International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 03 | Mar-2016 www.irjet.net p-ISSN: 2395-0072

EFFECT ON STRENGTH PARAMETERS OF DOUBLE MIXED SULPHATE ON FLY ASH BLENDED CEMENT MORTAR

G.Narasimhulu[1*], C.Sashidhar[2], G.Reddy Babu[3] and B.Madhusudhana Reddy[4]

[1]Civil Engg.Deptt. JNTUA, Anantapuramu, Andhra Pradesh, India(Presently working at Kasturba Institute of Technology, Civil(PHEE)Dept. Govt. of Delhi,Pitampura,Delhi-88)
[2]Professor, Civil Engg. Dept. JNTUA, Anantapuramu, Andhra Pradesh, India.
[3]HOD(Civil Engg. Deptt.) Narasaraopeta Engg. college, Narasaraopeta, Andhra Pradesh, India.
[4] Senior Environmental Engineer, Delhi Pollution Control Committee, Govt. of Delhi, Delhi, India.

Abstract: *This paper presents the effect on strength parameters of Mixed Double Sulphate Combination ($CaSO_4$+$MgSO_4$) on Fly ash based Blended Cement Mortar (FBCM). The FBCM cubes of size 70.6x70.6x70.6mm were prepared with different dosages of equal proportion having a gross dosage of 1000, 1500, 2000, 2500, 3000, 3500 and 4000mg/l mixed double sulphate is added in deionised water. Control specimen was prepared with deionised water without adding any sulphate chemical for comparison purpose. The setting times on Fly ash Blended Cement and compressive strength on Fly ash Blended Cement Mortar (FBCM) were evaluated for 7days, 28days, 90days and 180days apart from studying rapid chloride ion permeability on 28days aged specimens. The results showed that, as mixed double Sulphate concentration increases, there is increase in initial and final setting of Fly ash blended cement. The percentage increase of Initial setting time(IST) of blended cement with Mixed sulphate chemical is 11.76% to 58.82% and that of Final setting time(FST) is 5.77% to 23.08%. Compressive strength of FBCM cubes, when tested on compressive strength testing machine has shown that strength loss or gain is marginal when compared with control specimens. It was also observed that chloride ion permeability trend on 28 days aged specimens followed more or less same with control sample.*

Key Words: *Mixed Double Sulphate Combination ($CaSO_4$+$MgSO_4$), FBCM, IST & FST, Compressive Strength, Rapid Chloride Ion Permeability.*

1. INTRODUCTION

Cement Mortar or Concrete deterioration due to sulphate attack is the second major durability problem, after reinforcement corrosion. This type of deterioration is noted in the structures exposed to sulphate bearing soils, ground water and waste waters. Though, concrete deterioration due to sulphate attack is reported from many countries, the mechanisms of sulphate attack have not been thoroughly investigated. If sulphate ions present in mixing water, soils, and ground water in more than permissible limit cause deterioration of concrete. In hardened cement C_3A reacts with sulphate ions in the presence of calcium hydroxide to form ettringite and gypsum, leading to degradation of concrete into a non cohesive granular mass and disruptive expansion given by Rasheeduzzafar et al,1994, Al-Amoudi OSB et al,1995 [1,2]. Sulphate attack on concrete is a complex process as reported by MD Cohen et al,1991[3]. Many factors, such as cement type, sulphate cat ion type, sulphate concentration and exposure period, may affect the sulphate resistance and water is an essential ingredient in mortar. However, different permissible limits of sulphate in mixing water for ordinary Portland cement were given by various codes. For example, IS:456-2000 has given 400 mg/l[8], AS 1379 has given 1000mg/l[9], BS EN 1008-2002 has given 2000mg/l[10]and ASTM C94–1992 has given 3000mg/l[7]. Generally, the sulphate encountered in mixing water, soils, and ground water may consists of different individual sulphates and mixed sulphate combinations. In nature, sulphates may present in surface water, soils, and ground water more than or equal to two compounds. Despite the above codes had given broad limits on sulphates in mixing water for ordinary Portland cement, but they did not give permissible limit of a particular sulphate and sulphates in a particular combination in mixing water for blended cement. For this reason, a guideline based on careful scrutiny on tolerable limit of a mixed double sulphate in a particular combination in mixing water for blended cement is needed.

