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Study on Corrosion of Reinforced Concrete Beams with Fly Ash and glass Fiber Reinforced Polymer

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Abstract : Reinforced concrete has good durability and excellent structural performance.But there are cases of early deterioration due to a number of factors, one prominent factor being corrosion of steel reinforcement. The process of corrosion sets in due to ingress of moisture, oxygen and other ingredients into the body of concrete, which is unsound, permeable and absorbent. Cracks due to structural and other causes such as creep, shrinkage, etc also allow ingress of moisture and other harmful ingredients and thus accelerate the rate of corrosion. There are several interactive factors both external and internal, which lead to corrosion of reinforcement and ultimately failure of structures. Suitable addition of mineral admixture like fly ash in concrete improves the strength and durability of concrete due to considerable improvement in the microstructure of concrete composites, especially at the transition zone. Secondary reinforcement in the form of fibre is added to concrete, which provides three dimensional random reinforcement in the entire mass of concrete.

Reinforced concrete beams of size 0.1 m X 0.15 m and length 1m have been cast using M25 grade of concrete. The beams after curing process were subjected to corrosion process by impressing an external Direct Current (Galvanostatic Method) for a period of 15 days under stressed and unstressed conditions. The corroded beams were tested by applying two point loads to determine the ultimate load carrying capacity and cracking pattern and the results of specimens were compared with that of the companion specimens. Gravimetric method is used to quantify corrosion that has occurred.

The steel reinforcement in concrete can be protected from corrosion by applying coating on rebars and providing modified environment around them. In this experimental work, an attempt is made to study the reduction of corrosion in rebars by applying Epoxy Nitro Zinc Primer coating. The concrete beams, which consists of Ordinary Portland Cement (OPC) and fly ash were cast using coated and uncoated rebars and tested under both stressed and unstressed conditions. The Epoxy Zinc Rich Primer is a product ofFOSROC Chemicals (India) Ltd. and available in the name of Nitro Zinc Primer.

M25 grade of concrete with Ordinary Portland Cement (OPC) and fly ash (replacing OPC 40% by weight) have been used. Uncoated rebars and rebars coated with Nitro Zinc Primer were used. Selected specimens were added with Glass fiber reinforced polymer (0.7% by weight of Cement).

Keywords : Carbonation, Corrosion, Cracking, Spalling.

1.1 Introduction

Reinforcement corrosion is the main cause of damage and early failure of reinforced concrete structures worldwide with subsequent enormous cost for maintenance, restoration and replacement. During past two decades, concrete structures in various parts of the country have shown signs of distress essentially due to corrosion of reinforcement. Corrosion is usually faster than the other deterioration process. This is so, especially in areas of heavily polluted atmosphere due to industrial stack emissions etc., and areas closer to coastal line. India has large coastline measuring 3500 km and in general polluted atmosphere, which aids the onset and progress of corrosion. This corrosion of reinforcement is one of the most important and serious causes of corrosion concern for low durability of concrete.

The process of corrosion sets in due to ingress of moisture, oxygen and other deleterious substances in to the body of concrete which is unsound, permeable and absorbent. Cracks due to structural and other causes such as creep, shrinkage, etc., also allows ingress of moisture and other harmful ingredients and thus accelerate the rate of corrosion. There are several interactive factors both external and internal, which leads to corrosion of reinforcement and ultimately failure of structure. Corrosion of reinforcement caused by low cover is commonly referred to as carbonation induced corrosion and may occur either in conjunction with or independently of chloride induced corrosion. The mechanism of reinforcement corrosion caused by carbonation and chloride will be discussed in the following sub sections. Anti-Corrosive coatings are often used to protect materials from hostile environments and so also from corrosion.

