CHEMICAL EFFECT ON BLENDED CEMENT MORTAR

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Abstract - ***Concrete is majorly used material in today's world. Our country produced 280 million tonnes of cement last year. Cement is the main ingredient in concrete. This binds the course aggregate and fine aggregate together and forms a hardened mass. When water is added to cement, cement attains binding property. In this hydration process, water reacts with cement and attains required strength. If undesirable chemicals are present in water, it may weaken the concrete strength. Many investigations showed that blending of cement can be done to overcome such effects. As the blended cements offers a greater resistance to the chemical attacks. However blended cements does not offer complete resistance to the chemical attacks of all concentrations and combinations of chemicals. In this present investigation sulphate attack on blended cement mortar is with different combinations and concentrations are considered. Five sulphates are used in this investigation. They are Calcium Sulphate ($CaSO_4$), Magnesium Sulphate ($MgSO_4$), Sodium Sulphate (Na_2SO_4), Ammonium Sulphate ($(NH_4)_2SO_4$), Ferrous Sulphate $FeSO_4$. These chemicals are mixed with combinations of three, four and five combinations. The chemicals are mixed in water with 2000, 2500, 3000 mg/l concentrations. These combinations are mixed with deionised water separately. The same is used for both mixing and curing purpose. Cement mortar cubes of standard size are casted. For each combination nine cubes are casted. The specimens are tested for compressive test. Test is conducted on 7, 28, 90 days curing. Test results showed that blended cement offered resistance only to some combinations of triple combination. But it failed to offer resistance to four and five combinations of sulphates.***

Key Words: *Compressive Strength, Cement mortar cubes, Blended cement.*

1. INTRODUCTION

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 waters which are 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 codes does not give the relation for the water quality and compressive strength and other parameters.

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 taken from areas such as mining, industrial areas should be checked. This can be used if is recycled. 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.

1.1 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.

1.2 BLENDED CEMENTS

The concept of blending the cement is not a new one. In way long ago during the Roman times this concept was used. They mixed slaked lime with volcanic ash with slaked lime, which is a very fine grained particle. This showed a greater early strength and durability than normal slaked lime. It can be still visualised in Aqueducts and Coliseums. Volcanic ash was discovered in Italy at a place named pozzuola, hence it is named as pozzolana. It is believed that roman knew the cement manufacturing process. They used argillaceous lime and burnt for the manufacture of binding material. This is similar to the cement manufacturing process. From the decline of Roman empire that process was lost. Later this was again discovered in Britain.

Blended Cement is generally made by adding pozzolanic material to the Ordinary Portland Cement. The pozzolanic material is generally fly ash from Thermal power plant is used. This can be mix in cement at two phases. Generally it is mixed in silos during the packing of cement. For better mixing fly ash is mixed at clinker stage in the cement manufacturing process. There are limits specified for the blending of fly ash. There are many systems for blending of cement. Blending is done depending upon the requirement of concrete mix.

1.2.1 Fly ash Blended Cement

Fly ash is a bi product left after the combustion of coal. Generally it refers to the ash residue left over or waste product from Thermal power stations. In our country nearly 70 million tons fly ash is produced per annum. After the knowing its usage in cement, a small quantity of fly ash is used in the cement production. Past it was released out along with the flue gases. Later by the orders of Pollution control board, later it was separated by electro static precipitator or particle separating equipment before flue gases reach chimney.

Fly ash consists of inorganic, incombustible matter present in the coal that has been fused during combustion into a glassy, amorphous structure. Fly ash particles are generally spherical in shape and range in size from 2 µm to 10 µm. They consist mostly of Silicon dioxide (SiO_2), Aluminium Oxide (Al_2O_3) and Calcium Oxide (CaO), the main mineral compounds in coal-bearing rock strata. As per IS 3812: 1981, the percentage of silica and alumina should be minimum 70% and maximum loss on ignition 12 %. Greater superior quality of fly ash is available from thermal power stations than specified in IS code.

