International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 02 Issue: 05| Aug-2015 www.irjet.net p-ISSN: 2395-0072

EFFECT OF SULPHATES IN THE PRESENCE OF WATER ON THE STRENGTH CHARACTERISTICS OF BLENDED CEMENT

Shaik.Ismail[1], C. Sashidhar[2], D. Pavan Kumar[3]

[1] *Master of technology, Department of Civil Engineering, Jawaharlal Nehru Technical University, Anantapuramu, Andhra Pradesh, India.*
[2] *Professor, Department of Civil Engineering, Jawaharlal Nehru Technical University, Anantapuramu, Andhra Pradesh, India.*
[3] *Lecturer, Department of Civil Engineering, Jawaharlal Nehru Technical University, Anantapuramu, Andhra Pradesh, India.*

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 CO_2. The most effective way to decrease the CO_2 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 2000, 2500, 3000 mg/l. The sulphates used in the present investigation are sodium sulphate, calcium sulphate, magnesium sulphate, ammonium sulphate and ferrous sulphate. The effect is studied with individual and double 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.*

1. INTRODUCTION

Concrete has become an indispensable construction material and it is now used in greater quantities than any other material. Ordinary Portland cement has a high calcium base affecting the microclimate of concrete and mortar. The interface bond between the cement paste and aggregates can be improved with better pore structure and minimized micro cracks using mineral admixtures like fly ash, granulated blast furnace slag, rice husk, silica fume etc. Out of the above, the use of fly ash has gained prominence due to growing awareness about the benefits and easy availability of the good quality fly ash.

Ordinary Portland cement is made by grinding Clinker and Gypsum, One ton of clinker requires approximately 1.5 tons of limestone whose reserves are limited. The remedy for the above problem is blended cement. Blended Cement is the cement with a fixed percentage of pozzolans (A mineral admixture that acts as a supplement to "standard" Portland cement hydration products to create additional binder in a concrete mix.) and the Portland cement clinker of the cement mix. Blended cement is usually understood as cement that is blended by a cement manufacturer rather than a ready-mix supplier.

Since water helps to form the strength giving cement gel, the quality of water is to be critically monitored and controlled. In practice, very often, great control on properties of cement and aggregate is exercised, but the control on the quality of water is often neglected. Water used for mixing purpose, exceeding the tolerable limits of impurities, may affect not only the strength and durability but also setting time, soundness, efflorescence (deposits of white salts on the surface of structure) and corrosion of reinforcing or pre-stressing steel.

Most soils contain some sulphate in the form of calcium, sodium, potassium and magnesium. They occur in soil or ground water. Water behaves as the Main Culprit in the detrition of the structure. It acts as a carrier for deleterious material, leaves vulnerable voids, shrinkage problems, causes cracks, causes segregation, bleeding. Due to the above reason an approaching method was carried out in the present investigation to analysis the influence of various individuals and double combination of sulphate such as sodium sulphate, calcium sulphate, magnesium

sulphate, ammonium sulphate and ferrous sulphate on compressive strength development at 7days, 28days and 90 days of fly ash based cement motar.

2. LITERATURE REVIEW

American Concrete Institute (ACI) Manual of Concrete Practice part1 terminology says blened cement as "A hydraulic cement consisting essentially of an intimate and uniform blend of granulated blast-furnace slag and hydrated lime; or an intimate and uniform blend of portland cement and granulated blastfurnace slag, portland cement and pozzolan, or portland blast-furnace slag cement and pozzolan, 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."[1]

The advantages likely to be derived from the use of blended cements in structures are better resistance to thermal cracking because of lower heat of hydration, enhancement of ultimate strength, low permeability due to pore refinement, and a better durability to chemical attacks such as chloride, sulphate, protection against steel corrosion and alkali- aggregate expansion. In marine conditions, structures containing blended cements show enhanced durability. [2]

As per Indian Standard Portland Pozzolana cement specification Part 1 Fly Ash Based (IS 1489 (Part 1): 1991) terminology, "An intimately interground mixture of Portland clinker and pozzolana with the possible addition of gypsum (natural or chemical) or an intimate and uniform blending of Portland cement and fine pozzolana."[3]

