Effects of Sulphates on the Characteristics of Ordinary Portland Cement

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Abstract. This project presents the results of an experimental investigation in which the effects of sulphates on the initial and final setting times of ordinary Portland cement and compressive strength of cement is investigated. It was observed that the type of Sulphate and the ion concentration affect the setting times significantly; the increase in initial setting time is more prominent. The parameters reduce the compressive strength of cement at different ages. In the present study water cement ratio is taken depending on the normal consistency arrived based on different concentrations of sulphates mixed with OPC (Ordinary Portland Cement) an increase in setting times is observed as the concentration of sulphates in the cement paste increased. The soundness test results also showed an increased pattern which means that there is an increase in volume of cement paste because of sulphate attack. Compressive strength characteristics also showed an increased pattern when compared to cubes cast with distilled water.

1. Introduction

Cement concrete construction is getting progressively perplexing and the significance of creating structures that are both financially savvy and strong has never been higher. Sulphate attack in cement concrete has been known to happen when sulphates solutions gotten either from a constituent in the concrete, or from outer sources, for example, groundwater, react with the concrete hydrates present in the solidified cement paste to frame the items which can involve more prominent volume than the reactants. The significant wellsprings of these salts are soils (especially Arid Region), groundwater, seawater, modern synthetic substances and squanders, and manures. The three items acquired because of the reaction for example gypsum, ettringite and Thaumasite has more noteworthy volumes than the reactants and in this manner brings about the arrangement of cracks and inevitable disturbance in the solidified concrete. The fundamental point of this venture is to examine the pernicious impacts of sulphatese exposure to Portland cement and impact of water cement ratios that guarantees strength of concrete against exposure of sulphates salts. Accentuation is put on a basic examination of models that depict the connection among quality and impact of sulphates with curing age. Information on the increase of compressive strength with age and pertinent properties of concrete, for example, soundness and setting times are examined within the sight of sulphates [1-7].

Ettringite development is viewed as the reason for the greater part of the expansion and disruption of concrete structures associated with sulphates attack, anyway not really any sulphates attack is shaped
by ettringite arrangement more over ettringite development can benificially utilized with no sulphate on concrete this undertaking presents basic examination of connection between ettringite formation and sulphates attack including some special cases of this attack those identified with thaumasite development are "postponed ettringite arrangement". The term sulphates attack utilized here methods decay of concrete including any sort of sulphate communications with cement paste freely on cooling temperature and sulphates source.

The concrete cubes are helpless against both internal and external sulphates attack. It is likewise perceived and examined in the paper about the quality impacting attributes of sulphates on cement with increment in age [8-15]. The adverse impacts depend on the life span of the attack. Subsequently vital safety measures are to be taken in this angle.

2. Materials

2.1. Materials
Test examination materials include:
- 53-Grade Ordinary Portland Cement (OPC)
- Sand
- Distilled Water
- Sulphates (MgSO4.7H2O+Na2SO4+(NH4)2SO4)

The properties of these materials are given in the accompanying sub-segments

2.1.1 Cement
Experiments like initial setting time, final setting time, soundness of mortar cubes and compressive strength were tested on 53-grade cement. Oxides and their percentages of 53-grade OPC are presented in Table 1.

| Oxides | Percentage of contents |
|--------|------------------------|
| CaO    | 65.4                   |
| Na2O   | 0.12                   |
| SiO2   | 21.6                   |
| MgO    | 0.7                    |
| Al2O3  | 5.9                    |
| SO3    | 1.6                    |
| Fe2O3  | 3.8                    |
| K2O    | 0.4                    |

The percentage composition of the major compounds (known as the Bogue compounds) present in the cement is presented in Table 2 [2].