Corrosion of reinforcing steel is widely accepted as the primary cause of premature deterioration in reinforced concrete structures. Corrosion is defined as the destruction or deterioration of a material because of its reaction with environment. In the case of corrosion, formation of an oxide of iron due to oxidation of the iron atoms in solid solution is a well-known example of electrochemical corrosion, commonly known as rusting. These oxides are loosely attached and spall off from the surface of steel. During the process of corrosion, weight of material decreases as depth of corrosion layer (pits) increases. The magnitude of reinforcement corrosion has a significant effect on flexural strength, deformational behaviour, ductility, bond strength and mode of failure of RC structures

2 Behaviour of Corroded Steel Rebars

Corrosion damages the superficial layer of steel rebars, causing a worsening of their mechanical properties, in terms of strength and ductility. The effects of atmospheric corrosion were studied by Maslehuddin et al, and according to their observation after 16 months of exposition no significant variations of mechanical properties of reinforcing steel were observed. On the contrary based on Almusallam results the corrosion caused by penetration of chlorides on reinforcing steel rebars embedded in concrete appeared to affect in a significant way the behaviour of the bars. Apostolopoulos assessed the effects of artificial corrosion damage on the mechanical properties of steel reinforcement. Even if the influence of the corrosion on the steel tensile behaviour is clearly highlighted, no relationships of deterioration of steel mechanical properties were given. Azher found that where concrete has been carbonated to the depth of the steel reinforcement and a small but uniform amount of moisture is present, the steel is likely to corrode fairly uniformly. If chlorides are concentrated near the surface of the steel or access of water and oxygen is restricted to a single location on the steel, severe pitting corrosion may occur. This reduces considerably the cross-sectional area of the bars at these locations, while the remainder of the bar may be left no corroded. Structural cracking, or honeycombing, can also create conditions favourable to pitting corrosion by allowing the localized ingress of aggressive agents.

3 Types of Corrosion

Corrosion of the metals occurs by the attack of surrounding environment /medium on the surfaces of the metals. This attack occurs in two ways (i) Direct chemical or dry corrosion, and (ii) Electro-chemical or Wet or Immersed corrosion.

3.1 Dry Corrosion

This type of corrosion occurs mainly through the direct chemical action of environment gases such as oxygen, halogen, hydrogen sulphide, sulphur-dioxide, nitrogen or an hydrous inorganic liquid with metal surfaces in immediate proximity. Ex: Attack on steel by furnace gases.

3.2 Wet Corrosion

This type of corrosion occurs when a liquid phase is present. This usually involves aqueous solutions or electrolytes and accounts for the greatest amount of corrosion. Ex: Corrosion of rebar by the salt solutions (Sea water).

The moisture plays an important role in the corrosion. The dry chlorine is a non-corrosive to ordinary steel, but the moist chlorine is extremely corrosive andattacks most of common metals. It is reverse, in the case of titanium i.e., the moist chlorine is a non-corrosive to titanium, but the dry chlorine is corrosive to titanium.

4 Corrosion of Steel in Concrete

Rust, the corrosion product of iron, is the result of an electrochemical process. Rust occurs because of differences in electrical potential between small areas on the steel surface involving anodes, cathodes and an electrolyte. These differences in potential on the steel surface are caused by the

1. Variations in composition / structure
2. Presence of impurities
3. Uneven internal stress
4. Presence of non-uniform environment

These differences in the presence of electrolyte, a medium for conducting ions, create corrosion cells. Corrosion cells consist of microscopic anodes and cathodes. Because of differences in potential within the cell, negatively charged electrons flow from anode to cathode and iron atoms in the anode area are converted to positively charged iron ions. The positively charged iron ions **(Fe^{++})** of the anode attract and react withthe negatively charged hydroxyl ions **(OH^-)** in the electrolyte to form iron oxide,or rust. Negatively charged electrons **(e-)** at the cathode surface with positively charged hydrogen ions (**H^+**) in the electrolyte to form hydrogen gas.

Impurities present in the electrolyte create an even better medium for the corrosion process. For example, these sulphur oxides, chlorides or other pollutants present in damp climate or dissolved in surface moisture. Calcium hydroxide, present in hardened concrete, will also act as an electrolyte in the presence of moisture.

Under normal conditions, concrete is alkaline with a **pH** of about **12.0** due to the presence of calcium hydroxide. In such as alkaline environment, a passivating iron oxide film is formed over the surface of the steel rebar, causing almost complete inhibition of corrosion. As the **pH** of the concrete surrounding the reinforcement is reduced by intrusion of salts, leaching or carbonation, the passivity is reduced and corrosion may proceed.