In manufacturing process of cement, calcium carbide is converted to carbon dioxide. As a result carbon dioxide is evolved. Approximately one hundred and forty kilograms of CO_2 is produced per one ton of cement. When cement is blended with fly ash, emission of CO_2 is considerably reduced due to decrease in the volume of cement. And the fly ash usage also reduces the cost of cement. Its demand is also increasing gradually and the pozzolans are no more considered as a waste material.

Fly ash based PPC is produced by mixing the pozzolans at the clinker stage or during the cement packing. When fly ash is inter grinded with cement a uniform mix and a greater degree of fineness is achieved.

This kind of cement has greater improved qualities than compared with Ordinary Portland Cement. This cement produces less heat of hydration, so it is used for mass constructions like dams, bridges, foundations, slabs etc,. The permeability of cement is reduced, so the corrosion of reinforced bars is prevented. The workability of cement is also increased. This cement is eco friendly in nature. Resistance for sulphates and chlorides are also observed when compared to Ordinary Portland Cement. This is highly recommended for adverse soil conditions in the site. Fly ash contains a high percentage of silica in the form of silicon dioxide, which appears as hollow glass spheres when viewed under a microscope. Silica in fly ash reacts with calcium hydroxide present in the cement paste of hardened concrete. Calcium hydroxide, a by-product of the Portland cement hydration process, is a very weak material that adds no structural strength to concrete. This leaches out of the structure and makes concrete porous. When the silica in fly ash reacts with calcium hydroxide, beneficial calcium silica hydrate (C-S-H) is formed. It is C-S-H that cements the sand and large aggregates into a solid mass known as concrete. It has been found that fly ash can be safely used to economically replace as much as 25% to 30% of the Portland cement in concrete.

2. MATERIALS AND EXPERIMENTATION

This chapter deals with the materials such as blended cement, fine aggregate, water and the chemicals used in the experimental procedure, their properties. The standard experimental procedures laid down from IS codes, which were adopted for the determination of compressive strength. List of materials used in the experimental investigation are represented below.

1. Fly ash based blended cement
2. Fine aggregate
3. Deionised water
4. Sulphates $MgSO_4$, $CaSO_4$, Na_2SO4, $(NH_4)_2 SO_4$) and $FeSO_4$

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 1 below

Table -1: Properties of Cement

S. No	Parameter	Result	Requirements IS:1489-1991 (PART-1)
1	Fineness (m^2/kg)	319	300 Min
2	Standard Consistency (%)	31.5	-
3	Setting Time (minutes) a. Initial b. Final	220 310	30 Min 600 Max
4	Soundness a. Le-Chat Expansion (mm) b. Autoclave Expansion (%)	1.4 0.029	10 Max 0.8 Max
5	%of Fly Ash addition	25.00	15.0 Min 35.0 Max

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

Fig -1: Different grades of fine aggregate

2.3 DEIONISED WATER:

Deionised water has been 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. Chemicals are added in mixing water as well as curing ponds. The characteristics of deionized water, to which various chemical substances are presented in the Table 2

Table -2: Characteristics of Deionized Water

S. No	Parameter	Amount
1	pH	7.0
2	TDS (mg/l)	6.5
3	Alkalinity(mg/l)	9
4	Acidity(mg/l)	2
5	Hardness (mg/l)	1
6	Sulphates (mg/l)	0.3
7	Chlorides (mg/l)	9

2.4 SULPHATES

Various Sulphates in the powdered form used for the present investigation are mentioned below

1. Calcium sulphate $CaSO_4$
2. Magnesium sulphate $MgSO_4$
3. Sodium sulphate Na_2SO_4
4. Ammonium sulphate $(NH_4)_2SO_4$
5. Ferrous sulphate $FeSO_4$

Fig -2: Figure showing various sulphates

2.5 CASTING

Portland Among all the properties, compressive strength is considered as important property of cement. Strength of cement is found by standard experimental procedure. 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 of (6 No's) of cubes, the mould of size is being 7.06 cm. The area of the face of the cube will be equal to 50 Sq cm and the materials were taken as 1125 gms of Cement, Standard sand with Grade-1, 1125 gms; grade-2, 1125 gms; Grade-3, 1125gms and with sulphate concentrations range from 2000 mg/l to 3000mg/l in a non-porous enamel tray and mix them with a trowel for one minute, then add deionised water of quantity 562.5 ml and concentrations of sulphates mixed thoroughly and immediately after mixing , the mortar is filled in to a cube mould and then compacted.