2.1.2. Sand
Sand utilized all through the test is acquired from the Ennore, near to Chennai (Ennore sand IS 650:1991). The sand was acquired from Tamilnadu minerals, Chennai. It is the main association in India, affirmed by Indian Standard Institution to fabricate and flexibly of sand adjusting to IS 650:1991 [8]. The sand utilized in the test work has the accompanying particle size distribution
- Passing through 2mm X retained in 1mm; 1mm X retained in 0.5 mm and 0.5mm X retained in 0.09mm
- The Distilled water is used as mixing water.
- Sulphates (MgSO4.7H2O+Na2SO4+(NH4)2SO4)
Magnesium sulphate heptahydrate (MgSO$_4$·7H$_2$O) having the molecular weight of 246.48 gm/mol and its pH is 5-8.

Sodium sulphate (Na$_2$SO$_4$) having the molecular weight of 142.04 gm/mol and its pH is 5-7.

Ammonium sulphates ((NH$_4$)$_2$SO$_4$) having the molecular weight of 133.13 gm/mol and its pH is 5-6.

The sulphates used are the Analytical Reagents (AR) and is supplied by SDFCL, Mumbai

### Table 2. % Composition of the Chief Mixtures Existing in the Test Cement [14, 15]

| Sl. No. | Compound | Conversion formulas | % in cement |
|---------|----------|---------------------|-------------|
| 1       | Tetracalcium alumino ferrite (4CaO·Al$_2$O$_3$·Fe$_2$O$_3$) | 3.04 (Fe$_2$O$_3$) | 11.70       |
| 2       | Tricalcium silicate (3CaO·SiO$_2$) | 4.07 (CaO) -7.60 (SiO$_2$) -6.72 (Al$_2$O$_3$) -1.43 (Fe$_2$O$_3$) -2.85 (SO$_3$) | 51.49       |
| 3       | Tricalcium aluminate (3CaO·Al$_2$O$_3$) | 2.65 (Al$_2$O$_3$) -1.69 (Fe$_2$O$_3$) | 9.31        |
| 4       | Dicalcium silicate (2CaO·SiO$_2$) | 2.87 (SiO$_2$) -0.754(3CaO·SiO$_2$) | 23.37       |

### Table 3. Ennore Sand characteristics

| Sl. No. | Properties            | Unit    | Results              |
|---------|-----------------------|---------|----------------------|
| 1       | Specific Gravity      | -       | 2.64                 |
| 2       | Bulk density          | KN/m$^3$| 15.54                |
| 3       | Fineness modulus      | -       | 2.72                 |
| 4       | Particle size variations | mm    | 0.09 to 2.0          |
| 5       | Colour                | Hazan   | Grayish white        |
| 6       | Absorption in 24 hours | -       | 0.8%                 |
| 7       | Shape of grains       | -       | Sub angular          |

### Table 4. Details of Test Program

| Sl. No. | Sulphates Concentrations MgSO$_4$·7H$_2$O+NaSO$_4$+(NH$_4$)$_2$SO$_4$ (mg/l) | specimens for setting times test | specimens for soundness test | specimens for compression test | aggregate |
|---------|-----------------------------------------------------------------------------|---------------------------------|------------------------------|-------------------------------|----------|
| 1       | 0                                                                            |                                 |                              |                               |          |
| 2       | 333+333+333                                                               | 3 (for all conc.)               | 3 (for all conc.)            | 3x4 (for all conc.)           | 18       |
| 3       | 500+500+500                                                                |                                 |                              |                               |          |
| 4       | 667+667+667                                                                | 3 (for all conc.)               | 3 (for all conc.)            | 3x4 (for all conc.)           | 18       |
| 5       | 834+834+834                                                                |                                 |                              |                               |          |
| 6       | 1000+1000+1000                                                             |                                 |                              |                               |          |
| 7       | 1167+1167+1167                                                            |                                 |                              |                               |          |
| 8       | 1334+1334+1334                                                            |                                 |                              |                               |          |

3. Methods

The trial strategies embraced were as per the standard systems in BIS. They are quickly introduced in the accompanying sub segments.