5 Materials

5.1 Cement

The cement used in this study was 53 grade Ordinary Portland Cement (OPC) IS: 8112-1989 & Fly ash in already 25 % present in (PPC). Cement is the most important constituent of concrete, in that it forms the binding medium for the discrete ingredients made out of naturally occurring raw materials and sometimes blended with industrial wastes. OPC cement of 53 grade is used for experimental study.

5.2 Fly Ash

Fly ash produced from the burning of younger lignite or sub bituminous coal generally contains more than 20 percent lime (CaO). This type of ash does not require an activator & the contents of Alkali and sulfate (SO_4) are generally higher as compare to the fly ash.

5.3 Fine Aggregate

Natural river sand is used as fine aggregate. The properties of fine aggregate are determined by conducting tests as per IS: 2386 (part-10). Specific gravity of fineaggregate is 2.60. Fineness modulus of fine aggregate is 2.30. It was locally available in sand quarry. The specific gravity and water absorption were found to be 2.7 and 1,0% respectively, with sieve analysis data and fineness modulus value of sand confirms to grading zone II as per IS 383-2009.

5.4 Coarse Aggregate

Crushed stone and natural gravel are the common materials used as coarse aggregate for concrete. It is obtained by crushing various types of granites, schist and gneiss, crystalline and lime stone and good quality sand stones. Concrete made with sand stone aggregate give trouble due to cracking because of high degree of shrinkage. For coarse aggregate crushed 20mm, normal size grade aggregate was used. Fineness modulus of coarse aggregate is 7.10 used. The specific gravity and water absorption were found to be 2.7 and 0.5% respectively.

5.5 Glass Fiber Reinforced Polymer

Glass fibers are having excellent properties like high strength, flexibility, stiffness and resistance to chemical harm.It may be in the form of roving"s, chopped strand, yarns, fabrics and mates. Each type of glass fibers have unique properties and are used for various applications in the form of polymer composites. The mechanical, tribological, thermal, water absorption and vibrational properties of various glass fiber reinforced polymer composites were reported.

5.6 Portable Water

This is the least expensive but most important ingredient of concrete. The water, which is used for making concrete , should be clean and free from harmfulimpurities such as oil, alkali, acid, etc., in general, the water, which is fit for drinking should be used for making concrete.

6 Results and Discussions

6.1 Determination of Compressive Strength

Cubes of size 150 mm X 150 mm X 150 mm were cast using M 25 grade of concrete and tested after 7days and 28 days for compressive strength for the following combinations.

- OPC
- OPC+Fly Ash (replacing cement - 40% by weight)
- OPC+Glass Fiber Reinforced Polymer (added @ 0.7% by weight of cement)
- OPC + FlyAsh + Glass Fiber Reinforced Polymer

It was observed that the compressive strength is highest (39.80N/mm^2) for the cube with the combination of OPC, Fly ash and Fibre. Fig. 6.1 shows the 7 days and 28 days compressive strength values of the different combinations mentioned.

Table 6.1 Compressive strength results

Compressive strength (N/mm^2)		
Specimens	**7th day**	**28th day**
OPC	26.50	35.90
OPC+Fly ash	30	38.90
OPC+GFRP	27.40	37
OPC+Flyash+ GFRP	31.60	40.50

