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Corrosion of steel in concrete due to chloride and sulphate attack

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Abstract

Recently, The corrosion of concrete structures has received great attention related with deterioration of sea-side and industrial-side structures, such new airport, bridges and nuclear power plants etc. In this regards, many studies have been done on the chloride and sulphate attack in concrete structures. An experimental studies is carried out on the corrosion behaviour of steel bar which is placed at the centre of the concrete block (size 6in*4in*4in).These blocks are submerged in chloride and sulphate ion solution for weight loss measurement due to corrosion. In this experiment test was carried out using plain steel bar of dimension 8mm in diameter and 150 mm in length. The present study allows more realistic assessment of durability for such concrete structures which is subjected to combined attack of both chloride and sulphate. The test results indicate that, the corrosion rate due to attack of chloride ion is more than the attack of sulphate ion. The corrosion rate due to attack of chloride and sulphate ion is a linear function. The purposes of the study is to explore the influences of chloride and sulphate attack of concrete structures.

Keywords: Concrete structure, chloride attack, sulphate attack, steel bar, corrosion.

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1. Introduction

Corrosion of reinforcement has been established as the predominant factor causing widespread premature deterioration of concrete structures worldwide, specially of the structures located in the coastal marine and industrial side environment. Mild steel is widely used constitutional materials in many industries due to its good mechanical properties. The corrosion of mild steel is of fundamental and industrial concern that has received considerable amount of attention. The use of inhibitors is one of the most practical methods for protection against corrosion, especially in acidic media. In order to ensure safety of reinforced concrete structures, it is not necessary to repair the damage appropriately, but also to evaluate the strength of reinforcement of RC members. The losses of the structural performance of RC members are caused by the reduction in the effective cross sectional areas of concrete due to cracking of the cover concrete, losses in the bond performance of concrete with rebar.

Reinforced concrete uses steel to provide the tensile properties that are needed in the structural concrete. Liu (1991)studied concrete structures in marine environment. Concrete structures in marine environment are exposed simultaneously to the action of number physical and chemical determination processes. Damage can vary from aesthetic through severe structural deterioration, depending on the environment in which it resides. The deterioration process may be the combined effects of chemical action of sea-water constituents on cement hydration products, crystallization of salts within concrete, alkali-aggregate expansion, corrosion of steel bars, freezing and thawing a cold climate, and physical erosion due to wave action and floating objects. Neville (1995)according to the author, the chloride attack on concrete is different from other mechanisms of deterioration because the primary action of chlorides is to cause corrosion of steel reinforcement and it is only as a consequence of this corrosion that the surrounding concrete is damaged. Zhou et al. (2015) studied the degradation mechanism of concrete strength in sulphate environment. The authors describe the corrosion of concrete by sulphates as a gradual process that starts from the surface layer to the core. In this paper, an accelerated corrosion by a sulphate solution in a dry-wet cycle was introduced to simulate the external sulphate corrosion environment.

Fig. 1. Corroded reinforcing steel in concrete deck.

Fig. 2. Corroded reinforcement.

Fig. 3. Salt and acid.

The chloride attack leads to corrosion of the reinforcing steel and a subsequent reduction in the strength, serviceability, and aesthetics of the structure. The affects the time for chlorides to reach the reinforcing bars and, consequently, the corrosion initiation time. Zhang et al. (2015)studied the influence of carbonation on sulphate attack of concrete materials. Several experiments have been carried out to determine the effect of carbonation on the resistance of sulphate attack of concrete materials. The accelerated carbonate testing was used to prepare the carbonate specimens, and wetting-drying cycles were used to evaluate the resistance of sulphate attack. Results show that longer carbonate time leads to greater depth of carbonation, and fly ash may accelerate the carbonation of concrete materials. There is a decrease of flexural and compressive strength. Carbonation is detrimental to the resistance of sulphate attack of concrete materials. Verma et al. (2013**)** evaluated effect of chloride attack and concrete cover on the probability of corrosion.

The authors describe chloride ions penetration in concrete structures as a significant threat to the durability of concrete structures. It has been revealed that in reinforced concrete structures corrosion takes place when passive protective layer is destroyed by chloride ingress.

1.1 Objective of Study

- To determine the weight loss of steelbar due to chloride and sulphate induced corrosion.
- To observe the behavior the corrosion rate under various concentration of salt and acid.
- To observe the behavior of corrosion rate of steel under variation ratio of cement sand in exposure duration.