K. J. Kucche.et.al [4] gave the following definitions.

1. Potable water: Water which is suitable for consumption of human being.
2. Recycled water: Water which is treated up to acceptable limit which is suitable for its intended use.
3. Blackish water: Waste water generated from toilet, urinals which are directly contaminated with human excreta.
4. Gray water: Waste water from wash basins, showers, laundries and kitchen

F. M. Lee [5] described that, water which is acidic owing to the presences of uncombined carbon dioxide, of organic or inorganic acids are more aggressive in their action, the degree and rate of attack increases as the acidity increase. Acid solutions which attack cement mortars by dissolving part of the hard cement paste do not cause any expansion but weaken the material by removal of the cementing constituent and eventually soft and mushy mass is remains

H.Y.Ghorab et.al [6] has investigated; the effect of natural available water on setting time of hydraulic cement. From studies, it is reported that, setting time of OPC mostly affected by the water type. The initial setting time reduced by 4% with use of Nile river water and approximately 25% with the ground and sea water when compare with tap water.

Solid salts do not attack constructions but, when present in solution, they can react with hydrated cement paste. The compounds responsible for sulfate attack are water-soluble sulfate-containing salts, such as alkali-earth (calcium, magnesium) and alkali (sodium, potassium) sulfates that are capable of chemically reacting with components of hardened cement paste. Below table 1 shows the classification of Severity of Sulphate Environment as per ACI 318-08 (A.M. Neville) [7]

Table -1: Classification of Severity of Sulphate Environment

Exposure	Concentration of water-soluble sulphates expressed as SO_4	
	In soil per cent	In water ppm
Mild	<0.1	<150
Moderate	0.1 to 0.2	150 to 1500
Severe	0.2 to 2.0	1500 to 10,000
Very severe	>2.0	>10,000

(Wojciech Piasta.et.al) [8] Calcium sulphate attacks only calcium aluminate hydrate, forming calcium sulfo aluminate ($3CaO.Al_2O_3.3CaSO_4.32H_2O$), and known as ettringite. Sodium, ammonium sulphates first react with $Ca(OH)_2$ to form gypsum which in turn reacts with hydrated calcium aluminates to form calcium sulpho aluminate. The typical reaction is shown below.

$$Ca(OH)_2 + Na_2SO_4.10H_2O \rightarrow CaSO_4.2H_2O + 2NaOH + 8H_2O.$$

$$2(3CaO.Al_2O_3.12H_2O) + 3(Na_2SO_4.10H_2O) \rightarrow 3CaO.Al_2O_3.3CaSO_4.32H_2O + 2Al(OH)_3 + 6NaOH + 17H_2O.$$

Magnesium sulfate has a more far reaching action than other sulphates because it reacts not only with Calcium hydroxide and hydrated calcium aluminate like other sulphates but also decomposes the hydrated calcium silicates. [9] The pattern of reaction is as follows:

$$3CaO.2SiO_2.aq + 3MgSO_4.7H_2O \rightarrow 3CaSO_4.2H_2O + 3Mg(OH)_2 + 2SiO_2.aq.$$

Thaumasite and delayed ettringite formation (DEF) are the two different forms of sulphate attack. Thaumasite is a calcium-silicate-sulfate-carbonate hydrate ($CaSiO3{\cdot}CaCO3{\cdot}CaSO4{\cdot}15H2O$).This type of attack occurs

in concrete buried in the ground. Thaumasite problems have been encountered in a number of bridge supports in the UK. Delayed ettringite formation (DEF) occurs at late ages and the formation of ettringite in mature concrete tends to be disruptive and harmful, and is a form of sulfate attack, resulting in the compound $3CaO.Al_2O_3.3CaSO_4.32H_2O$. (M. Collepardi). [10]

Madhusudana Reddy.B et.al [11] have investigated the effect of lead (Pb+) present in mixing water on compressive strength, setting times and soundness of cement mortar. Cement mortar specimens were cast using deionised water and known concentration of lead i.e. 10, 50, 100, 500, 1000, 2000, 3000, 4000 and 5000mg/l whereas cement mortar specimens casted using deionised water used for reference purpose. On comparison with reference specimens, at higher concentrations of lead in water, test samples had shown considerable loss of strength, and also their setting times had significantly increased. However, at 2000 mg/L concentration of lead, the compressive strength and setting time marginally increased.

