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Experimental Investigation On The Behavior Of Blended Cement Motar Under The Effects Of Sulphates

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ABSTRACT -

Cementatious materials have been used by mankind for construction from time immemorial. The every rising functional requirement of the structures and the capacity to resist the aggressive elements has necessitated developing the new cementatious materials. Concrete is an artificial material in which the aggregates both fine and coarse are bonded together by the cement when mixed with water. The most important part of the concrete is cement, whose production produces a lot of CO2. The most effective way to decrease the CO2 emission of cement industry is to substitute a proportion of cement with other materials. Blended cement is the best solution for the problem. Recent research works has been focused on the durability characteristics of the blended cement. This paper presents the effect of sulphates on the strength properties of the Blended Cement (fly ash based). For this purpose cement mortar cubes were casted using the deionized water in three different sulphate concentrations of 500, 1000, 1500, 2000, 2500, 3000 mg/l. The sulphates used in the present investigation are sodium sulphate, magnesium sulphate, ammonium sulphate and ferrous sulphate. The effect is studied with single, double and triple combination of the sulphates. Controlled sample specimen were casted using deionized water with no concentration for comparison. Specimens are tested for compressive strength by using compression testing machine. Testing is done at age of 7, 28 and 90 days. And from this investigation we can conclude that with this concentrations the effect on compressive strength of the blended cement is slightly less when compared with the controlled sample specimen.

Key Words: Blended cement, deionized water, sulphates.

INTRODUCTION

1.1 GENERAL

Cement mortar is a composite mixture, which consists of fine aggregate, cement and water. The most common type of aggregate is sand, and ordinary Portland cement is used in the construction work. Many other substances are also added in the mix to attain various properties for the mortar. The dry form of cement mix do not possess binding property, it attains binding property only when it is mixed with water. This property of gaining strength through chemical process is known as Hydration of cement. Cement mortar is a mixture that used to bind bricks, rocks, and other constructional units.

Water is the important ingredient of cement mortar. It not only participates in hydration but also contributes workability for fresh mix. The cement in the concrete needs water to hydrate and form Calcium-Silicate-Hydrate (C-S-H) which is the glue that holds the concrete together. The water is chemically bound (consumed) during the reaction with the cement at approximately 25 pounds of water to every 100 pounds of cement. So there is a direct effect of water on strength. Water is abundantly found in nature, it is considered as universal solvent. So, water to be checked for undesirable compounds. Much importance is given for the quality of cement, and even aggregate is also checked. But less priority is given for the water quality. The common specifications regarding quality of mixing water is water should be fit for drinking. Such water should have inorganic solid less than 1000 ppm. But some water which is not potable may be used in making concrete with any significant effect. Water used for concrete making should satisfy the requirements of standards of American society for testing and materials (ASTM) or with the Indian standards (IS 456-2000). However the standard code does not give the relation for the water quality and compressive strength and other parameters.

Past experiences shows deteriorations of the structure due to usage of improper quality of water in both cases of concrete mixing and curing. And in many cases where impure water is in constant contact with the structure showed damage. This impure water not only effects the strength but also durability of the concrete. In such cases the efflorescence deposits are also observed on the concrete structure. The other effects of impure water are decrease in setting time, deposits of salts on surface of structure, soundness.

There is a saying as water for mix of concrete is suitable if it satisfies the requirements for drinking. Accordingly, water unfit for drinking is not suitable for mixing mortar. But water which is acidic salty, alkaline, coloured, brackish, foul smelled can be used for concrete mix as it does not show much variation on strength of concrete. House hold water contains greater than 1000 ppm. Water for the mix, however to be checked from mining and other industrial origin.

Generally sea water contains about 35000 ppm of dissolved salts, does not show effect on strength of cement mortar. But, it is not recommended for reinforced concrete and pre-stressed concrete works. Water molecules being small can percolate through the smallest pores of the surface. Hence when the water comes into contact with surface of structure, it percolates deep and reaches to steel bars. Thus the corrosion of the steel takes place. The water containing organic matter such as algae, oils, salts, sugar should right away be rejected.

Water also causes hydrostatic pressure and increase the internal pressure of the structure. Water causes disruptive volume changes if it happens to internal movement and changes in structure of water. In some cases due to different ionic concentration osmotic pressure causes differential vapour pressures. In cold weather areas water in the pores of structure get frozen. As the water freezes volume increases, this causes internal pressure.

1.2 NEED OF PRESENT INVESTIGATION

Water is a universal solvent. It dissolves all kinds of impurities in it. Due to various minerals in soil, land composition also changes. So the composition of water differs from place to place. If there is a water constraint in construction site, the excessive water available other than human consumption will not serve the need for construction purpose. During such time locally available natural water is used without giving much importance to quality of water. Then water is not questionable if it satisfies the standards specified.

In such cases quality of water is accepted by conducting a simple procedure by which comparison of strength and setting time are made with standard water. IS 456 2000 specifies that, in case of questionable water quality, compressive strength and setting time should be examined. According to the standards motor cubes are made with the standard water and questionable water. They are examined for both the setting time and compressive strength. The compressive strength variation of questionable water and standard water cubes should not be less than 90 percent. Difference in the setting time of cubes should not be greater than 30 minutes. If these requirements are satisfied the water can be used for construction purpose.

In IS 456 2000 there are a specified limits for pH value and solids present in water to be used for construction purpose. But, there is no specific explanation on limits and their effect as alkaline, basic or neutral. In present investigation there is a specific relation between compressive strength and concentration of chemicals. Work is carried on cement mortar cubes for different sulphates attack for 7 days, 28 days and 90 days.

1.3 OBJECTIVES

1. To study the effect of water quality on the compressive strength on blended cement based cement mortar.

2. To study the effects of different sulphates on compressive strength of cement mortar cubes in deionised water.

LITERATURE REVIEW

2.1. INTRODUCTION

In the cement industry the use of pozzolanic materials is attaining paramount importance due to their beneficial effect on various properties of the cement. In this context, by using the pozzolana material in the cement, the cement production companies are releasing different cements, under various brands, such as Portland Pozzolana Cement (Fly ash based (IS 1489 Part I)), Portland Pozzolana Cement (calcinated clay based(IS 1489 Part II)) etc.