1.2 Corrosion of steel reinforcement in R.C.C structures

Corrosion of reinforcement plays an important role in the durability of concrete structures and therefore it deserves due consideration. Damage of concrete due to corrosion is one of the most important reasons for the lack of durability of concrete structures. A world wide investigation shows that more than 40% of the failure of structure is due to rusting of steel reinforcement.

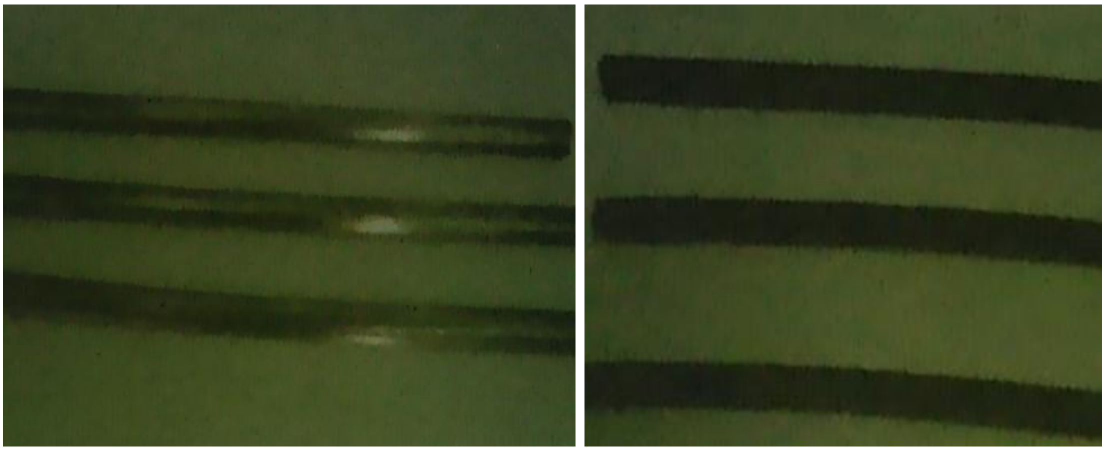
(a) (b)

Fig. 4. (a) Specimen before cleaning (b) After cleaning.

2. Materials

- Reinforcing steel (dia 8mm and length 150mm)
- Cement
- Sand
- Wooden block (150mm*100mm*100mm)
- Salt (NaCl)
- Acid (sulphuric acid)

2.1 Testing variable

The test was carried out by changing the following variables:

- Percentage of salt in solution.
- Percentage of acid in solution.
- Variation of water cement ratio.
- Variation of sand cement ratio.

3. Experimental program

3.1 *Specimen preparation*

This process includes following steps

- Cutting: At first the plain steel bar was cut with the help of lathe machine. About 40 pieces of bar was cut to a specific length of 150mm.
- Cleaning: In order to determine the accurately the amount of material lost to corrosion, the specimen was cleaned and it was cleaned by mechanical process.

3.2 *Preparation of concrete block*

After preparation the specimen**,** concrete block was made by placing the specimen at the center of the block. The block was made with the variation of cement sand and water cement ratio.

Fig. 5. Concrete block with specimen.

Fig. 6. Preparation of solution.

3.3 *Solution preparation*

When the specimen was ready to immerge into solution after cleaning, then the solution of (NaCl + water) and (water + sulphuric acid) were prepared in a plastic dish. Percentage of salt and acid were varied according to need. Usually 3,5,7 % of salt and acid (0.5M) were used with water.

4. Experimental results and discussion

4.1 *Chloride and sulphate series graph*

By this graph weight loss is compared between the salt and acid solution in different percentage. From the figures, it is clear that increasing rate of weight loss of salt is higher than acid. Nearly the same but magnitude are different for various exposure duration.

It is also noted that, there is not greater variation in weight loss between salt and acid exposure specimen of same exposure duration and different concentration due short time exposure duration.

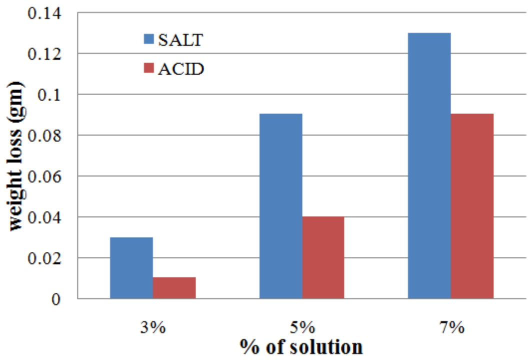

Fig. 7. Weight loss comparison of steel specimen with salt and acid series when cement sand ratio 1:2 and water cement ratio 0.40.