3. SCOPE AND OBJECTIVES

The specific objectives of the present investigation are:

1. To study the effect of individual substances like Ca_2SO_4, Na_2SO_4, $MgSO_4$, $(NH_4)_2SO_4$, $FeSO_4$ with different concentrations in mixing water on short term and long term compressive strength development of Fly ash based blended cement mortar.
2. To study the effect of double combination of the above mentioned chemical substances with different concentrations in mixing water on short term and long term compressive strength development of Fly ash based blended cement mortar.
3. To study the efficacy of blended cement against sulphate attack.

The scope of the present investigation is to investigate the effect of the sulphate present in water with three different concentrations on the strength properties of blended cement. Based on the availability of equipment in the laboratory experimental work was conducted on the cement mortar cubes so that it leads to evaluate compression strengths. There is a need to study the microstructure of the particles of the cement by conducting the X-ray diffraction. Due to the limitation of the equipment, it was confined to finding of above said compressive strength only.

4. PROPERTIES OF MATERIALS USED

4.1 Cement

Portland pozzolana cement (Fly Ash based) conforming to IS: 1489-1991(PART-1) was used. The various properties of the Portland pozzolana cement used are presented in table 2.

Table -2: Properties of cement

S.No	Parameter	Result	Requirements of IS:1489-1991(PART-1)
1	Fineness (m2/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

4.2 Fine Aggregate

Locally available river sand passing through 2 mm IS sieve conforming to IS: 650-1991 standard requirements for Standard sand is used in testing of cement. . The standard sand shall (100 percent) pass through 2 mm IS sieve and shall be (100 percent) retained on 90-micron IS Sieve. As per IS: 650-1991, standard sand with the following particle size distribution is used.

Particle size	Percentage
Smaller than 2 mm and greater than 1 mm	33.33
Smaller than 1 mm and greater than 500 µ	33.33
Below 500 µ but greater than 90 µ	33.33

4.3 Deionized Water

Deionized water is also called as demineralized water. Demineralization is the removal of mineral ions such as cations (Na+, Ca2+, etc.,) and anions (Cl-, SO4 2-, etc.,). As provided by the supplier, the characteristics of deionized water, to which various chemical substances are presented in the table 3.

Table -3: The 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

4.4 Sulphates

Various Sulphates in the powdered form used for the present investigation are calcium sulphate, magnesium sulphate, sodium sulphate, ammonium sulphate and ferrous sulphate as shown in figure 1.

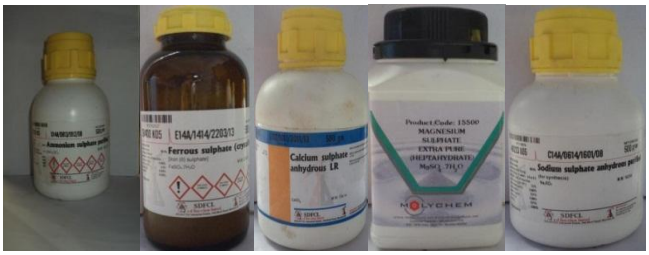

Fig -1: Figure showing various sulphates

4.5 Casting

The cubes were cast in the moulds of 70.6 mm size conforming to IS: 10080-1982. All the materials are weighed for each sample in the mix ratio of 1:3 and mixed with the quantity of water obtained by (P/4 + 3.0) percent of combined mass of cement and sand, whether P is the percentage of water required to produce a paste of standard consistency determined as described in IS: 4031 (Part 4) – 1988.

4.6 Curing

The filled moulds are kept in moist closet or moist room for 24 hours after the completion of vibration. At the end of that period, they are removed from the moulds and immediately submerged in deionized water as shown in figure 2.

