The Effect of Sulfate Attack on Physical Properties of Concrete

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Abstract: The effects of different concentrations of sulfate for erosion age on compressive strength, flexural strength, weight analysis, density loss and visual appearances for concrete specimens of different grades were investigated. Experimental studies were carried out on different grades of concrete (M-25, M-30 and M-35). Concrete specimens were immersed in different concentration of sulfate solution i.e. 4.0pH, 5.0pH and 6.0pH. Reduction in compressive strength loss was noticed when the grade of concrete is increased from M-25 to M35. The results of weight analysis and density analysis also confirm the compressive strength loss and flexural strength. Discoloration of concrete was noticed on the concrete blocks when left immersed in sulfate solution at 4.0pH, 5.0pH and 6.0pH for 75days and 90days. It appeared like flakes of concrete and resembled like mold growth.

Keywords: Compressive Strength Loss, Weight Analysis, Sulfates Attack, Concrete, pH Concentration.

I. INTRODUCTION

The effects of Sulfate on physical and chemical characteristics require complex procedures to study in detail. The disintegration of concrete depends on the cementious material used. [1] The sulfate attack can result in the generation of expansive products and the decomposition of hydration products of cement [2]. Concrete, as an artificial porous material also suffers from degradation caused by salt crystallization. For the past few decades, most laboratories have studied the durability of concrete exposed to sulphates. Compound sulphate assault includes synthetic response between sulphate particles and concrete hydration items or the principle segments of concrete. In the case of chemical sulfate attack, sulphates of sodium, potassium, calcium, or magnesium in soil or dissolved in groundwater or seawater in the vicinity of concrete structures enter concrete, attack the hardened cement paste and increase the potential of deterioration [3,10,23]. Harm of cement because of salt crystallization has been portrayed as an actual salt assault [4]. In recent years, sulfate attack with existing environmental and mechanical factors have attracted the attention of scholars, such as sulfate attack under drying-wetting and heating–cooling environments , frost action, static flexural loading , flexural fatigue loading , static flexural loading and drying-wetting cycles, static flexural loading and freeze–thaw cycles [6,10,13].

Sulfate attack triggers changes to concrete hydration process leading to undesired harmful effects. Decalcification of the C–S–H stage, filtering and decrement of the pH because of sulfate assault leads to solidify glue corruption. Sulfate attack is a complicated phenomenon affected by many parameters, salt weathering [7, 11]. Solid constructions may experience the ill effects of sulfate assault, which causes genuine disintegration of the solid and influences the assistance life of the designs. Sulfate particles infiltrate the pores and consequently structure a forceful arrangement, which respond with specific segments of hydrated concrete (calcium hydroxide, hydrated calcium aluminate and AFm stages) to frame ettringite (AFt) and gypsum that instigate extension [8,9]. This can be characterized as a compound response between the sulphate particles, having infiltrated into the solid by an exchange system, and the mineral segments of the solidified concrete glue, principally Tricalcium aluminate [12, 13, and 14].

II. EXPLORATORY EXAMINATION

2.1 Material properties

2.1.1 Cementitious material: The Pozzolana Portland cement was used in the experimental study confirming to IS 1489 (part1). The physical properties of these cementous materials are shown in table 1.

| Table 1 Physical property of cementious materials |
|-----------------------------------------------|
| Physical properties | Specifi c gravity | Fineness s | Consistenc y | Initial setting time | Final setting time |
|---------------------|------------------|------------|--------------|---------------------|------------------|
| Results             | 2.88             | 2.5%       | 33%          | 45min               | 290min           |

2.1.2 Coarse and Fine Aggregate

Fine Coarse aggregate generally consists of natural sand or crushed stone with most particles passing through a 4.75mm sieve. Coarse aggregate are any particles greater than 4.75mm.
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Gravel constitutes the majority of coarse aggregate used in concrete with crushed stone making up most of the remaining aggregate. Physical properties of these aggregates are shown in table 2.

Table 2 Physical properties of fine and coarse aggregates

| Characteristic | Gradating zone | Fineness modulus | Specific gravity | Water absorption |
|----------------|----------------|------------------|------------------|-----------------|
| Fine aggregate | Zone II        | 2.82             | 2.65             | 1%              |
| Coarse aggregate | 16mm         | 6.91             | 2.65             | .15%            |

2.2 Mix proportions

In this study, three different grade of concrete were considered that is M25, M30, and M35. The details of mix proportions are given in table 3.