The researchers/scientists in Civil Engineering are also looking to develop the strength of the cement and concrete to higher side when compared to available cements. In these situations, the research is focused on the use of pozzolana materials in the existing cements. In the present investigation, the available Portland pozzolana cement (fly ash based) available in the market and silica fume blended with PPC were used for experimental work. In this connection, a brief review has been presented about the above cited cements in the following sub sections.

2.2. BLENDED CEMENTS

Evidence of the first blended cements dates back to Roman times, when volcanic ash was used in a crude blend with slaked lime to give the user a product that developed higher early strength than the usual slaked lime as well as significant durability. Evidence of this can be seen in the Aqueducts and the Colosseum in Rome. The area in Italy where the volcanic ash was discovered is called Pozzuola, hence the term for a reactive substance being called a pozzolan. Some academics have assumed that the Roman Empire discovered the process of cement manufacturing, which was lost with the decline of this empire and rediscovered in the nineteenth century in Britain. In truth, it is more likely that the lime the Romans calcined (burnt) for the purpose of slaking approached an argillaceous lime in chemical composition and hence had to be milled rather than naturally slaked. When mixed in the normal manner with water, this product showed large early strengths and was probably the first cement made.

A mixture of Portland cement and other material such as granulated blast-furnace slag, pozzolan, hydrated lime, etc., combined either during or after the finish grinding of the cement at the mill. ACI 116, Cement and Concrete Terminology1, defines blended cements as hydraulic cements "consisting essentially of an intimate and uniform blend" of a number of different constituent materials. They are produced by "intergrinding portland cement clinker with the other materials or by blending Portland cement with the other materials or a combination of intergrinding and blending.”. Concrete can be produced with blended cement containing slag plus other cementitious materials (most commonly fly ash or silica fume) added at the batch plant. These are considered ternary systems. Ternary systems can be designed to attain performance characteristics that may be difficult to achieve in a binary system.

There are a number of systems that are used to make blended cements. Some systems are capable of "on-demand" blending, while others may blend the materials in a fixed percentage into a storage silo. All of the systems meter the constituent products in the desired proportions, and then blend them to a uniform mixture. In most cases proportions can be adjusted to produce blends that optimize the desired properties in concrete.

2.2.1 Fly-ash based PPC

Fly ash is the ash precipitated electro-statically from the exhaust fumes of coal fired power station. In India nearly 70 million tons of fly ash is being produced every year while a very small quantity is used in manufacturing of cement. It is an eco-friendly product. The fly ash particles are spherical and are generally of higher fineness than cement so that the silica is readily available for reaction. As per IS 3812: 1981, the percentage of silica and alumina should be minimum 70% and maximum loss on ignition 12 %. Much superior quality fly ash is available from thermal power plants than specified in IS code.

For every ton of cement that is produced approximately four hundred and forty kilograms of carbon dioxide is emitted, this results from the conversion of calcium carbonate to calcium oxide. The use of fly ash or slag results in a net reduction of the amount of cement used and a corresponding reduction in the amount of carbon dioxide emitted. The consistent requirement of the ash distributor to maintain the level of carbon in ash to below five percent will ensure that the ash producer achieves increased burning efficiency and results in increased life of ash dams.

In the past the major benefit has always been that the net cost of the cement has been reduced and this has always been the argument for the use of pozzolans. The ratification and adoption of the Kyoto protocol with regard to carbon dioxide emissions has made the use of pozzolans a requirement and in some countries the use of pozzolans is legislated for environmental protection and structural longevity. The demand for pozzolan is steadily increasing worldwide and is being viewed as a resource rather than as a waste material.

Though blended cement with fly ash is ideally suitable under aggressive condition, it is necessary that quality of fly ash is properly evaluated, as quality of Fly ash available at most of the places is doubtful. Use of inferior quality of Fly ash with cement, may affect corrosion resistant properties adversely. Thus, it is necessary that quality of Fly ash is evaluated by reputed laboratory. It should be tested for chlorides, sulphate, alkalinity and heat of hydration as per IS : 3812. The quality of fly ash to be blended with cement and the concrete made out of it should be approved for corrosion resistant properties by reputed organization like Central Electrochemical Research Institute (CECRI), Central Building Research Institute (CBRI), Central Road Research Institute (CRRI) etc.

Fly-ash based PPC is made by intergrinding high strength clinker with specially processed fly ash. This imparts a greater degree of fineness to Fly-ash based PPC cement, improved workability properties while mixing, and makes concrete more corrosion resistant and impermeable. All of this makes for better long term strength and improved corrosion resistance and therefore, greater life for constructions. Fly-ash based PPC is eco-friendly cement.

Fly-ash based PPC easily replaces OPC and provides additional advantages for practically all types of construction applications - commercial, residential, bungalows, complexes, foundation, columns, beams, slabs and RCC jobs. It is especially recommended for mass concreting work, and where soil conditions and the prevailing environment take heavy toll of constructions made with ordinary cements.

Due to its inherent characteristics, Fly-ash based PPC makes very corrosion resistant concrete that is superior to concrete made with OPC. It is more impermeable to oxygen, CO2, chlorides, etc. Leaching of alkalis is reduced and the alkaline environment around steel is maintained.

The blended cements are manufactured by adding pozzolanic or cementitious materials like fly ash or ground granulated blast furnace slag (GGBFS) or condensed silica fumes (CSF) to Portland cement clinker and Gypsum. Alternatively, these pozzolanic and cementitious materials can be introduced into Portland cement concrete during concrete making operations.

