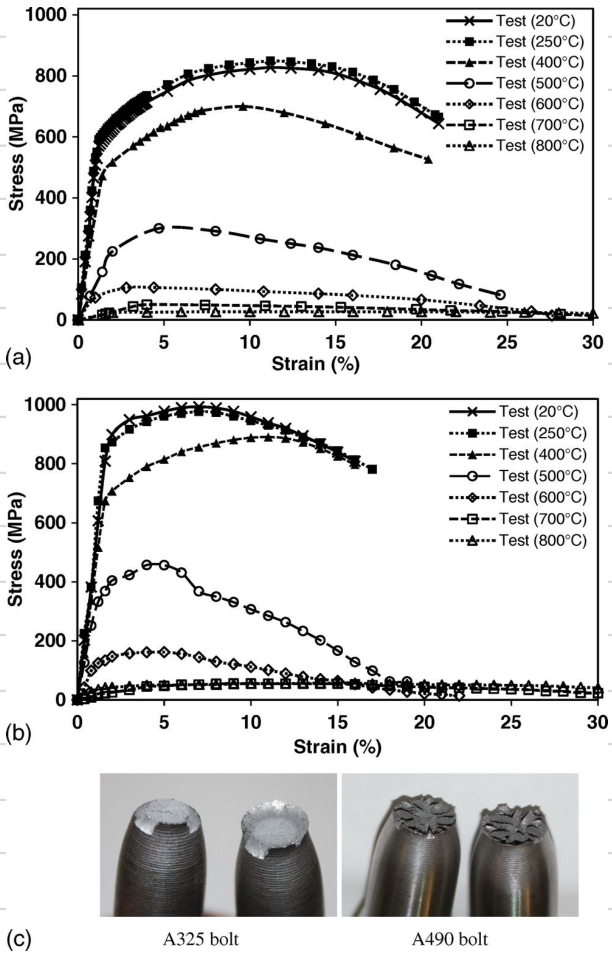




Shear strength of bolts

Variation of shear strength and stress-strain relationship of A325 and A490 bolts.

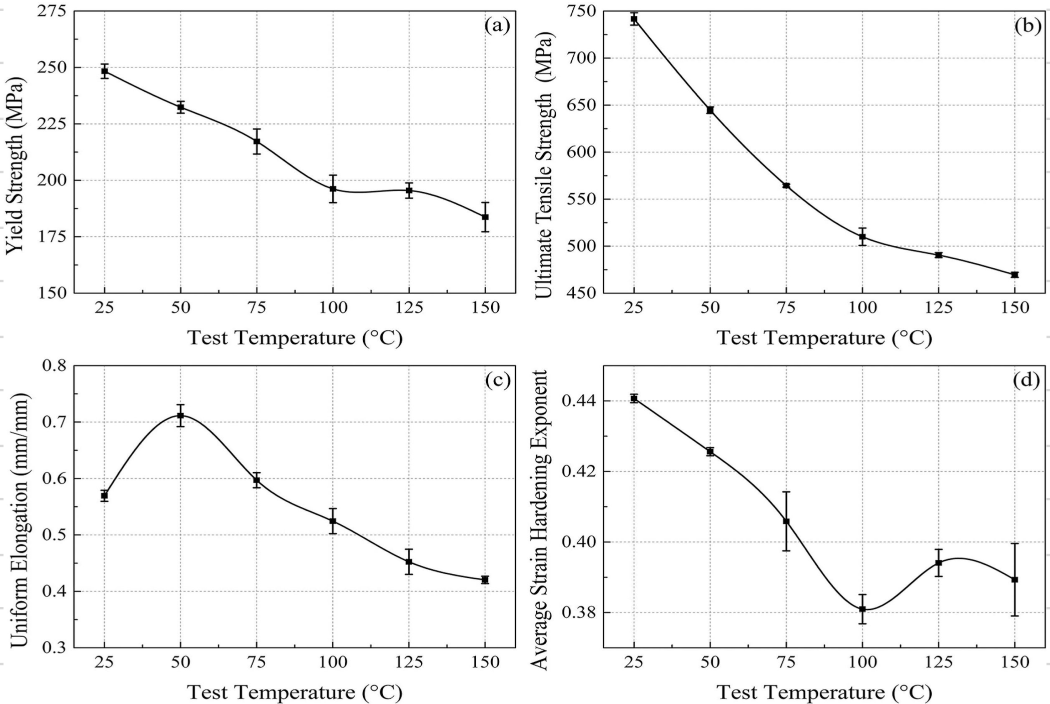




(a) (b) (c)

Other mechanical properties at high temperatures

The tensile strength of steel decreases with increase in temperature because with the increase in temperature the yield strength decreases.