2. Research significance

This research examines the maximum permissible limit of a mixed double sulphate in a particular combination in mixing water with fly ash blended cement. External sulphate attack is caused by sulphates from ground water, soils, solid industrial waste and fertilizers, atmospheric SO_2

or liquid industrial wastes. Torres et al,2003[4], Senhadji et al,2005[5] reported that ready availability of these sulphates causes damage to mortar, depending on its concentration. Many studies had shown that the ingress of sulphates into a concrete structures by ground water containing soluble sulphates or soils laden with sulphates led to several expansive reactions and the alteration of the microstructure[6](Crammond and Halliwell, 1995). Ettringite is a common mineral formed during this process and may lead to the volume expansion and microcracking of mortar. Besides Ettringite, Gypsum is also formed in the system, which depends on type of cement. As per literature and practical observations, sulphate degrades quality of strength of ordinary Portland cement mortar, but strength degradation severity is less in blended cement mortar compared to that of ordinary Portland cement mortar. Formation of gypsum softens the cement paste and therefore leads to the deterioration of the cement microstructure. Even though, considerable work was done on the external attack of sulphates on blended cement mortar, but a little or negligible work is carried out on maximum permissible limit of a double mixed sulphate in a particular combination in mixing water for blended cement mortar. Blended cement mortar when a mixed sulphate or no sulphate present in mixing water for blended cement mortar. Hence, this investigation will be carried out to precise permissible limit of mixed double sulphate combination in the above conditions.

3. MATERIALS AND METHODOLOGY

3.1 Fly ash Blended Cement

Portland Fly ash based blended Pozzolana Cement containing fly ash was used in this investigation. The compositions of major compounds present in the cements are presented in Table 1.

3.2 Fine Aggregate

The fine aggregate (sand) used throughout the experimental work was obtained from the river Pandameru near Anantapuramu(Andhra Pradesh). According to IS:650-1996, the sand used in cement mortar should confirm to the following specifications.

Sand shall be of quartz, light gray or whitish variety and free from silt. The grains shall be angular. The shape of grains shall approximate to spherical form, enlarged and flattened grains shall be present only in negligible quantities.

3.3 Grading of Aggregate

- Passing through 2mm I.S.Sieve 100%
- Retained on 90μ I.S. Sieve 100%
- Particle size greater than 1mm 33.33%
- Particle size smaller than 1mm and greater than 500μ 33.33%
- Particle size smaller than 500μ 33.33%

Sand shall be free from organic impurities and loss of weight on interaction with hot hydrochloric acid (specific gravity 1.15) shall not exceed 0.25%. The specific particle size composition of the sand was prepared as per the I.S.Code:650-1966 and I.S. Code: 383-1970. Sand was thoroughly washed with tap water to remove impurities like decayed vegetable matter, humus, organic matter and deleterious materials like clay, fine silt and fine dust and was oven dried for 42 hours then cooled to room temperature. This sand was used for the experimental work.

3.4 Water

Deionised water spiked with Mixed Double sulphate of calcium sulphate and magnesium sulphate of equal proportion combined to get a different gross concentrations i.e. 1000,1500, 2000,2500,3000,3500 and 4000 mg/l.

4. Experimental programme

The influence of mixed double sulphate mentioned above at different concentrations was studied when the mixed sulphate is spiked with deionised water as test samples and are compared with the control samples. This comparison may not be possible in case of control samples made with locally available potable water since it varies in chemical composition from place to place. This is the reason for mixing of mixed double Sulphate in the deionised water as per the dosage mentioned above. This water is used for preparation of samples for setting times (Initial & final) of Fly ash Blended Cement. For determining the initial and final setting times of blended cement, Vicat's apparatus was used and to assess the compressive strength, 96 Blended cement mortar cubes of size 70.6x70.6x70.6mm were cast and tested on compressive strength testing Machine. To determine the chloride ion permeability, RCPT apparatus was used, for which 24 specimens were cast and tested.