2.2.2. Advantages of concrete made from blended cement

Blended cements can be produced to provide the benefits in performance that are also available when slag cement is used as a separate component of the concrete mix. By varying the proportions of the blend, attributes such as sulfate resistance and resistance to alkali silica reaction can be attained with blended cement. A blend designed for a specific project requirement can also be produced. For concrete producers, blended cement may allow them to take advantage of the benefits of slag cement despite storage constraints.

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2.2.3. Strength development

The 28 days and later compressive strengths are same as for OPC. However, the rate of gain of strength up to 7 days is slower, due to heat of hydration being low. The drop in early strength should not be considered as sign of poor quality as this is often accompanied by enhancement of other properties.

2.2.4. Curing

Curing is a very important stage in the life of a conventional concrete, it becomes a critical factor in concrete containing blended cement. A good curing method is essential, because blended cement hydrates slower than OPC. It is potentially more vulnerable to drying conditions, thus the wet curing requirements, which is the most neglected activity in the fields, is very important. The curing method and period must be specified.

2.2.5. Bleeding

The Pulverised Fuel Ash (PFA), Ground Granulated Blast Furnace Slag (GGBFS), Silica fumes being finer than OPC, less bleeding is observed. The freshly placed concrete is very stable, being very cohesive and having strong internal cohesion. This has a negative effect in the form of plastic shrinkage.

2.2.6. Workability

The workability increases, and thus water content can be reduced by about 3 %. The „ball bearing‟ action of cementitious particles improves the workability. Silica fumes demand high water due to higher fineness. The problem is circumvented by the addition of suitable super plasticizers.

The engineering benefits likely to be derived from the use of mineral admixtures (blended cements and cement + mineral admixtures can be used interchangingly) in concrete are improved resistance to thermal cracking because of lower heat of hydration, enhancement of ultimate strength, reduction in permeability due to pore refinement, and a better durability to chemical attacks such as chloride, sulphate water, soil and alkali-aggregate expansion.

2.2.7. Temperature rise

In large concrete pours like bridges, foundations and water retaining structures, it is vital to minimize the rise of early age thermal cracking by controlling the temperature rise caused by hydration. One method of doing this is by use of concrete containing blended cements.

2.2.8. Chloride resistance

Blended cement concretes have a higher resistance to the penetration of chlorides. The diffusivity is substantially reduced in case of blended cement. This is due to two mechanisms. Firstly, the incorporation of slag reduces the permeability of the concrete and secondly the hardened paste of slag cement bind greater amounts of chlorides than that of OPC, resulting in much lower portion of free chlorides in the pore solution.

2.2.9. Protection to steel corrosion

The blended cement concrete is more resistant to Chloride penetration and thus provides protection in coastal areas against corrosion many more times than OPC concrete.

2.2.10. Sulphate resistance

Blended cement with slag content more than 50%, exhibits better sulphate resisting properties. Depending upon the severity of the exposure to sulphate, limitations are placed on C3A content in cement.

2.2.11. Alkali-silica reaction

Blended cement with high slag is a safe cement system for the use with reactive aggregate.

2.3 Literature Review:

Pavla Halamickova et al (1995) had studied the effect of the sand content on the development of pore structure, the permeability to water, and the diffusivity of chloride ions on Portland cement mortars. Mortars of two water-to-cement ratios and three sand volume fractions were cast together with pastes and tested at degrees of hydration ranging from 45 to 70%. An electrically-accelerated concentration cell test was used to determine the coefficient of chloride ion diffusion while a high pressure permeability cell was employed to assess liquid permeability. The coefficient of chloride ion diffusion varied linearly with the critical pore radius as determined by mercury intrusion porosimetry while permeability was found to follow a power-law relationship vs. this critical radius. The data set provided an opportunity to directly examine the application of the Katz-Thompson relationship to cement-based materials.

Omar Saeed Baghabra Al-Amoudi (1998) studied the performance of cement paste, mortar and reinforced concrete specimens made with plain and blended cements in magnesium sulfate, sodium sulfate and mixed-sulfate environments was evaluated for a period of up to 44 months. Based on the data developed in this investigation, he has concluded that Blended cement concrete mixtures exhibited an advanced stage of deterioration when compared to plain cement mixtures in magnesium-rich sulfate environments. Silica fume concrete mixtures performed better than fly ash and blast-furnace slag ones, the worst performance being that of BFS cement. The mode of deterioration in magnesium-based sulfate exposures was characterized by spalling and softening, akin to the eating away of the hydrated cement paste and the progressive reduction of it to a cohesionless granular mass, leaving the aggregate exposed. Despite the advanced deterioration observed in the silica fume reinforced concrete specimens, its dense microstructures preserved the passivity of the reinforcing steel, even after an exposure period of 44 months. Blended cements, particularly those made with silica fume and blast furnace slag, performed much better than plain cements in sodium sulfate environments in terms of both strength reduction and expansion. Comparison of the weight loss data of concrete cylinders with the reduction in strength of small mortar cubes prepared with the same water-to-binder ratio and exposed to the same mixed-sulfate environment indicated the possibility of predicting the performance of concrete structures made with blended cements only. The use of silica fume cement concrete, with the application of a good quality water-resistant epoxy-based coating on the exposed members, appears to be the rational approach to protecting reinforced concrete structures from both sulfate attack and reinforcement corrosion in sulfate environments with similar w/c.

Cheung et al (2011) had reviewed the impact on hydration of several classes of chemicals with an emphasis on the current understanding of interactions with cement chemistry. These include setting retarders, accelerators, and water reducing dispersants. The ability of the chemicals to alter the aluminate–sulfate balance of cementitious systems is discussed with a focus on the impact on silicate hydration.

As a key example of this complex interaction, unusual behavior sometimes observed in systems containing high calcium fly ash is highlighted.