Creep of steel at high temperatures

Creep deformation in metals with small loads is obvious at high temperatures and the high-temperature, creep deformation can be fully used in the processing of bending and straightening of steel slab continuous casting.

Based on the elastic-plastic theory, the stress within the elastic limit will not lead to material permanent deformation. However, at the high temperature the permanent deformation of material occurs although the stress is less than yield strength. This is steel creep deformation but not plastic deformation.

Steel creep rate at high temperature is much higher than it at normal temperature.

Fire Protection Methods

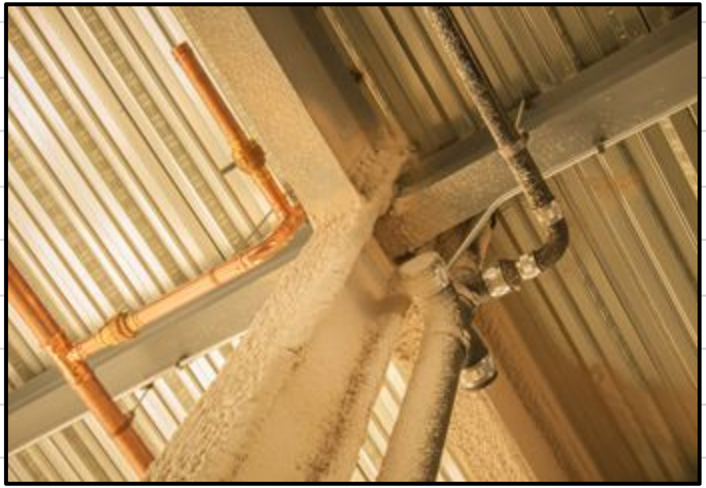
Rigid Board Fireproofing

1.Rigid board fireproofing provides the right fireproofing requirements as well as thermal and acoustic control.

2.This type of fireproofing can be mechanically fastened and can prevent pests and termite attacks.

3.Can withstand moisture and humidity without losing its fire-stopping characteristics.

4.Boards can be designed to precise measurements and can include decorative finishes.



Flexible Blanket Systems

1.Specifically designed flexible blankets used as fireproofing material

2.Easy to install and maintain a toxin-free environment in case of fire

3.This application can meet almost all safety standards and codes, providing a cost-effective and reliable system to prevent a fire from spreading to structural members..

4.Blanket systems can be a good option when dealing with complex shapes.

Concrete encasement

1.This option is far less common.

2.It can be beneficial to encase large sections of steel in concrete.

3.It tends to be less aesthetically pleasing than other options.

4.Structures like large parking garages are less concerned with these factors, so such structures might still employ this method.

5.Additional fire protection can be achieved by including reinforcements, such as rebar, between the flanges that are held in place by concrete.

Autoclaved Aerated Concrete

1.Enhance and provide fire resistance when needed, especially around steel columns.

2.This produces fireproofing characteristics when installed between the flanges and tied to the web of rolled sections.

3.When you need to have longer fire resistance requirements, it can be beneficial to pour concrete between the flanges of the steel components using shear connections attached to the steel web.

Intumescent Coatings

1.One of the key benefits is that intumescent coatings will expand as much as 100 times the original thickness of the material which provides superior fire resistance by creating a buffer between the fire and the steel members.

2.The product is applied just like paint.

3.The coating will undergo a chemical reaction and expand when subjected to extreme temperatures.

4.Intumescent coatings are a great solution when aesthetics come into play with steel that is exposed to the general public.

Provisions from National Building Code, IS 800

Cl.15.2: Requirements for Durability **(Corrosion protection)**

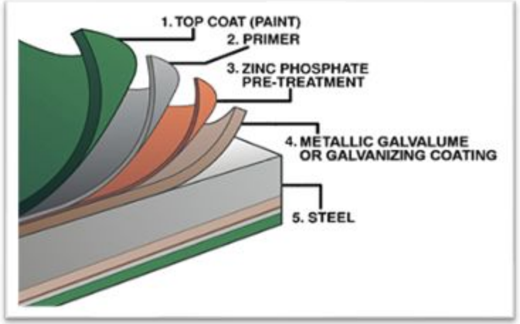
Cl.15.2.2.1: The general environment, to which a steel structure is exposed during its working life is classified into five levels of severity, as given in Table 28.

Cl.15.2.2.3: When exposed to sulphate concentrations of >2% in soil and >5% in water, some form of lining such as polyethylene, polychloroprene sheet or surface coating based on asphalt, chlorinated rubber or epoxy should be used.

Cl.15.2.3: Corrosion Protection Methods.