Table 3 Concrete mix proportion / (kg-m-3).

| Strength grade | Cement | Fine aggregate | Coarse aggregate | Water | Superplasticizer |
|----------------|--------|----------------|-----------------|-------|-----------------|
| M25            | 348    | 792            | 1095            | 167   | 1.74            |
| M30            | 367    | 770            | 1108            | 161   | 2.93            |
| M35            | 375    | 753            | 1128            | 157   | 3.75            |

2.3 Experimental processes

The test method was carried out in accordance to IS 456-2000 and it was used to determine the long term performance and endurance of ordinary concrete. The size of concrete cube was 150mm ×150mm ×150mm and the same for concrete beam specimen size 100mm ×100mm×500mm. Concrete mix was prepared for these different grades of concrete M-25, M-30 and M-35. After casting all specimens were then demoulded after 24 hour and cured for 28 days at a room temperature. Firstly prepared the sulfate solution with different pH (4.0pH, 5.0pHHand 6.0pH) in the solution boxes. Thereafter all the concrete specimens were undergone water curing for 28 days and subsequently immersed into sulfate solution. At that point, the solution boxes were covered with the plastic film to guarantee that water was not evaporated. Finally, the specimens were taken out from sulfate solution and dried at room temperature when the erosion age reached to 75 days and 90 days.

III. RESULTS AND DISCUSSION

3.1 Compressive strength analysis

The figures are showing loss of compressive strength in these different grades of concrete M-25, M-30 and M-35 with sulfate concentration. These results were determined after 75 days and 90 days sulfate exposure at 4.0pH, 5.0pH and 6.0pH. For M-25 grade of concrete, the reduction in compressive strength after 75 days of exposure is 11.2%, 10.20% and 8% with pH4.0, pH5.0 and pH6.0 respectively.
The compressive strength loss after 90 days of exposure is 14.8%, 12.34% and 8.6% with pH 4.0, pH 5.0 and pH 6.0 respectively. For M-30 concrete grade the reduction in compressive strength after 75 days of exposure is 8.1%, 6% and 3.8% with pH 4.0, pH 5.0 and pH 6.0 respectively.

The reduction in compressive strength loss after 90 days of exposure is 13.6%, 9% and 6% with pH 4.0, pH 5.0 and pH 6.0 respectively. For M-35 concrete grade mix with sulphate, the compressive strength loss after 75 days of exposure is 7.1%, 3% and 2.1% with pH 4.0, pH 5.0 and pH 6.0 respectively. The compressive strength loss after 90 days of exposure is 11.7%, 63% and 4.8% with pH 4.0, pH 5.0 and pH 6.0 respectively. The strength loss of specimen may be attributed to the internal pressure caused by the sulphate.

3.2 Weight analysis

| s.no. | pH value | M-25 grade of concrete | M-30 grade of concrete | M-35 grade of concrete |
|-------|----------|------------------------|------------------------|------------------------|
|       |          | 28days | 75days | 90days | 28days | 75days | 90days | 28days | 75days | 90days |
| 1     | 4        | - 8.129 | 8.072 | -       | 8.139 | 8.160 | -       | 8.245 | 8.143 |
| 2     | 5        | - 8.185 | 8.113 | -       | 8.196 | 8.273 | -       | 8.298 | 8.287 |
| 3     | 6        | - 8.231 | 8.200 | -       | 8.213 | 8.292 | -       | 8.312 | 8.354 |
| 4     | 7.5      | 8.263  | 8.273 | 8.275   | 8.361 | 8.365 | 8.367   | 8.441 | 8.443 |

The effect of concrete grade M-25 and sulphate dosages on the weight loss of concrete mixes after 75 days and 90 days of pH 4.0, pH 5.0 and pH 6.0 sulphate exposure is shown in above figures. From these figures it is observed that M-25 concrete grade has a noticeable effect on weight loss of concrete subjected to pH 4.0, pH 5.0 and pH 6.0 sulphate attack. The weight loss after 75 days is 1.7%, 1% and .5% with pH 4.0, pH 5.0 and pH 6.0 respectively. The reduction in weight after 90 days of exposure is 2.4%, 1.9% and .9% with pH 4.0, pH 5.0 and pH 6.0 respectively. In M-30 the reduction in weight after 75 days is 2.7%, 2% and 1.8% with pH 4.0, pH 5.0 and pH 6.0 respectively. The weight loss after 90 days of exposure is 2.4%, 1.1% and .8% with pH 4.0, pH 5.0 and pH 6.0 respectively. Similarly for M-35 the reduction in weight after 75 days is 2.3%, 1.7% and 1.5% with pH 4.0, pH 5.0 and pH 6.0 respectively. The reduction in weight after 90 days of exposure is 3.5%, 1.8% and 1% with pH 4.0, pH 5.0 and pH 6.0 respectively.