Aiad Hussain, 2013, studied on Effect of $MgSO_4$ on self compacting concrete containing supplementary cementitious material. In this paper, the assessment of magnesium sulphate (MS) attack on concrete containing various ratios of the supplementary cementitious materials (SCM) was investigated for concrete containing FA, RHA, and GGBS with cement replacement levels of 15%, 10%, and 5%, respectively, based on the selected samples from the concrete to the statement of the effect of magnesium on some of the characteristics of concrete such as compressive strength, height, and weight compared with similar samples but under laboratory conditions dry and moist water treatment. Test results showed that the SCC content SCM appear to have higher strength values than those stored in water and air sample; the highest value of mass loss is recorded for the control mixture compared with concrete content SCM, and the change in length in curing concrete is much less relative to the change for concrete immersed in MS.

Mohamed R. Shatat(2014) studied the effects of addition rice husk ash on the mechanical properties of blended cement containing metakaolin have been investigated experimentally as well as sulphate and chloride resistance of these blends. The influence of aggressive media such as 5% $MgSO_4$ and 5% $MgCl_2$ on the mechanical properties of the prepared pozzolanic cement pastes was studied. The pastes were made from ordinary Portland cement containing 25 wt % metakaolin with partial replacement of metakaolin by different ratios (0, 5, 10, 15 and 20 wt %) of rice husk ash. All cement pastes immersed in tap water for 28 days (zero time) then immersed in aggressive media for 1, 3, 6, 9 and 12 months. The mechanical properties were measured by determination of the compressive strength. Total sulphate and chloride contents at each curing time in the aggressive mediums up to one year as well as their physico-chemical properties were monitored periodically and analyzed by XRD, DTA and visual inspection. The results showed that, the partial replacement of metakaolin by 10 wt % rice husk ash improves the resistance of hardened cement pastes against 5% $MgSO_4$ attack. Whereas 15 wt % rice husk ash improves the resistance against 5% $MgCl_2$ attack.

From the literature, it is can be observed that there is a scope for the investigation of sulphates attack on blended cement mortar. In this scenario, the present investigation has focused to study the effect of various sulphates, in mixing water and their influence on compressive strength \of Blended Cement.

SCOPE OF THE PRESENT INVESTIGATION

3.1 GENERAL

In process of construction process water plays an important role. Dry form of cement does not bind the course and fine aggregate together. Cement attains binding property only if it is mixed with water. Water makes the dry form of cement into paste form which binds the course and fine aggregates together. Slowly the paste hardens and attains strength, this process is hydration of cement. In hydration process cement compounds forms chemical bonds with water. If there are undesirable chemicals present in water, required strength is not attained by the cement. So the quality water to be considered to a greater extent.

3.2 OBJECTIVES OF THE TEST PROGRAMME

The specific objectives of the present investigation are:

1. To study the effect of water quality in short term and long term compressive strength of blended cement based Cement mortar.
2. To study the Compressive strength of cement mortar in the environment of different sulphates.
3. To study the efficacy of blended cement against sulphate attack.

To achieve the objectives of the present research, the test programmed is organised as follow:

Total 387 cement mortar cube specimens are prepared. Of which 9 cubes are casted with no concentration, 162 cubes were casted with individual sulphate, 162 cubes were casted with double combinations of sulphates and 54 cubes were casted with triple combinations of sulphates.

3.3 NOMENCLATURE

Table 3.1: Nomenclature

EXPERIMENTAL INVESTIGATION ON THE BEHAVIOR OF BLENDED CEMENT MOTAR UNDER THE EFFECTS OF SULPHATES

Sl.No.	Nomenclature	Description
1	NC	NC means No concentration
2	1-A	1 means Magnesium Sulphate, A means 500 mg/l concentration
3	1-B	1 means Magnesium Sulphate, B means 1000 mg/l concentration
4	1-C	1 means Magnesium Sulphate, C means 1500 mg/l concentration
5	1-D	1 means Magnesium Sulphate, D means 2000 mg/l concentration
6	1-E	1 means Magnesium Sulphate, E means 2500 mg/l concentration
7	1-F	1 means Magnesium Sulphate, F means 3000 mg/l concentration
8	2-A	2 means Ferrous Sulphate, A means 500 mg/l concentration
9	2-B	2 means Ferrous Sulphate, B means 1000 mg/l concentration
10	2-C	2 means Ferrous Sulphate, C means 1500 mg/l concentration
11	2-D	2 means Ferrous Sulphate, D means 2000 mg/l concentration
12	2-E	2 means Ferrous Sulphate, E means 2500 mg/l concentration
13	2-F	2means Ferrous Sulphate, F means 3000 mg/l concentration
14	3-A	3 means Ammonium Sulphate, A means 500 mg/l concentration
15	3-B	3 means Ammonium Sulphate, B means 1000 mg/l concentration
16	3-C	3 means Ammonium Sulphate, C means 1500 mg/l concentration
17	3-D	3 means Ammonium Sulphate, D means 2000 mg/l concentration
18	3-E	3 means Ammonium Sulphate, E means 2500 mg/l concentration
19	3-F	3 means Ammonium Sulphate, F means 3000 mg/l concentration
20	4-A	4 means Magnesium Sulphate+ Ferrous Sulphate, A means 500 mg/l concentration
21	4-B	4 means Magnesium Sulphate+ Ferrous Sulphate, B means 1000 mg/l concentration
22	4-C	4 means Magnesium Sulphate+ Ferrous Sulphate, C means 1500 mg/l concentration
23	4-D	4 means Magnesium Sulphate+ Ferrous Sulphate, D means 2000 mg/l concentration
24	4-E	4 means Magnesium Sulphate+ Ferrous Sulphate, E means 2500 mg/l concentration
25	4-F	4 means Magnesium Sulphate+ Ferrous Sulphate, F means 3000 mg/l concentration
26	5-A	5 means Magnesium Sulphate+ Ammonium Sulphate, A means 500 mg/l concentration
27	5-B	5 means Magnesium Sulphate+ Ammonium Sulphate, B means 1000 mg/l concentration
28	5-C	5 means Magnesium Sulphate+ Ammonium Sulphate, C means 1500 mg/l concentration
29	5-D	5 means Magnesium Sulphate+ Ammonium Sulphate, D means 2000 mg/l concentration
30	5-E	5 means Magnesium Sulphate+ Ammonium Sulphate, E means 2500 mg/l concentration
31	5-F	5 means Magnesium Sulphate+ Ammonium Sulphate, F means 3000 mg/l concentration
32	6-A	6 means Ferrous Sulphate+Ammonium Sulphate, A means 500 mg/l concentration
33	6-B	6 means Ferrous Sulphate+Ammonium Sulphate, B means 1000 mg/l concentration
34	6-C	6 means Ferrous Sulphate+Ammonium Sulphate, C means 1500 mg/l concentration
35	6-D	6 means Ferrous Sulphate+Ammonium Sulphate, D means 2000 mg/l concentration
36	6-E	6 means Ferrous Sulphate+Ammonium Sulphate, E means 2500 mg/l concentration
37	6-F	6 means Ferrous Sulphate+Ammonium Sulphate, F means 3000 mg/l concentration
38	7-A	7 means Magnesium Sulphate+Ferrous Sulphate+Ammonium Sulphate, A means 500 mg/l concentration
39	7-B	7 means Magnesium Sulphate+Ferrous Sulphate+Ammonium Sulphate, B means 1000 mg/l concentration
40	7-C	7 means Magnesium Sulphate+Ferrous Sulphate+Ammonium Sulphate, C means 1500 mg/l concentration
41	7-D	7 means Magnesium Sulphate+Ferrous Sulphate+Ammonium Sulphate, D means 2000 mg/l concentration
42	7-E	7 means Magnesium Sulphate+Ferrous Sulphate+Ammonium Sulphate, E means 2500 mg/l concentration
43	7-F	7 means Magnesium Sulphate+Ferrous Sulphate+Ammonium Sulphate, F means 3000 mg/l concentration

