CORROSION OF REINFORCED CONCRETE AND ITS PROTECTION

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ABSTRACT

Concrete is used as construction material in the form of plain or reinforced concrete through out the world. It has to withstand the physical, chemical and environmental effects for fulfilling the durability characteristics. The environmental changes due to pollution, lack of maintenance, poor quality of work, lack of supervision, use of defective materials etc have also taken a heavy toll of concrete structures. Among various factors affecting the reinforced concrete structures the atmosphere, water, salts are most common factors which play a key role for reinforcement corrosion.

The damage due to corrosion is a serious effect upon the mechanical properties of concrete structures. Once the corrosion of reinforcement starts due to formation of oxide and if the structure is under load, the stress acting on it increases. In such case the ultimate tensile stress (UTS) exceeds and finally the structure fails.

The present paper highlights the corrosion of reinforced concrete structures, factors influencing corrosion of reinforcement, and its remedial measures to some extent.

INTRODUCTION

Concrete is one of the most versatile and widely used as construction material throughout the world. Reinforced concrete structures has to withstand the environmental conditions throughout its life-span if properly prepared and placed. It has been demonstrated by the large number of concrete structure built over the last 100 years in different part of the world. In India, the construction of reinforced concrete structures were taken up during the formative years of the 20th century. Such a durable reinforced concrete structure is in Mumbai - the Gateway of India.

The steel embedded in the concrete structure whether as reinforcement or prestressed tendon, being ferrous material, is prone to corrosion which cannot be to tally eliminated. Corrosion related distress is not confined to India but have been experienced all over the world. All developed countries have carried out necessary preventive measures including revision of the concrete codes by incorporation of suitable durability practices in seventies and eighties. However, this process has been very slow in India, even the basic concrete code IS : 456-2000, has not been fully updated for durability requirement.

Corrosion of steel results in reduction of cross-section area of steel and cracks and splittig of cover concrete. Due to reduction of cross-section, the load carrying capacity is reduced, in addition to reduction of elongation properties and fatigue strength.

CAUSES OF CORROSION

General

Corrosion is a destruction of material because of its reaction with the environmental conditions the most predominant among various factors of corrosion is the atmospheric corrosion which causing the rusting of steel. Appreciable corrosion only starts when the relative humidity of the air exceeds around 65%. In dry, pure air and below freezing point of water there is no danger of the corrosion. Corrosion may be defined as the involuntary destruction of substances such as metals and mineral building materials by surrounding media.

Factors Influencing Corrosion of Reinforcement

In reinforced cement concrete construction the corrosion of reinforcement takes place due to the presence of chlorides and sulphates beyond a critical limit and when sufficient alkalinity is not obtained within the concrete to maintain steel in a positive condition.

The following factors are also responsible for corrosion of steel reinforcement in concrete structures.

Quality of Concrete

Concrete consists of coarse aggregate, fine aggregate, cement and water. The right quality of materials with proper w/c ratio, correct mixing, adequate compaction by tamping or vibration and proper curing results in good quality concrete.

High strength concrete i.e. dense concrete, rich in cement content is impervious to a large degree and generally resists the corrosion of embedded steel.

Cover Thickness of Concrete Over Reinforcement

The reinforcement is protected by suitable concrete cover over it. The greater the cover thickness, more is the degree of protection against the various climatic and other environmental condition. For various structural members, the cover thickness should be different depending upon their importance and degree of exposure. Evenness of the cover over the reinforcement is also very important for its corrosion protection.

Condition of Reinforcement

The surface condition of the steel reinforcement, at the time of its placing in concrete, affect its corrosion rate. If the reinforcement is contaminated with salt or badly corroded, the corrosive action on reinforcement after placement in concrete is aggravated and promoted rapidly.

Effect of Environmental and other Chemicals

Chemical either from environmental or from within the concrete making materials are the main source of deterioration process. Due to the attack of chemicals, the concrete. develops crack which is the first sign of deterioration. The effect of chemicals is mainly due to presence of salt, carbonation, chloride attack and reaction of sulphates with tricalcium aluminate (CsA) present in cement.

Concrete is an intimate mixture of cement, aggregate and water which in the green stage is highly alkaline. The hydration of cement, develops calcium hydroxides which increases the pH values upto 12.5. In such alkaline conditions, the reinforcing steel is covered with thin film of oxide which protects the steel.

Porosity of Concrete

The penetration of aggressive chemicals is possible due to permeability or porosity of concrete. The porosity of concrete depends on size, distribution and continuity of capillary pores. This depends upon the w/c ratio for given degree of hydration. The porosity also depends upon number of factors such as age of concrete, degree of compaction, the size and grading of aggregates, type of cement etc.

Effect of High Thermal Stresses

Normal concrete can withstand temperature upto 100°C. Beyond this temperature the deterioration of concrete starts. The concrete in industrial plants and power stations required special protective measures otherwise the concrete may develop thermal cracks.

Freezing and Thawing Condition

In cold regions, the moisture in the pores of concrete freezes. The ice formation gives rise to volumetric expansion which may exerts bursting pressure on surrounding concrete mass. This results in development of cracks in concrete.

Total Loss of Steel due to Corrosion

The Steel Authority of India (SAIL) has calculated the total loss of steel during the period 1990 to 1999 and it has been found that about 200 million tonnes of steel as reinforcement, steel sections, plates, wires, cables etc are consumed and its 3% of steel consumption is lost by corrosion every year.