Table1: Chemical composition of Fly ash blended cement

Sl.No	Composition	Result (%)
1.	Lime (CaO)	17.25
2.	Silica (SiO_2)	36.83
3.	Alumina (Al_2O_3)	30.14
4.	Iron oxide (Fe_2O_3)	4.15
5.	Magnesium oxide (MgO)	3.64
6.	Soda (Na_2O)	0.95
7.	Potash (K_2O)	1.09
8.	Sulphur trioxide (SO_3)	2.40
9.	Loss on Ignition (% by mass)	3.55

5. RESULTS AND DISCUSSION

5.1 EFFECT OF DOUBLE MIXED SULPPHATE ($CaSO_4$+$MgSO_4$):

The chemical sulphate substance, viz.,($CaSO_4$+$MgSO_4$) is categorized as Mixed Double Sulphate combination. The effect of presence of this mixed sulphate chemical on various durability parameters such as setting times, compressive strength and chloride ion permeability were discussed. The effect of presence of mixed double sulphate in mixing water on setting times of Fly ash blended cement, compressive strengths of fly ash Blended Cement Mortar(FBCM) (for 7days, 28days, 90days &180days)and chloride ion permeability (28days) were presented in the following sub sections.

5.1.1 Effect of Double Sulphate Combination ($CaSO_4$+$MgSO_4$) on Setting times of Fly ash Blended Cement.

The effect of mixed double sulphate on initial and final setting times of Fly ash Blended Cement (FBC) is presented in Table 2, Fig.1 and Fig 2. From the table and figure, it is observed that both the initial and final setting times have increased with the increase in concentration of mixed double sulphate in deionised water. The percentage increase in Initial setting time is 11.76% to 58.82% and that of final setting time is 5.77% to 23.08% for different concentrations of mixed double sulphate in the range of 1 to 4g/l with an increment of 0.5g/l. When the concentration of the mixed double sulphate is 2.5g/l (maximum), the difference in the initial and final setting times is 37 minutes and 38 minutes (which is more than 30 minutes & considered to be significant as per IS 456 code). It was also observed that, when the concentration of the mixed double sulphate is 2.5 g/l (maximum), the percentage increase in the initial setting time and final setting is 43.53% and 14.62% respectively when compared with that of the control mix. Laure et al,2011[14] also reported the increase in setting times due to mortars based on calcium sulphate.

Table 2. Setting times of Fly ash Blended Cement corresponding to Mixed Double Sulphate ($CaSO_4$+$MgSO_4$) concentration.

Sl. No	Water sample	Setting time in minutes, Percentage change in setting times & Difference of setting time in minutes					
		Initial	% change	Difference	Final	% change	Difference
1	Deionised water(cont-rol)(g/l)	85	0	0	260	0	0
2	1.0	95	11.76	10	275	5.77	15
3	1.5	108	27.06	23	282	8.46	22
4	2.0	110	29.41	25	288	10.77	28
5	**2.5 ***	**122**	**43.53**	**37**	**298**	**14.62**	**38**
6	3.0	130	52.94	45	314	20.77	54
7	3.5	133	56.47	48	318	22.31	58
8	4.0	135	58.82	50	320	23.08	60