3.4 SCOPE OF PRESENT WORK:

As the present experimental work was conducted only on compression strengths, there is a need to study the microstructure of the particles of the cement with the help of the X-ray diffraction, which can be investigated later. Due to the limitation of the equipment, it was confined to finding of above said compressive strength only.

EXPERIMENTATION INVESTIGATION OF MATERIALS

4.1 GENERAL

This chapter deals with the materials used in the experimental procedure such as blended cement, fine aggregate, water and the chemicals and their properties are tabulated as follows. The standard experimental procedures laid down from IS codes were adopted for the determination of the material properties.

4.2 MATERIALS

The materials used in the present research are listed below:

1. Fly ash based blended cement
2. Fine aggregate
3. Deionised water
4. Sulphates ($MgSO_4$, $(NH_4)_2SO_4$ and $FeSO_4$)

4.2.1 Blended Cement:

Portland pozzolana cement (Fly Ash based) conforming to IS: 1489-1991(PART-1) was used. The various properties of this cement used are presented in table 4.1 below

Table 4.1: Physical Properties of Cement

S. No	Parameter	Result	Requirements of IS:1489-1991 (PART-1)
1	Fineness (m^2/kg)	316	300 Min
2	Standard Consistency (%)	32.5	-
3	Setting Time (minutes) a. Initial b. Final	 210 326	 30 Min 600 Max
4	Soundness a. Le-Chat Expansion (mm) b. Autoclave Expansion (%)	 1.3 0.022	 10 Max 0.8 Max
5	%of Fly Ash addition	25.00	15.0 Min 35.0 Max

4.2.2 Fine Aggregate:

Locally available river sand conforming to IS: 650-1991 requirements for Standard sand is used in experimentation. The standard sand shall be of quartz, light grey or whitish variety and shall be free from silt. The sand grains might be angular, the shape of the grains approximating to the spherical form elongated and flattened grains being present only in very small or negligible quantities. The standard sand shall pass through 2 mm IS sieve and shall be retained on 90-micron IS Sieve.

As per IS: 650-1991, standard sand with the following particle size distribution is used.

Particle size Percentage

Less than 2mm and greater than 1mm 33.33

Less than 1mm and greater than 500 microns 33.33

Below 500 microns but greater than 90 microns 33.33

But in the present investigation ennore sand available in markets with the above mentioned different grades.

4.2.3 Deionised Water

Deionised water was used both for mixing and curing of the cement mortar specimens. Deionization is a chemical process that uses specially manufactured ion exchange resins which exchange hydrogen ion and hydroxide ion for dissolved minerals, which then recombine to form water. Different concentrations are maintained using the deionised water. The characteristics of deionized water, to which various chemical substances are presented in the Table 4.2

Table 4.2: The Characteristics Of Deionized Water

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S. No	Parameter	Amount
1	Ph	7.0
2	TDS (mg/l)	6.4
3	Alkalinity(mg/l)	9.3
4	Acidity(mg/l)	2.2
5	Hardness (mg/l)	0.8
6	Sulphates (mg/l)	0.3
7	Chlorides (mg/l)	9

4.2.4 Sulphates:

Various Sulphates in the powdered form available in the market are used for the present research are given below

1. Magnesium sulphate MgSO4
2. Ammonium sulphate (NH4)2SO4
3. Ferrous sulphate $FeSO_4$

Figure 4.1: Figure showing various sulphates

4.3 CASTING:

In the present research compressive strength of the cement is considered. For cement mortar cubes, specimens are casted in moulds of size 70.6mm conforming to IS: 10080-1982. Cement and sand are taken as 1:3 in ratio by weight. Water is added to the mixture as (P/4 + 3.0) percent of combined mass of cement and sand, where P is the percentage of water required to produce a paste of standard consistency determined as described in IS: 4031 (Part4) – 1988.

For casting of one sample cube, the mould of size is being 7.06 cm. The area of the face of the cube will be equal to 50 cm^2 and the materials were taken as in the ratio of 1:3 and the cubes were casted using the required concentration of sulphate in the mixing water.

Figure 4.2: Cube Moulds

4.4 CURING:

The cement mortar cubes are removed from moulds after 24 hrs and they are allowed for curing in the corresponding concentration containing ponds. The specimens are cured for interval time of testing at 7 days, 28 days and 90 days.