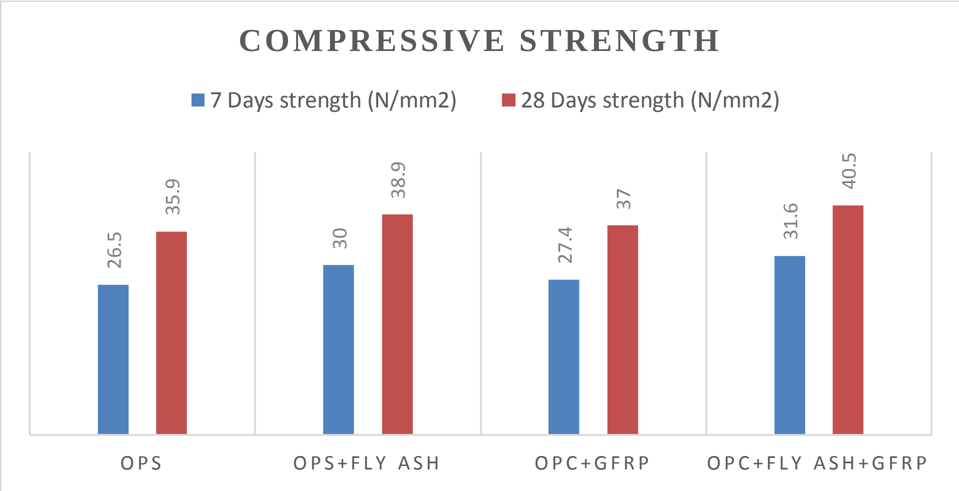

Fig. 6.1 Graph showing 7 and 28 days compressive strength result

Table 6.2 Flexural strength results

Flexural strength (N/mm²)		
Specimens	**7th day**	**28th day**
OPC	3.46	4.60
OPC+Fly ash	3.40	4.50
OPC+GFRP	4.32	5.36
OPC+Flyash+GFRP	3.92	5.47

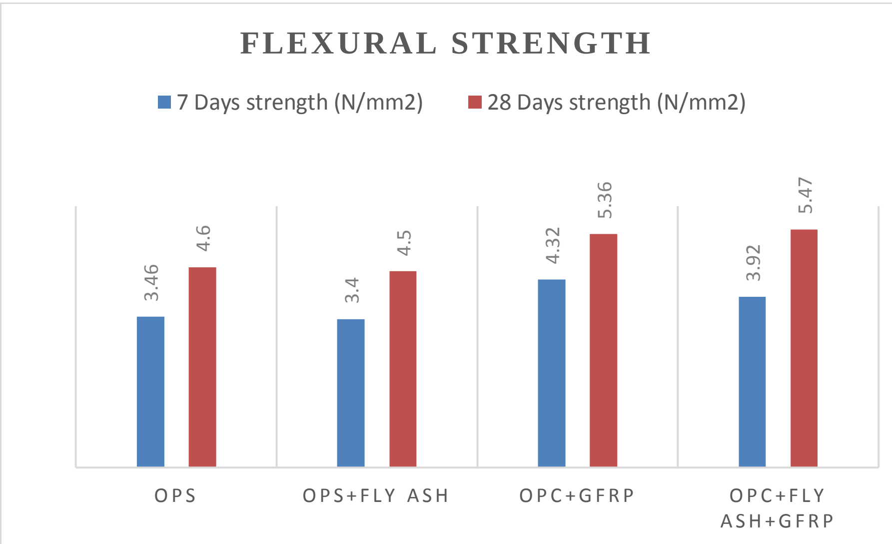

Fig. 6.2 Graph showing 7 and 28 days flexural strength results

6.2 Determination of Flexural Strength

Prisms of size 100 mm x 100 mm x 500 mm were cast using M25 grade of concrete and tested after 7days and 28 days for flexural strength of the concrete mix for the following combinations.

- OPC
- OPC+Fly Ash (replacing cement - 40% by weight)
- OPC+Glass Fiber Reinforced Polymer (added @ 0.7% by weight of cement)
- OPC + FlyAsh + Glass Fiber Reinforced Polymer

It was observed that the compressive strength is highest (5.47 N/mm^2) for the cube with the combination of OPC, Fly ash and Fibre. Fig. 6.2.shows the 7 days and 28 days flexural strength.

7 Conclusions

- Due to the reuse of materials considered as waste the economy is being stabilised.
- The use of Fly ash as a replacement for sand is environment friendly
- It was observed that the compressive strength is highest (39.80 N/mm^2) for the cube with the combination of OPC, Fly ash and Fiber.
- It was observed that the flexural strength is highest (5.47 N/mm^2) for the cube with the combination of OPC, Fly ash and Fiber.
- The main aspect followed in this project is to reduce the waste disposal and save the earth from environmental hazards.

8 References

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