*- Significant

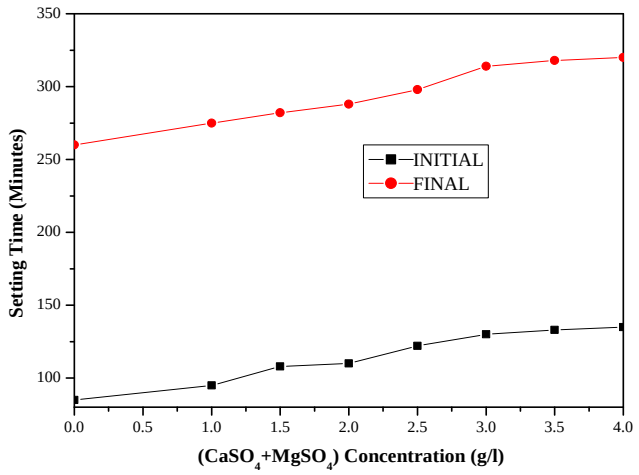
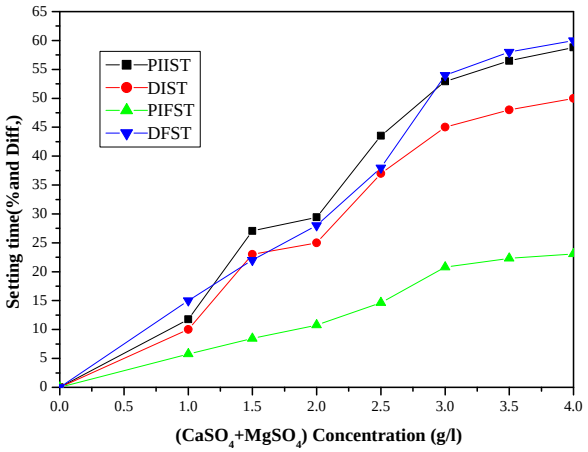


Fig.1 Setting times (Initial and Final) of Fly ash Blended Cement vs Mixed Double Sulphate ($CaSO_4$+$MgSO_4$), concentration.



PIIST: Percentage Increase in Initial Setting Time
DIST: Difference in Increase in Initial Setting Time
PIFST: Percentage Increase in Final Setting Time
DFST: Difference in Increase in Final Setting Time

Fig.2 Percentage variation and difference in Setting times of Fly ash Blended cement vs Mixed Double Sulphate ($CaSO_4$+$MgSO_4$) concentration.

5.1.2 Effect of Mixed Double Sulphate Combination($CaSO_4$+$MgSO_4$)on Compressive Strength of Fly ash Blended Cement Mortar(FBCM):

The effect of mixed double Sulphate($CaSO_4$+$MgSO_4$) concentrations on the compressive strength of fly ash blended cement mortar(FBCM) are presented in Table 3 & Fig.4 and degree of variation is presented in Fig.5. The results indicate that the strength loss or gain is marginal when compared with control sample. Compressive strength for FBCM with mixed double sulphate concentration from 1 to 4 g/l, has increased from 25.71 to 26.11MPa for 7days, 40.50 to 41.63MPa for 28 days, 46.86 to 47.63MPa for 90days and 50.45 to 51.70MPa for 180days aged specimens respectively. When mixed double sulphate concentration is maximum, i.e., 2.5 g/l the percentage increase in compressive strength is 1.99% for 7days, 2.18%for 28days, 1.62% for 90days and 2.66% for 180days when compared with that of cubes prepared with the deionised water(control test sample). Ettringite and Gypsum formation causes volume increase or expansion, causing damage and cracking of mortar leading to strength loss as given by Roziere E et al,(2009)[12].The said enhancement in compressive strength may be due to residue of anhydrous fly ash in the mix and its reaction with mixed sulphate which is affecting the hydration process in turn giving increased compressive strengths.

Table.3 Compressive strength of FBCM corresponding to Mixed Double Sulphate Combination($CaSO_4$+$MgSO_4$), Concentrations.

Sl. no	Water Sample	Flyash Blended Cement Mortar (FBCM)							
		Compressive Strength(MPa)				% variation			
		7 days	28 days	90 days	180 days	7 days	28 days	90 days	180 days
i	Deionised water (Control)	25.60	40.42	46.84	50.31	0	0	0	0
ii	1.0 g/l	25.71	40.50	46.88	50.45	0.43	0.20	0.09	0.28
iii	1.5 g/l	25.80	40.55	46.86	51.22	0.78	0.32	0.04	1.81

iv	2.0 g/l	25.83	41.25	47.51	51.43	0.90	2.05	1.43	2.23
v	**2.5 g/l***	**26.11**	**41.30**	**47.60**	**51.65**	**1.99**	**2.18**	**1.62**	**2.66**
vi	3.0 g/l	26.07	41.54	47.63	51.70	1.84	2.77	1.69	2.76
vii	3.5 g/l	26.05	41.63	47.55	51.70	1.76	2.99	1.52	2.76
viii	4.0 g/l	25.88	41.62	47.45	51.69	1.09	2.97	1.30	2.74