Fig -3: Standard Moulds

Fig -4: Cement mortar specimens

3.1 CURING

The cement mortar cubes is removed from moulds after 24 hrs and they are kept immersed in the deionised water to which chemicals are added. The specimens are cured for interval time of testing at 7 days, 28 days and 90 days.

Fig -5: Curing of mortar specimens

3.2 TESTING

A total of 441 cement mortar cubes of (70.6 x 70.6mm) 50 cm^2 cross-sectional area were tested at 7days, 28 days and 90 days for compressive strength. The summary of the different specimens used in the present experimental work are presented in the Table 3.

Table -3: Summary of different specimens

S. No	Nomenclature	Concentration mg/l	No of Cube specimens
1	3-1-A	2000	9
2	3-1-B	2500	9
3	3-1-C	3000	9
4	3-2-A	2000	9
5	3-2-B	2500	9
6	3-2-C	3000	9
7	3-3-A	2000	9
8	3-3-B	2500	9
9	3-3-C	3000	9
10	3-4-A	2000	9
11	3-4-B	2500	9
12	3-4-C	3000	9
13	3-5-A	2000	9
14	3-5-B	2500	9
15	3-5-C	3000	9
16	3-6-A	2000	9
17	3-6-B	2500	9
18	3-6-C	3000	9
19	3-7-A	2000	9
20	3-7-B	2500	9
21	3-7-C	3000	9
22	3-8-A	2000	9
23	3-8-B	2500	9
24	3-8-C	3000	9
25	3-9-A	2000	9
26	3-9-B	2500	9
27	3-9-C	3000	9
28	3-10-A	2000	9
29	3-10-B	2500	9
30	3-10-C	3000	9
31	4-1-A	2000	9
32	4-1-B	2500	9
33	4-1-C	3000	9
34	4-2-A	2000	9
35	4-2-B	2500	9
36	4-2-C	3000	9
37	4-3-A	2000	9
38	4-3-B	2500	9
39	4-3-C	3000	9
40	4-4-A	2000	9
41	4-4-B	2500	9
42	4-4-C	3000	9
43	4-5-A	2000	9
44	4-5-B	2500	9
45	4-5-C	3000	9
46	5-1-A	2000	9
47	5-1-B	2500	9
48	5-1-C	3000	9

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 patens 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, 28 days and 90 days for each sample of the concentration.

Fig -6: Compression Testing Machine

3.2 TESTING

The test results of the present investigation are represented both in tabular and graphical forms. After the required period of curing the samples are allowed to dry for a day, later they are taken for testing purpose. Compression test is conducted on all the samples. The samples are tested for 7 days, 28 days and 90 days. And their consecutive strengths should be 24 N/mm², 36 N/mm² and 47 N/mm² respectively. The chemical substances $MgSO_4$, $FeSO_4$, $(NH_4)_2SO_4$, $CaSO_4$, Na_2SO_4 are the sulphates used. Effect of compressive strength with usage of sulphates in cement mortar cubes for a period of 7 days, 28 days and 90 days is represented in the following tabular form.