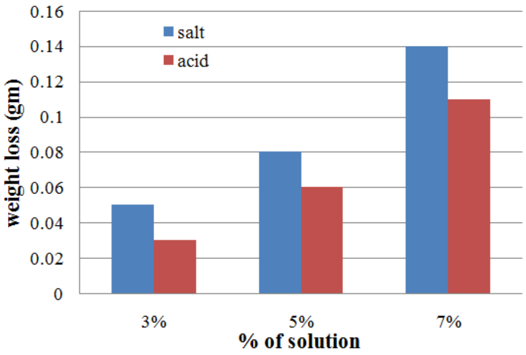

Fig. 8. Weight loss comparison of steel specimen with salt and acid series when cement sand ratio 1:2 and water cement ratio 0.50.

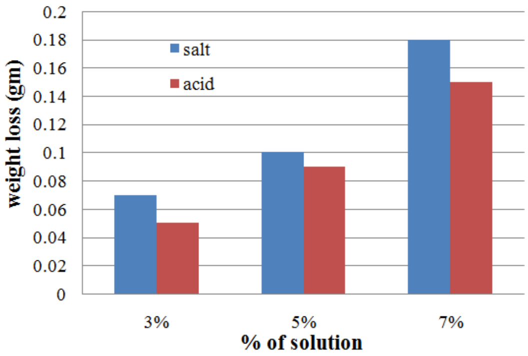

Fig. 9. Weight loss comparison of steel specimen with salt and acid series when cement sand ratio 1:2 and water cement ratio 0.55.

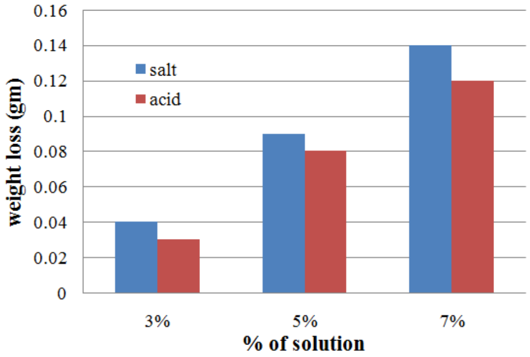

Fig. 10. Weight loss comparison of steel specimen with salt and acid series when cement sand ratio 1:3 and water cement ratio 0.40.

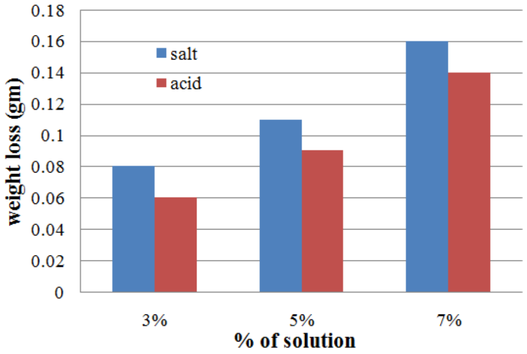

Fig. 11. Weight loss comparison of steel specimen with salt and acid series when cement sand ratio 1:3 and water cement ratio 0.50.

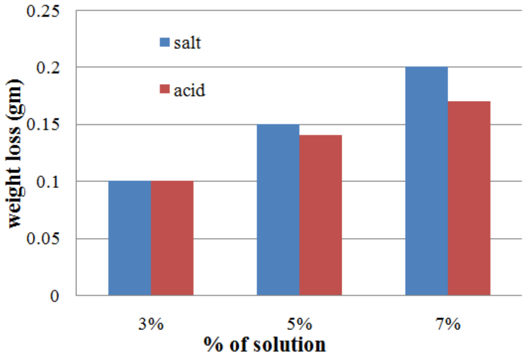

Fig. 12. Weight loss comparison of steel specimen with salt and acid series when cement sand ratio 1:3 and water cement ratio 0.55.

5. Conclusion

Sulphate exposure specimen display a significantly lower loss of weight due to corrosion to salt exposure. The magnitude of weight loss increase with the increase in percentage of chloride ion in solution. The weight loss due to corrosion increase with increase in percentage of sulphate ion in solution.

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