Total loss of steel during one decade = $(3/100) \times 200 \times 10^6 1 = 6 \times 10^6 1$ and Total cost of loss per decade = $6 \times 10^6 \times 16{,}000$ Rs/t = 96×10^9 Rs/decade i.e. 960 crores Rs/year.

Thus, it is clear that the corrosion of steel is a serious matter and it must be protected by considering suitable remedial measures.

REMEDIAL MEASURES

The deterioration of concrete may be due to either corrosion of concrete/ reinforcement steel or formation of expansive chemical compounds such as calcium silicate hydrate (C-S-H) or ettringite in aggressive environments. The loss due to corrosion of steel is heavy. To produce the durable concrete and resist the harmful effects of aggressive environment, the concrete should be produced with almost care. The following steps, implemented scientifically will help to produce durable concrete.

Improving the Quality of Concrete

a) By Adopting the Rich Mix

Higher cement content and lower w/c ratio give stronger and impermeable concrete. Table-1 shows the minimum cement content and maximum w/c ratio for plain and reinforced concrete.

Table - 1 : Minimum Cement Content Required in Cement Concrete to Ensure Durability under Specified Conditions of Exposure

Exposure	Plain Concrete		Reinforced Concrete	
	Minimum cement content (kg/m^3)	Maximum W/C ratio	Minimum cement content (kg/m^3)	Maximum W/C ratio
Mild - For example, completely protected against weather or aggressive conditions, except for a brief period of exposure to normal weather conditions during construction	220	0.6	300	0.55
Moderate - For example, sheltered from heavy and wind driven rain and against freezing while saturated with water, buried concrete in soil and concrete continuously under water	240	0.6	300	0.50
Severe - For example, exposed to sea water, alternate wetting and drying and to freezing while wet, subject to heavy condensation or corrosive fumes.	250	0.5	320	0.45

b) Adopting the Best Mix Proportion

By designing the best suitable mix proportion the impermeable concrete can be produced.

c) Efficient Compaction During Casting

This gives dense concrete with minimum voids.

d) Leakproof Formwork

This reduces the leakage of cement slurry during casting of concrete.

e) Adopting Salt Free Sand

The salt content of mix can be reduced by washing the sand properly.

f) Using Plasticizers

The use of plasticizers improves the workability without increasing the water content.

g) Using sulphate resisting cement and pozzolana cement.

Increasing Depth of Concrete Cover to Reinforcement

Extra cover depth lengthens the time for ingress of corrodents. Such a remedy increases weight due to additional concrete requiring changes in structural design. Increased cover thickness should be provided when surfaces of concrete members are exposed to the action of harmful chemicals, acids, vapours, saline atmosphere, sulphurous smoke, etc. As per observations, the increase in cover thickness may be between 15 mm and 40 mm, the total cover thickness should not exceed 50 mm. Concrete cover more than

50 mm is not recommended as it may give rise to increase crack widths which may further allow direct ingress of deleterious materials to the reinforcement.

Concrete Coating and Sealers

When untreated reinforcing bar is used, the best method is to apply protective coatings to concrete surface to seal entry of moisture, carbon dioxide and chlorides. The dry concrete surface should be roughened by chiseling, and a workable mixture of 1:3 cement sand mortar should be applied on the concrete surface after watering over the surface properly by trowelling to a thickness of 6 mm. The surface should be finished with neat cement slurry consisting of water and cement in ratio 2:1.

Galvanizing

In this type of treatment, zinc itself becomes a sacrificial anode and then protects the bar from corrosion for five years approximately. In India, a Government Corporation is doing galvanizing. This is being used when no superior treatment is available.

Fusion Bonded Epoxy Coating (FBEC)

Today the world over, Fusion Bonded Epoxy Coating (FBEC) has proved to be most effective reliable and long-term economical method of anti-corrosive treatment for reinforcing bars. It is applied directly on the reinforcing steel which presents corrosion by isolating and insulating the steel from the corrosive environment. These coatings protect against external and internal corrodents.

Coating of Rebars

The corrosion of rebars can be prevented by applying proper coating to rebars. The coating can be one of the following (i) Paint (ii) Chemical Compounds (iii) Metallic Epoxy Coating and (iv) Fusion Bonded.

STORAGE AND STACKING OF REINFORCEMENT STEEL

As per IS : 4082-1977, steel reinforcement shall ordinarily be stored in such a way as to avoid distortion and to prevent deterioration and corrosion. It is desirable to coat reinforcement with cement wash before stacking to prevent scaling and rusting.

In case of long storage, reinforcement bars should be stacked above ground level by at least 150 mm. Also in coastal area or in case of long storage, a coat of cement wash shall be given to prevent scaling and rusting.

CONCLUSIONS

The following conclusions may be arrived at:

1. Due to reinforcement corrosion, the cross-sectional area of steel is reduced and it will fail under designed load as its cross-sectional area becomes less than calculated for design.
2. Due to corrosion of reinforcement, cracks in concrete structures is commonly appear on face of the concrete surface. This can be eliminated by using proper concrete grade, curing and compacting.
3. There are many methods to protect the steel from corrosion. But the best method is cathodic protection of steel against corrosion, which is too costly. This method is not being used except in few important structures.
4. Coating over steel bars is a temporary method, short life and the bonding between steel and concrete gets reduced.
5. The use of steel should be done before it react with corrodent.

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