Table -4: Compression Strength for Triple Combination

Sl. No	Chemical combinations		7 Day	28 Day	90 Day	Conclusion
1	C+M+Na (3-1)	2000	22.1	34.4	45.4	No variation of strength
		2500	20.2	24.2	34	considerable decrease
		3000	22.9	31.8	43.9	No variation of strength
2	C+M+NH (3-2)	2000	22.3	35.4	42.6	No variation of strength
		2500	28.6	37.1	46.2	increase in strength
		3000	26.5	34.4	43.6	No variation of strength
3	C+M+Fe (3-3)	2000	19	33.2	46.4	No variation of strength
		2500	17.7	30.5	41	decrease in strength
		3000	28	40	43	No variation of strength
4	C+Na+NH (3-4)	2000	19.2	27.6	40.2	decrease in strength
		2500	24	29.1	39.5	decrease in strength
		3000	23.2	29	46.6	No variation of strength
5	C+Na+Fe (3-5)	2000	27.2	29.3	31.3	decrease in strength
		2500	28.9	33.3	45.4	No variation of strength
		3000	25.4	26.5	25.3	decrease in strength
6	C+NH+Fe (3-6)	2000	26.6	31.2	36	decrease in strength
		2500	22.6	28.2	31.9	decrease in strength
		3000	18.3	30.2	36.4	decrease in strength
7	M+Na+NH (3-7)	2000	22	26	34	decrease in strength
		2500	21.5	24.5	37.2	decrease in strength
		3000	21	29	35.2	decrease in strength
8	M+Na+Fe (3-8)	2000	22	26.9	32.4	decrease in strength
		2500	20.4	54.3	29.3	decrease in strength
		3000	24.2	28.3	32.6	decrease in strength
9	M+NH+Fe (3-9)	2000	23	30.3	39	considerable decrease
		2500	18.3	29.5	36.3	decrease in strength
		3000	20.2	29.2	38.2	considerable decrease
10	Na+NH+Fe (3-10)	2000	21.4	26	35.2	decrease in strength
		2500	22.1	27.2	32.8	considerable decrease
		3000	23.4	30.6	39	considerable decrease

Table -5: Compression Strength for Four Combinations

Sl. No	Chemical combinations		7 Days	28 Days	90 Days	Conclusion
1	C+M+Na +NH (4-1)	2000	23.4	33.6	41.3	No variation of strength
		2500	24.5	32.5	41	No variation of strength
		3000	22.8	31.4	43.9	No variation of strength
2	C+M+Na +Fe (4-2)	2000	19.2	23.6	30.6	Decrease in strength
		2500	19.2	26	33.2	Decrease in strength
		3000	19.1	24.2	37	Decrease in strength
3	C+Na+NH+Fe (4-3)	2000	23.2	30.2	36.1	Decrease in strength
		2500	20.2	31.6	32.6	Decrease in strength
		3000	22.5	33.2	39.3	Decrease in strength
4	C+M+NH +Fe (4-4)	2000	19.2	25	36.2	Decrease in strength
		2500	20	24.2	29.3	Decrease in strength
		3000	19.2	22.5	30.3	Decrease in strength
5	M+Na+NH+Fe (4-5)	2000	21	26.3	31.6	Decrease in strength
		2500	21.5	29	31	considerable decrease
		3000	20.8	33.9	36.3	considerable decrease

Table -6: Compression Strength for Five Combinations

Chemical combinations		7 Days	28 Days	90 Days	Conclusion
C+M+Na. +NH+Fe (5-1)	2000	20.4	29	36.8	Considerable decrease
	2500	21.1	28.6	35.2	Considerable decrease
	3000	19.5	26.4	32.1	decrease in strength