4.5 Test programme:

A total of 387 cement mortar cubes of 50 cm2 cross-sectional area were tested at 7 days, 28days and 90 days for compressive strength. The detailed particulars of the different specimens used in the investigational work are listed in the following Table 4.3.

Table 4.3: Summary of different specimens

S. No	Nomenclature	Concentration, mg/l	No of Cube specimens
1	1-A	500	9
2	1-B	1000	9
3	1-C	1500	9
4	1-D	2000	9
5	1-E	2500	9
6	1-F	3000	9
7	2-A	500	9
8	2-B	1000	9
9	2-C	1500	9
10	2-D	2000	9
11	1-E	2500	9
12	1-F	3000	9
13	3-A	500	9
14	1-B	1000	9
15	1-C	1500	9
16	1-D	2000	9
17	1-E	2500	9
18	1-F	3000	9
19	4-A	500	9
20	1-B	1000	9
21	1-C	1500	9
22	1-D	2000	9
23	1-E	2500	9
24	1-F	3000	9
25	5-A	500	9
26	1-B	1000	9
27	1-C	1500	9
28	1-D	2000	9
29	1-E	2500	9
30	1-F	3000	9
31	6-A	500	9
32	1-B	1000	9
33	1-C	1500	9
34	1-D	2000	9
35	1-E	2500	9
36	1-F	3000	9
37	7-A	2000	9
38	1-B	2500	9
39	1-C	3000	9
40	1-D	2000	9
41	1-E	2500	9
42	1-F	3000	9
43	NC	0	9
Total			387

4.6 Testing:

Three cubes were tested for compressive strength for each concentration. The average of these three values is taken as compressive strength. Compression test on cubes is conducted with compression testing machine of 2000KN capacity. The cubes are tested on their sides without any packing between the cube and the steel plattens of the testing machine and the load on the cube is applied at a constant rate till to the failure of the specimen and the corresponding load is noted as ultimate load. Three cubes were tested for compressive strength each time in the compression testing machine at 7 days, 28days and 90days for each sample of the concentration.

Figure 4.3: Testing Machine

RESULTS AND COMPARISON

5.1 GENERAL

The compressive strength values of the present investigation are listed both in tabular and graphical forms in the following headings. After the required period of curing the samples are taken for testing of compressive strength. The controlled samples i.e. with no chemical concentration are tested for 7 days, 28 days and 90 days and their compressive strengths were 18.12 N/mm^2, 23.67 N/mm^2 and 38.43 N/mm^2 respectively.

5.2 Comparison of the Strength Values:

Effect of compressive strength with usage of different sulphates like $MgSO_4$, $FeSO_4$, $(NH_4)_2SO_4$ with different concentration in cement mortar cubes for a period of 7 days, 28days and 90 days are compared in the following listings.

5.2.1 Compressive Strength For Single Combination

Table 5.1: Single Combination of chemicals

Sl.No.	Nomenclature	7days	28days	90 days
1	1-A	17.01	21.11	33.12
2	1-B	16.79	20.68	32.83
3	1-C	16.57	20.25	32.55
4	1-D	16.34	19.82	32.26
5	1-E	16.12	19.40	31.98
6	1-F	15.90	18.97	31.69
7	2-A	16.98	22.01	34.20
8	2-B	16.52	21.42	33.28
9	2-C	16.08	20.84	32.38
10	2-D	15.64	20.27	31.50
11	2-E	15.22	19.73	30.65
12	2-F	14.81	19.19	29.83
13	3-A	17.50	21.80	32.85
14	3-B	16.94	21.10	31.79
15	3-C	16.39	20.42	30.77
16	3-D	15.86	19.76	29.78
17	3-E	15.35	19.12	28.82
18	3-F	14.86	18.51	27.89

5.2.2 Compressive Strength For Double Combination

Table 5.2: Double Combination of chemicals

Sl.No.	Nomenclature	7 days	28 days	90 days
1	4-A	15.12	20.87	32.11
2	4-B	14.90	20.44	31.82
3	4-C	14.68	20.01	31.54
4	4-D	14.45	19.58	31.25
5	4-E	14.23	19.16	30.97
6	4-F	14.01	18.73	30.68
7	5-A	14.98	20.91	32.01
8	5-B	14.58	20.35	31.15
9	5-C	14.18	19.80	30.30
10	5-D	13.80	19.26	29.49
11	5-E	13.43	18.74	28.69
12	5-F	13.06	18.24	27.92
13	6-A	14.08	20.20	30.99
14	6-B	13.63	19.55	29.99
15	6-C	13.19	18.92	29.03
16	6-D	12.76	18.31	28.09
17	6-E	12.35	17.72	27.19
18	6-F	11.95	17.15	26.31

5.2.3 Compression Strength For Triple Combination

Table 5.3: Triple Combination of chemicals

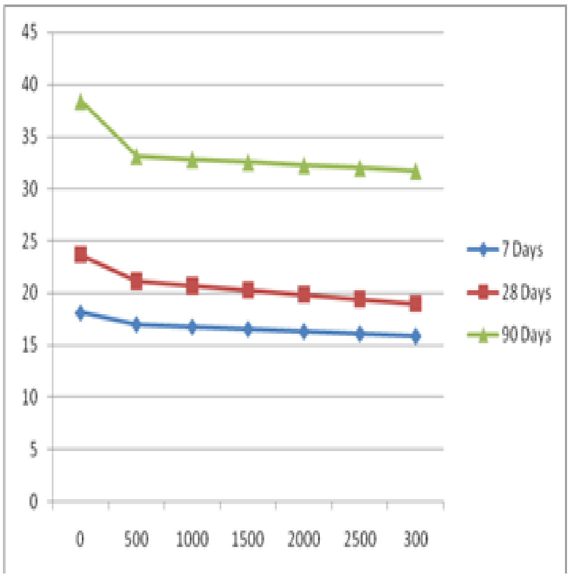
Sl.No.	Nomenclature	7 days	28days	90 days
1	7-A	15.11	20.43	31.83
2	7-B	13.75	19.67	30.78
3	7-C	12.51	18.95	29.76
4	7-D	11.39	18.25	28.78
5	7-E	10.36	17.57	27.83
6	7-F	9.43	16.92	26.91