3.3 Density analysis
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Table 6 density analysis

| s.no. | pH value | Density analysis in kg/m³ |
|-------|----------|--------------------------|
|       |          | M-25 grade of concrete | M-30 grade of concrete | M-35 grade of concrete |
|       | 28days   | 75days  | 90days | 28days   | 75days  | 90days | 28days   | 75days  | 90days |
| 1     | 4        | -       | 245.30 | 249.59  | -       | 251.66 | 252.31 | -       | 254.94  | 251.79 |
| 2     | 5        | -       | 253.09 | 250.86  | -       | 253.43 | 255.81 | -       | 256.58  | 256.24 |
| 3     | 6        | -       | 254.20 | 253.55  | -       | 253.95 | 256.40 | -       | 257.01  | 258.31 |
| 4     | 7.5      | 255.50  | 255.75 | 255.87  | 258.53  | 258.65 | 258.41 | 261.00  | 261.06  | 261.13 |

Table 7 flexural strength at 90days

| pH value | M-25 | M-30 | M-35 |
|----------|------|------|------|
| 4.0      | 3.37 | 3.91 | 3.92 |
| 5.0      | 3.60 | 4.24 | 4.29 |
| 6.0      | 3.93 | 4.41 | 4.76 |
| 7.5      | 4.36 | 4.72 | 5.20 |

Figure 7 density for M-25

Figure 8 density for M-30

Figure 9 density for M-35

Figure 10 flexural strength

The mass change of concrete cube fully immersed in the sulphate solution was monitored on 75th day and 90th day. Before measuring their mass, all concrete cubes were air-dried in the laboratory at room temperature. Figures showed the density loss on 75days and 90days exposure of sulphate.

3.4 Flexural strength tests

The mass change of concrete cube fully immersed in the sulphate solution was monitored on 75th day and 90th day. Before measuring their mass, all concrete cubes were air-dried in the laboratory at room temperature. Figures showed the density loss on 75days and 90days exposure of sulphate.

3.5 Weight analysis of beam

Table 8 Weight analysis of beam after 90days

| pH value | M-25 | M-30 | M-35 |
|----------|------|------|------|
| 4.0      | 12.140 | 12.200 | 12.260 | 12.280 |
| 5.0      | 12.370 | 12.410 | 12.420 | 12.460 |
| 6.0      | 12.470 | 12.640 | 12.730 | 12.960 |
The effect of sulphate dosages on the weight loss of concrete mixes after 90 days at pH 4.0, pH 5.0 and pH 6.0 sulphate exposure is shown in figures. From these figures it is observed that concrete grade has a noticeable effect on weight loss of concrete subjected to pH 4.0, pH 5.0 and pH 6.0 sulphate attack.

3.6 Visual Appearances

3.6.1 Visual Appearance at 75 days

A Discoloration appearing to be green in color was seen on the concrete blocks when left immersed in sulphate solution (pH 4.0) for 75 days. The discoloration was light pink color at pH 5.0, off white colour at pH 6.0.

3.6.2 Visual Appearance after 90 days

Discoloration of green color (4.0pH), light pink color (5.0pH) and off white colour (pH 6.0) was observed on the concrete blocks when left immersed in sulphate solution for 90 days. It appeared like flakes of concrete and resembled like mold growth.

IV. CONCLUSION

Based on the results obtained from this study, the following can be concluded:

- The compressive strength losses of M-25 concrete grade with sulphate concentration, determined after 75 days and 90 days at pH 4.0, pH 5.0 and pH 6.0 sulphate exposure is given as under:
  - The compressive strength loss after 75 days of exposure is 11.2%, 10.20% and 8% with pH 4.0, pH 5.0 and pH 6.0 respectively. The compressive strength loss after 90 days of exposure is 14.8%, 12.34% and 8.6% with pH 4.0, pH 5.0 and pH 6.0 respectively.
- The compressive strength losses of M-30 concrete grade with sulphate concentration, determined after 75 days and 90 days of pH 4.0, pH 5.0 and pH 6.0 sulphate exposure is given as under:
  - The reduction in compressive strength after 75 days of exposure is 8.1%, 6% and 3.8% with pH 4.0, pH 5.0 and pH 6.0 respectively. The reduction in compressive strength after 90 days of exposure is 13.6%, 9% and 6% with pH 4.0, pH 5.0 and pH 6.0 respectively.
- The compressive strength losses of M-35 concrete grade with sulphate concentration, determined after 75 days and 90 days of pH 4.0, pH 5.0 and pH 6.0 sulphate exposure is given as under:
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The reduction in compressive strength after 75 days of exposure is 7.1%, 3%, and 2.1% with pH 4.0, pH 5.0, and pH 6.0 respectively. The compressive strength loss after 90 days of exposure is 11.7%, 63%, and 4.8% with pH 4.0, pH 5.0, and pH 6.0 respectively.

- From the above results, it can be concluded that from the compressive strength point of view, the loss of compressive strength reduces as concrete grade is increased from M-25 to M-35. The test results of weight loss and density loss also confirm the same.

- Discoloration of concrete was observed on the concrete blocks when left immersed in sulfate solution (pH 4.0, pH 5.0, and pH 6.0) for 75 days and 90 days. It appeared like flakes of concrete and resembled like mold growth.

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