The subtleties of the test work are introduced in Table 4. A sum of 24 examples utilized in Vicat's device for initial and final setting time tests. Similar number of tests of standard form was utilized in Le-Chatelier's apparatus to test for adequacy.
A sum of 96 mortar cubes of 50 cm$^2$ cross sectional area was tested at various ages (3-days, 7-days, 28 days, and 90 days) for compressive strength

4. Results and Discussions
The results of initial and final setting times, soundness and percentage change in compressive strengths of the test samples are shown in the Figure 1 to Figure 4. The Effect of sulphates MgSO$_4$.7H$_2$O+Na$_2$SO$_4$+(NH$_4$)$_2$SO$_4$ on IST, FST of cement are shown in Figure 1 from the Figure, it is observed that both IST, FST process got accelerated with the increase in percentage of sulphates in Portland cement. Initial setting times are significantly increased at all the percentages of sulphates when compared with the results obtained with control samples. The increase in initial setting times are 48, 53, 123, 138, 153 & 163 minutes and final setting times are 15, 15, 20, 30, 45, 70 & 105 minutes for 1000, 1500, 2000, 2500, 3000, 3500 & 4000 mg/l respectively when compared with control samples.

4.1. Compressive strength
The effect of opted percentages of sulphates on the compressive strength of cement mortar is presented in Figure 3 and 4. The results indicated that there is increase in compressive strength of the cement mortar cubes when compared to cubes caste with distilled water. Average compressive strengths at 3, 7 and 28 for concentrations of sulphates MgSO$_4$.7H$_2$O+Na$_2$SO$_4$+(NH$_4$)$_2$SO$_4$ are shown in the Figure 3. The percentage change in the compressive strength of cement shown in the Figure 4. However, from all the results we noted that the compressive strength of cement increased with increase in concentrations from 1000-4000 mg/l.

4.2. Soundness
The Le–Chatelier test results for expansion measurement in cement should not be more than 10mm for Portland cement for passing soundness test. The effect of different mixing proportions of sulphates in cement on Soundness is given in Figure 2.
The expansion measured is 1.95, 2, 2.05, 2, 2, 2.05, 2.05 & 2.05 for 0, 1000, 1500, 2000, 2500, 3000, 3500 & 4000 mg/l respectively. As the measured values are less than 10 mm. All the samples are considered sound.

Figure 1. Effect of sulphatesMgSO$_4$.7H$_2$O+Na$_2$SO$_4$+(NH$_4$)$_2$SO$_4$ on IST, FST of cement
Figure 2. Effect of sulphates MgSO$_4$.7H$_2$O+Na$_2$SO$_4$+(NH$_4$)$_2$SO$_4$ on soundness of cement

Figure 3. Effect of sulphates MgSO$_4$.7H$_2$O+Na$_2$SO$_4$+(NH$_4$)$_2$SO$_4$ with different concentration on compressive strength of cement

Figure 4. Effect of sulphates MgSO$_4$.7H$_2$O+Na$_2$SO$_4$+(NH$_4$)$_2$SO$_4$ percentage transition of compressive strength of cement at different concentration sulphates

5. Conclusions
In light of the trial study the accompanying ends are drawn.
The setting time of concrete, monotonically increase with sulphate concentration.

For the same ion concentration % increase in final setting time is less than initial setting time

The rate increment in initial setting time is more contrasted with that of the final setting time for a similar particle concentration.

Cations related with sulphate solution impact the level of attack. Among the three sulphate solutions utilized in this examination, the impact of sodium sulphate on setting times of concrete is generally articulated.

Concrete exposed to sulphate attack, loses compressive strength and this loss increments as a component of sulphate concentration and time of exposure.

Impact of various sulphate solutions on compressive quality of concrete was not similarly serious. The impact of magnesium sulphate was discovered serious.

The cause for change in setting time of concrete within the sight of natural cations (Na+, Mg++, NH4+) and anions (So4- -) credited to the adjustment in solvency of cement paste cations (Ca++) and anions (aluminates and silicates).

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