3.3 NOMENCLATURE

3-1-A	Where 3 means triple combination, 1 refers to CaSO4 + MgSO4 + Na2SO4 and A refers 2000mg/l.
3-1-B	Where 3 means triple combination, 1 refers to CaSO4 + MgSO4 + Na2SO4 and B refers 2500mg/l.
3-1-C	Where 3 means triple combination, 1 refers to CaSO4 + MgSO4 + Na2SO4 and C refers 3000mg/l.
3-2-A	Where 3 means triple combination, 2 refers to CaSO4 + MgSO4 + (NH4)2SO4 and A refers 2000mg/l.
3-2-B	Where 3 means triple combination, 2 refers to CaSO4 + MgSO4 + (NH4)2SO4 and B refers 2500mg/l.
3-2-C	Where 3 means triple combination, 2 refers to CaSO4 + MgSO4 + (NH4)2SO4 and C refers 3000mg/l.
3-3-A	Where 3 means triple combination, 3 refers to CaSO4 + MgSO4 + FeSO4 and A refers 2000mg/l.
3-3-B	Where 3 means triple combination, 3 refers to CaSO4 + MgSO4 + FeSO4 and B refers 2500mg/l.
3-3-C	Where 3 means triple combination, 3 refers to CaSO4 + MgSO4 + FeSO4 and C refers 3000mg/l.
3-4-A	Where 3 means triple combination, 4 refers to CaSO4 + Na2SO4 + (NH4)2SO4 and A refers 2000mg/l.
3-4-B	Where 3 means triple combination, 4 refers to CaSO4 + Na2SO4 + (NH4)2SO4 and B refers 2500mg/l.
3-4-C	Where 3 means triple combination, 4 refers to CaSO4 + Na2SO4 + (NH4)2SO4 and C refers 3000mg/l.
3-5-A	Where 3 means triple combination, 5 refers to CaSO4 + Na2SO4 + FeSO4 and A refers 2000mg/l.
3-5-B	Where 3 means triple combination, 5 refers to CaSO4 + Na2SO4 + FeSO4 and B refers 2500mg/l.
3-5-C	Where 3 means triple combination, 5 refers to CaSO4 + Na2SO4 + FeSO4 and C refers 3000mg/l.
3-6-A	Where 3 means triple combination, 6 refers to CaSO4 + (NH4)2SO4 + FeSO4 and A refers 2000mg/l.
3-6-B	Where 3 means triple combination, 6 refers to CaSO4 + (NH4)2SO4 + FeSO4 and B refers 2500mg/l.
3-6-C	Where 3 means triple combination, 6 refers to CaSO4 + (NH4)2SO4 + FeSO4 and C refers 3000mg/l.