The main corrosion protection methods are given below:

a) Controlling the electrode potential,
b) Inhibitors, and
c) Inorganic/metal coatings or organic/paint systems.



Cl.15.2.4.1: In the case of mild exposure, a coat of primer after removal of any loose mill scale may be adequate. For more critical exposure conditions, Tables 29 a,b(i),b(ii) give guidance to protection of steelwork for different desired lives.

Table 29 (b) (i) Protection Guide for Steel Work Application — Specification for Different Coating System (Shop Applied Treatments)

(*Clause* 15.2.4.1)

Sl No.	Protection	Coating System					
		1	2	3	4	5	6
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Surface preparation	Blast clean	Blast clean	Blast clean	Blast clean	Girt blast	Blast clean
ii)	Pre-fabrication primer	Zinc phosphate epoxy, 20 μm	2 pack zinc-rich epoxy, 20 μm	—	2 pack zinc-rich epoxy, 20 μm	—	Ethyl zinc silicate, 20 μm
iii)	Post-fabrication primer	High-build zinc phosphate modified alkyd, 60 μm	2 pack zinc-rich epoxy, 20 μm	Hot dip galvanized, 85 μm	2 pack zinc-rich epoxy, 25 μm	Sprayed zinc or sprayed aluminium	Ethyl zinc silicate, 60 μm
iv)	Intermediate coat	—	High-build zinc phosphate, 25 μm	—	2 pack epoxy micaceous iron oxide	Sealer	Chlorinated rubber alkyd, 35 μm
v)	Top coat	—	—	—	2 pack epoxy micaceous iron oxide, 85 μm	Sealer	—

Section 16: Fire Resistance

Cl. 16.1.1: For protected steel members and connections, the thickness of protection material (hi) shall be ≥ that required to give a *Period of Structural Adequacy* (PSA) ≥ the required *Fire Resistance Level* (FRL).

Cl. 16.1.2: For unprotected steel members and connections, the exposed surface area to mass ratio (ksm) shall be ≤ that required to give a PSA = the required FRL.

Cl. 16.2: The FRL specified in terms of the duration (in minutes) of standard fire load without collapse depends upon:

a. the purpose for which structure is used, and
b. the time taken to evacuate in case of fire.

Cl. 16.3.2: The PSA shall be calculated by using one of the following methods:

a) Determining the limiting temperature of the steel (T,) [Cl. 16.5]
b) Determining the PSA as the time (in min) from the start of the test to the time at which the limiting steel temperature (t) is attained. [Cl. 16.6 (protected members) and Cl. 16.7 (unprotected members)]

Cl. 16.5: *Limiting Steel Temperature*

$$T_l = 905\text{-}690\, r_f$$

where

r_f = ratio of the design action on the member under fire to the design capacity of the member ($R_d = R_u/\gamma_m$) at room temperature,

R_d, R_u = design strength and ultimate strength of the member at room temperature respectively, and

γ_m = partial safety factor for strength.

Cl. 16.7: The time (t) at which the limiting temperature (T_l) is attained shall be calculated for unprotected members using the following equations:

a) Three-sided fire exposure condition

$$t = 5.2 + 0.022\,1\,T + \frac{0.433T_l}{k_{sm}}$$

b) Four-sided fire exposure condition

$$t = 4.7 + 0.026\,3T + \frac{0.213T_l}{k_{sm}}$$

where

t = time from the start of the test, in min,

T = steel temperature, in °C, 500 °C $\leq T \leq$ 750°C, and

k_{sm} = exposed surface area to mass ratio, 2×10^3 mm²/kg $\leq k_{sm} \leq 35\times10^3$ mm²/kg.

Cl. 16.6.2.1: The relationship between temperature (T) and time (t) for a series of tests on a group shall be calculated by least-square regression as follows:

$$t = k_0 + k_1 h_i + k_2 \frac{h_i}{k_{sm}} + k_3 T + k_4 h_i T + k_5 \frac{h_i T}{k_{sm}} + k_6 \frac{T}{k_{sm}}$$

where

t = time from the start of the test, in min;

k_0 to k_6 = regression coefficients from test data (*see* **16.6.2.2**.);

h_i = thickness of fire protection material, in mm;

T = steel temperature, in degrees celsius obtained from test as given in **16.6.1**, $T > 250°$C; and

k_{sm} = exposed surface area to mass ratio, in 10^3 mm²/kg.

Table 30 Regression Coefficients, *k*

k_0	k_1	k_2	k_3	k_4	k_5	k_6
(1)	(2)	(3)	(4)	(5)	(6)	(7)
-25.90	1.698	-13.71	0.0300	0.0005	0.5144	6.633

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THANKYOU!