5.3 GRAPHICAL REPRESENTATION

5.3.1 Compressive strength of Cement Mortar corresponding to MgSO4:

Table 5.4 Compressive strength values corresponding to MgSO4

Sl.No	Concentration (mg/l)	Compressive Strength of cement motor cubes N/mm^2		
		7 Days	28 Days	90 Days
1	0	18.12	23.67	38.43
2	500	17.01	21.11	33.12
3	1000	16.79	20.68	32.83
4	1500	16.57	20.25	32.55
5	2000	16.34	19.82	32.26
6	2500	16.12	19.40	31.98
7	3000	15.90	18.97	31.69



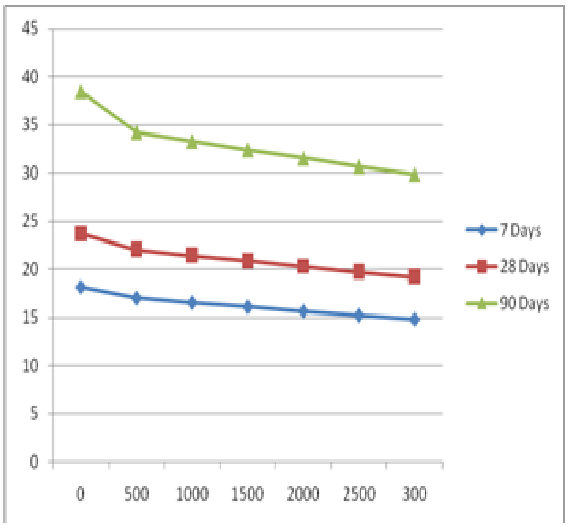
X axis – concentration in mg/l
Y axis – compressive strength in N/mm^2

Figure 5.1: Variation of compressive strength values corresponding to MgSO4

5.3.2 Compressive strength of Cement Mortar corresponding to FeSO4:

Table 5.5 Compressive strength values corresponding to FeSO4

Sl.No	Concentration (mg/l)	Compressive Strength of cement motor cubes N/mm^2		
		7 Days	28 Days	90 Days
1	0	18.12	23.67	38.43
2	500	16.98	22.01	34.20
3	1000	16.52	21.42	33.28
4	1500	16.08	20.84	32.38
5	2000	15.64	20.27	31.50
6	2500	15.22	19.73	30.65
7	3000	14.81	19.19	29.83



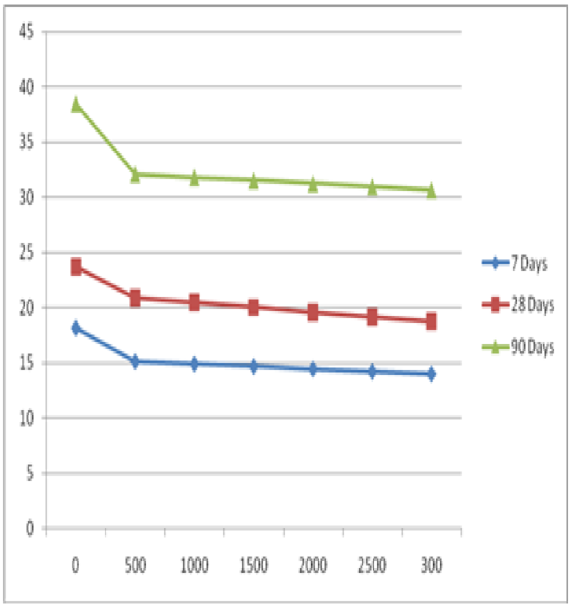
X axis – concentration in mg/l
Y axis – compressive strength in N/mm^2

Figure 5.2: Variation of compressive strength values corresponding to FeSO4

5.3.3 Compressive strength of Cement Mortar corresponding to (NH4)2SO4:

Table 5.6 Compressive strength values corresponding to (NH4)2SO4

Sl.No	Concentration (mg/l)	Compressive Strength of cement motor cubes N/mm^2		
		7 Days	28 Days	90 Days
1	0	18.12	23.67	38.43
2	500	15.12	20.87	32.11
3	1000	14.90	20.44	31.82
4	1500	14.68	20.01	31.54
5	2000	14.45	19.58	31.25
6	2500	14.23	19.16	30.97
7	3000	14.01	18.73	30.68



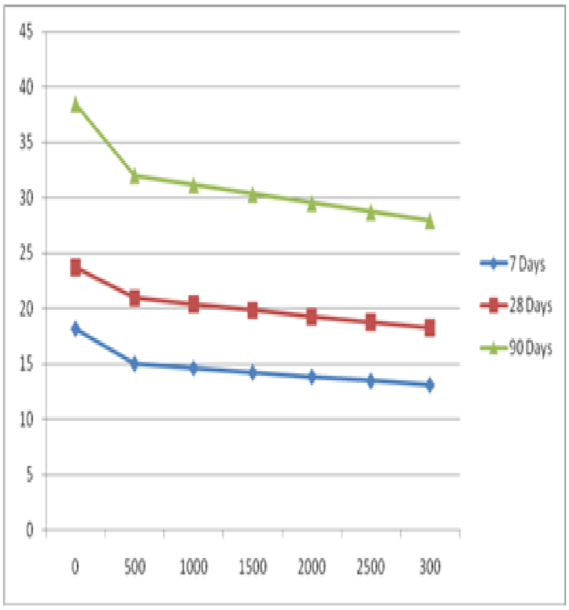
X axis – concentration in mg/l
Y axis – compressive strength in N/mm^2

Figure 5.4: Variation of compressive strength values corresponding to MgSO4+FeSO4