3-7-A	Where 3 means triple combination, 7 refers to MgSO4 + Na2SO4 + (NH4)2SO4 and A refers 2000mg/l.
3-7-B	Where 3 means triple combination, 7 refers to MgSO4 + Na2SO4 + (NH4)2SO4 and B refers 2500mg/l.
3-7-C	Where 3 means triple combination, 7 refers to MgSO4 + Na2SO4 + (NH4)2SO4 and C refers 3000mg/l.
3-8-A	Where 3 means triple combination, 8 refers to MgSO4 + Na2SO4 + FeSO4 and A refers 2000mg/l.
3-8-B	Where 3 means triple combination, 8 refers to MgSO4 + Na2SO4 + FeSO4 and B refers 2500mg/l.
3-8-C	Where 3 means triple combination, 8 refers to MgSO4 + Na2SO4 + FeSO4 and C refers 3000mg/l.
3-9-A	Where 3 means triple combination, 9 refers to MgSO4 + (NH4)2SO4 + FeSO4 and A refers 2000mg/l.
3-9-B	Where 3 means triple combination, 9 refers to MgSO4 + (NH4)2SO4 + FeSO4 and B refers 2500mg/l.
3-9-C	Where 3 means triple combination, 9 refers to MgSO4 + (NH4)2SO4 + FeSO4 and C refers 3000mg/l.
3-10-A	Where 3 means triple combination, 10 refers to NaSO4 + (NH4)2SO4 + FeSO4 and A refers 2000mg/l.
3-10-B	Where 3 means triple combination, 10 refers to NaSO4 + (NH4)2SO4 + FeSO4 and B refers 2500mg/l.
3-10-C	Where 3 means triple combination, 10 refers to NaSO4 + (NH4)2SO4 + FeSO4 and C refers 3000mg/l.
4-1-A	Where 4 means four combination, 1 refers to CaSO4 + MgSO4 + Na2SO4 + (NH4)2SO4 and A refers 2000mg/l.
4-1-B	Where 4 means four combination, 1 refers to CaSO4 + MgSO4 + Na2SO4 + (NH4)2SO4 and B refers 2500mg/l.
4-1-C	Where 4 means four combination, 1 refers to CaSO4 + MgSO4 + Na2SO4 + (NH4)2SO4 and C refers 3000mg/l.
4-2-A	Where 4 means four combination, 2 refers to CaSO4 + MgSO4 + Na2SO4 + FeSO4 and A refers 2000mg/l.
4-2-B	Where 4 means four combination, 2 refers to CaSO4 + MgSO4 + Na2SO4 + FeSO4 and B refers 2500mg/l.
4-2-C	Where 4 means four combination, 2 refers to CaSO4 + MgSO4 + Na2SO4 + FeSO4 and C refers 3000mg/l.
4-3-A	Where 4 means four combination, 3 refers to CaSO4 + Na2SO4 + (NH4)2SO4 + FeSO4 and A refers 2000mg/l.
4-3-B	Where 4 means four combination, 3 refers to CaSO4 + Na2SO4 + (NH4)2SO4 + FeSO4 and B refers 2500mg/l.
4-3-C	Where 4 means four combination, 3 refers to CaSO4 + Na2SO4 + (NH4)2SO4 + FeSO4 and C refers 3000mg/l.
4-4-A	Where 4 means four combination, 4 refers to CaSO4 + MgSO4 + (NH4)2SO4 + FeSO4 and A refers 2000mg/l.
4-4-B	Where 4 means four combination, 4 refers to CaSO4 + MgSO4 + (NH4)2SO4 + FeSO4 and B refers 2500mg/l.
4-4-C	Where 4 means four combination, 4 refers to CaSO4 + MgSO4 + (NH4)2SO4 + FeSO4 and C refers 3000mg/l.
4-5-A	Where 4 means four combination, 5 refers to MgSO4 + NaSO4 + (NH4)2SO4 + FeSO4 and A refers 2000mg/l.
4-5-B	Where 4 means four combination, 5 refers to MgSO4 + NaSO4 + (NH4)2SO4 + FeSO4 and B refers 2500mg/l.
4-5-C	Where 4 means four combination, 5 refers to MgSO4 + NaSO4 + (NH4)2SO4 + FeSO4 and C refers 3000mg/l.
5-1-A	Where 5 means four combination, 1 refers to CaSO4 + MgSO4 + NaSO4 + (NH4)2SO4 + FeSO4 and A refers 2000mg/l.
5-1-B	Where 5 means four combination, 1 refers to CaSO4 + MgSO4 + NaSO4 + (NH4)2SO4 + FeSO4 and B refers 2500mg/l.
5-1-C	Where 5 means four combination, 1 refers to CaSO4 + MgSO4 + NaSO4 + (NH4)2SO4 + FeSO4 and C refers 3000mg/l.

4. CONCLUSION

The following conclusions can be drawn based on the results obtained from the present experimental investigation.

1. In the triple combination of sulphates, the compressive strength is not much altered in 3-1, 3-2, 3-3, 3-4 chemical combination in 2000 & 3000 mg/l. However there is a decrease in the strength for concentration of 2500mg/l.
2. There is a decrease in compressive strength in 3-6, 3-7, 3-8 combinations at all concentrations. However the strength slightly increases from 2000 to 2500mg/l and strength decreases with further increase of concentration.
3. For 3-9, 3-10 combinations strength increases with increase in concentrations from 2000 to 3000mg/l. In all the triple combinations from 3-5 to 3-10 chemicals altered the strength to a greater extent.

4. In quadratic combination of sulphates, there is a decrease in the strength of specimens 4-2, 4-3, 4-4, 4-5 combinations. However it is observed that in quadratic combinations the strength is decreased only in combinations where ferrous salts are present.
5. Five combinations of chemicals also showed decrease in strength. It is clearly observed that with increase in concentration of chemicals there is a decrease in the strength of specimens.

The Portland pozzolana cement showed better resistance in some cases of triple combinations, but mostly it failed to show resistance in all the combination

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