Fig -2: Curing of Specimens

4.7 Test Programme

A total of 414 cement mortar cubes of 70.6 mm were tested at 7 days, 28 days and 90 days for compressive strength. Out of which nine cubes are casted with nil concentration i.e. using deionised water for mixing, 135 cubes are casted using individual sulphate like Ca_2SO_4, Na_2SO_4, $MgSO_4$, $(NH_4)_2SO_4$, $FeSO_4$ with three different concentration as 2000mg/l, 2500 mg/l and 3000 mg/l and remaining 270 cubes are casted using double sulphate combination of the above mentioned five sulphates with three different concentration as 2000 mg/l, 2500 mg/l and 3000 mg/l.

5. DISCUSSION OF TEST RESULTS

The compressive strength for all the samples is presented in the following tables. The compressive strength of cement mortar without adding any sulphates for 7 days, 28 days and 90 days are obtained as 24.65 N/mm^2, 36.54 N/mm^2, 47.73 N/mm^2 respectively.

5.1 Influence of Individual Sulphate on Compressive Strength

The compressive strength of cement mortar cubes cured in the individual sulphate environment for a period of 7days, 28days and 90 days are presented in the following table 4.

Table -4: Compressive Strength of Specimens

S.No.	Type of Sulphate	Concentration, mg/l	Compressive Strength, N/mm2		
			7 days	28 days	90 days
1	$CaSO_4$	2000	22.77	34.62	45.12
		2500	21.78	31.65	43.65
		3000	19.80	30.66	39.77
2	$MgSO_4$	2000	21.70	34.69	45.21
		2500	20.79	33.63	42.11
		3000	18.81	31.34	39.71
3	Na_2SO_4	2000	21.69	32.32	44.33
		2500	19.75	31.14	40.39
		3000	18.63	29.38	38.42
4	$(NH_4)_2 SO_4$	2000	22.55	33.30	45.32
		2500	20.59	32.38	42.36
		3000	19.61	29.31	40.20
5	$FeSO_4$	2000	21.57	33.66	44.12
		2500	20.63	31.68	43.14
		3000	18.63	27.72	38.24

5.2 Influence of Double Combination Sulphate on Compressive Strength

The compressive strength of cement mortar cubes cured in the double combination sulphate environment for a period of 7days, 28days and 90 days are presented in the following table 5.

Table -5: Compressive Strength of Double Combination Specimens

S.No.	Type of Sulphate Combination	Concentration, mg/l	Compressive Strength, N/mm2		
			7 days	28 days	90 days
1	$CaSO_4 + MgSO_4$	2000	22.77	32.67	43.56
		2500	21.78	31.68	42.57
		3000	19.80	28.71	40.59
2	$CaSO_4 + Na_2SO_4$	2000	22.73	34.65	44.55
		2500	20.79	30.69	42.50
		3000	19.84	27.72	39.60
3	$CaSO_4 + (NH_4)_2 SO_4$	2000	22.66	32.51	43.39
		2500	21.67	31.53	42.36
		3000	18.15	27.59	38.42
4	$CaSO_4 + FeSO_4$	2000	22.61	34.48	44.33
		2500	20.69	31.49	43.35
		3000	19.70	30.54	38.95
5	$MgSO_4 + Na_2SO_4$	2000	22.63	33.50	42.36
		2500	21.67	30.68	39.41

		3000	19.72	29.56	38.42
6	$MgSO_4$ + $(NH_4)_2$ SO_4	2000	22.55	33.33	43.14
		2500	21.57	32.35	40.20
		3000	19.61	29.41	39.22
7	$MgSO_4$ + $FeSO_4$	2000	21.53	34.27	44.12
		2500	20.59	31.41	41.18
		3000	18.63	30.39	40.32
8	Na_2SO_4 + $(NH_4)_2$ SO_4	2000	21.59	34.31	45.10
		2500	19.88	33.33	42.16
		3000	18.98	31.37	40.20
9	Na_2SO_4 + $FeSO_4$	2000	22.59	32.41	43.22
		2500	21.61	31.43	42.24
		3000	19.64	29.41	39.29
10	$(NH_4)_2$ SO_4 + $FeSO_4$	2000	22.51	34.38	44.20
		2500	20.63	31.43	40.27
		3000	19.78	29.47	38.31

6. CONCLUSIONS

In this present investigation, as the concentration of sulphate increases, there is an increase in compressive strength of cement mortar upto the concentration of 2500 mg/l and then decreases. And also the following conclusions can be concluded from the present experimental study.