5.3.5 Compressive strength of Cement Mortar corresponding to MgSO4+(NH4)2SO4:

Table 5.8 Compressive strength values corresponding to MgSO4+(NH4)2SO4

Sl.No	Concentration (mg/l)	Compressive Strength of cement motor cubes N/mm^2		
		7 Days	28 Days	90 Days
1	0	18.12	23.67	38.43
2	500	14.98	20.91	32.01
3	1000	14.58	20.35	31.15
4	1500	14.18	19.80	30.30
5	2000	13.80	19.26	29.49
6	2500	13.43	18.74	28.69
7	3000	13.06	18.24	27.92



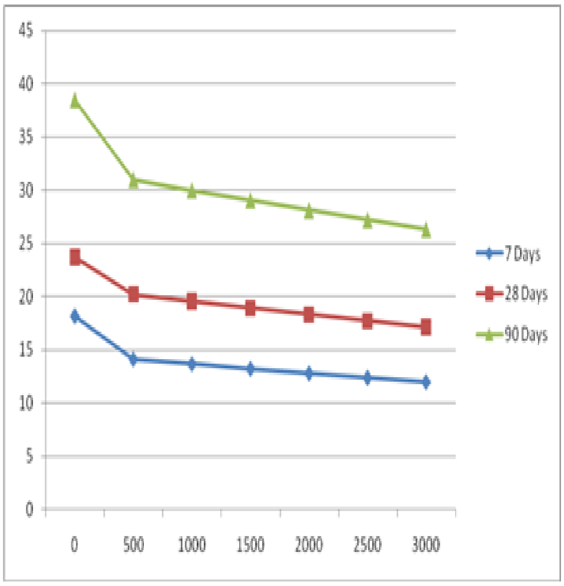
X axis – concentration in mg/l
Y axis – compressive strength in N/mm^2

Figure 5.5: Variation of compressive strength values corresponding to MgSO4+(NH4)2SO4

5.3.6 Compressive strength of Cement Mortar corresponding to FeSO4+(NH4)2SO4:

Table 5.9 Compressive strength values corresponding to FeSO4+(NH4)2SO4

Sl.No	Concentration (mg/l)	Compressive Strength of cement motor cubes N/mm^2		
		7 Days	28 Days	90 Days
1	0	18.12	23.67	38.43
2	500	14.08	20.20	30.99
3	1000	13.63	19.55	29.99
4	1500	13.19	18.92	29.03
5	2000	12.76	18.31	28.09
6	2500	12.35	17.72	27.19
7	3000	11.95	17.15	26.31



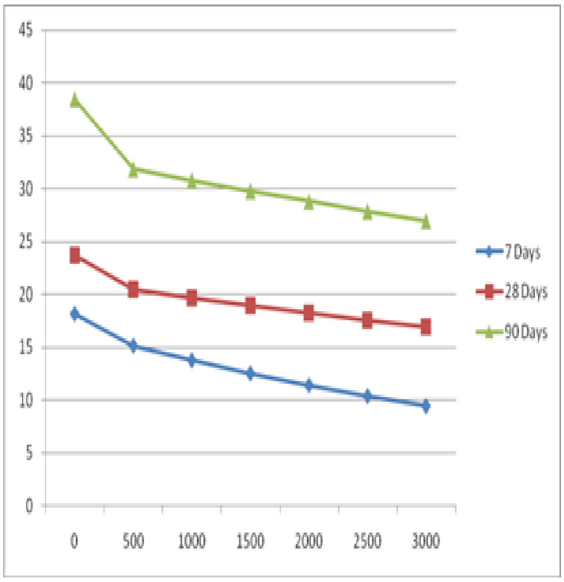
X axis – concentration in mg/l
Y axis – compressive strength in N/mm^2

Figure 5.6: Variation of compressive strength values corresponding to FeSO4+(NH4)2SO4

5.3.7 Compressive strength of Cement Mortar corresponding to MgSO4+FeSO4+(NH4)2SO4:

Table 5.10 Compressive strength values corresponding to MgSO4+FeSO4+(NH4)2SO4

Sl.No	Concentration (mg/l)	Compressive Strength of cement motor cubes N/mm^2		
		7 Days	28 Days	90 Days
1	0	18.12	23.67	38.43
2	500	15.11	20.43	31.83
3	1000	13.75	19.67	30.78
4	1500	12.51	18.95	29.76
5	2000	11.39	18.25	28.78
6	2500	10.36	17.57	27.83
7	3000	9.43	16.92	26.91



X axis – concentration in mg/l
Y axis – compressive strength in N/mm^2

Figure 5.7: Variation of compressive strength values corresponding to MgSO4+FeSO4+(NH4)2SO4

CONCLUSIONS AND FUTURE RECOMENDATIONS

6.1 CONCLUSIONS:

The conclusions which can be given based on the values obtained from the present experimental research are as follows.

1. In the individual combination of sulphates, the compressive strength is gradually decreasing as the concentration is increasing.
2. And it can be observed that as the curing age increases there is an increase in the compressive strength of the specimens.
3. In the double combination of sulphates also, the compressive strength is gradually decreasing as the concentration is increasing.
4. Similarly it can be observed that as the curing age increases there is an increase in the compressive strength of the specimens of the double combination of the sulphates.
5. Three combinations of sulphates also showed decrease in strength, which can be clearly observed that with increase in concentration of chemicals there is a decrease in the strength of specimens.
6. The same progress is observed in the triple combination when compared with the remaining two combinations, as the curing age increases there is an increase in the compressive strength of the samples of the triple combination of the sulphates.

6.2 FUTURE RECOMMENDATIONS:

The areas which can be taken under consideration for further investigation are as follows.

1. Further investigation can be done with the blended cements containing admixtures like Rice husk, Metakaolin, Ground Granulated Blast furnace Slag, Natural pozzolana and volcanic ash, Silica Fume etc. to find the effect of sulphate attack on the strength development and also the durability.

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