1. The compressive strength of 2000 mg/l, 2500 mg/l and 3000 mg/l were less when compared with the compressive strength of 0 mg/l for all the case.

2. The compressive strength of the cement mortar cube specimens of all individual and double combination sulphate environments showed a reduction in compressive strength with respect to the increase in the concentration of the sulphates.
3. The compressive strength of the cement mortar cube specimens cured in all individual and double combination sulphate environments gained strength as the curing age increased.

This study could enlighten the people to use the blended cements in all types of the construction works.

REFERENCES

[1] American Concrete Institute Manual of concrete Practice, Cement and Concrete Terminology-ACI 116R-78.
[2] http://www.rdso.indianrailways.gov.in/uploads/files/1296810752312-ch07.pdf
[3] IS 1489 (Part 1): 1991 Specification for Portland pozzolana cement, Part 1: Fly ash based.
[4] K. J. Kucche, Dr. S. S. Jamkar, Dr. P. A. Sadgir, *Quality of Water for Making Concrete: A Review of Literature* International Journal of Scientific and Research Publications, Volume 5, Issue 1, January 2015.
[5] F.M.Lee, *The chemistry of cement and concrete*, Longman scientific & Technical publication, 3rd edition1971, pp223-256.
[6] H.Y.Ghorab, M.S. Hilal and A. Anter, *Effect of mixing and curing water on the behavior of cement pastes and concrete part: 2*, Cement and concrete research. Vol. 20 pp. 69-72 1990, pregamon press plc.
[7] A.M. Neville, *Properties of Concrete* fourth edition, Pearson Education, 2012, pp. 508.
[8] Wojciech Piasta, *Some Aspects and Mechanisms of Sulphate Attack,* Structure and Environment, No. 3/2014 vol. 6 PL ISSN 2081-1500.
[9] M.S. Shetty, *Concrete Technology: Theory and Practice*, S. Chand & Company Ltd., New Delhi, 2013, pp. 420.

[10] Mario Collepardi, Title: *Ettringite Formation and Sulfate Attack on Concrete*, Publication: Special Publication, Volume: 200, pp. 21-38, 2001.
[11] Madhusudana Reddy.B, Reddy Babu.G and Ramana Reddy.I.V, *Effect of heavy metal present in mixing water on properties and sulphate attack on blended cement mortar,* International Journal of Civil and Structural Engineering, Volume 1, No 4, 2011.

BIOGRAPHIES

Shaik. Ismail has completed his B.Tech in Civil Engineering from Rajeev Gandhi Memorial College Of Engineering and Technology, Nandyal, Andhra Pradesh. He is currently pursuing his M.Tech in Structural Engineering from JNTUA college of Engineering, Anantapuramu, Andhra Pradesh, India.

Dr. C.Sashidhar is Professor in the Department of Civil Engineering, JNTUA, Anantapuramu. He received M.Tech and Ph.D from J.N.T. University, Hyderabad. His research interests include FRC, SIFCON, HPC and Non Destructive Test Evaluation. He has more than 15 years of teaching experience and guiding research scholars. And right now is working as controller of examinations in JNTUA University, Ananthapuramu, Andhra Pradesh, India.

D.Pavan Kumar has received his B.Tech in Civil Engineering and M. Tech in Structural engineering from JNTUA, Ananthapuramu in the year 2012. He has more than 3 years of teaching experience. Presently he is working as lecturer in Civil Engineering Department at JNTUA College of Engineering, Ananatapuramu, Andhra Pradesh, India.