*- Significant

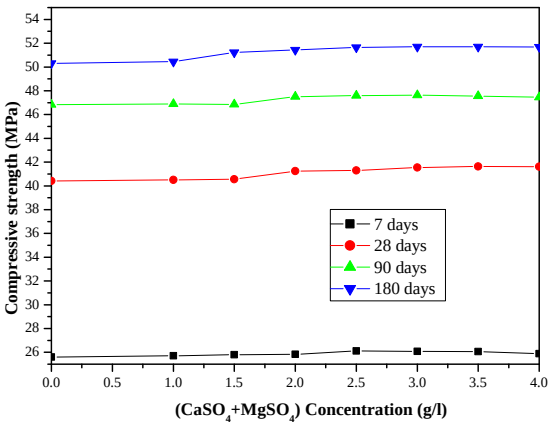


Fig.4Compressive strength of Fly ash Blended Cement Mortar (FBCM) vs Mixed Double Sulphate ($CaSO_4$+$MgSO_4$), concentration

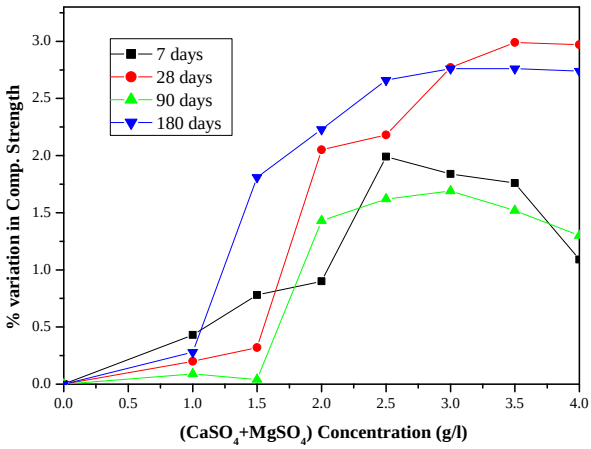


Fig.5 Percentage variation in compressive strength of Fly ash Blended Cement Mortar (FBCM) vs Mixed Double Sulphate ($CaSO_4$+$MgSO_4$) concentration.

5.1.3 Effect of Mixed Double sulphate ($CaSO_4$+$MgSO_4$) concentration on Chloride ion Permeability :

The rapid chloride permeability levels in terms of coulombs passed through Fly ash Blended cement Mortar(FBCM) observed after 28 days age testing are tabulated and listed in the Table 4. Quantum of coulombs passed and percentage of variation in the charge passed are depicted in Fig. 6 and Fig.7 below. Perusal of the said results and graphs establishes that the chloride ion permeability trend of the mixed double sulphate on blended cement studied had shown more or less same variation in reference to control sample. The pozzolanic reactions formed with different sulphate solutions consume CH and generate additional C-S-H, which promotes densification and lowers the permeability of paste as suggested by K.K.Veiga et al, 2012[11]. P.Chindeprasist et al,2008[13], for blended pozzolans says that the couloumb charges are very low with regard to permeability, the incorporation of pozzolan such as fly ash reduces the average pore size and results in a less permeable paste.

Table4. Chloride ion Permeability of Mixed double sulphate concentration of 2.5g/l at 28 days.

Sl. No	Water Sample	Flyash Blended Cement Mortar (FBCM)	
		Coulombs passed for 28 days	% variation
		($CaSO_4$+$MgSO_4$)	($CaSO_4$+$MgSO_4$)
i	Deionised water(Cont-rol)(g/l)	2295	0
ii	1.0	2292	-0.13
iii	1.5	2290	-0.22
iv	2.0	2291	-0.17
v	2.5	2290	-0.22
vi	3.0	2292	-0.13
vii	3.5	2289	-0.26
viii	4.0	2292	-0.13

* significant

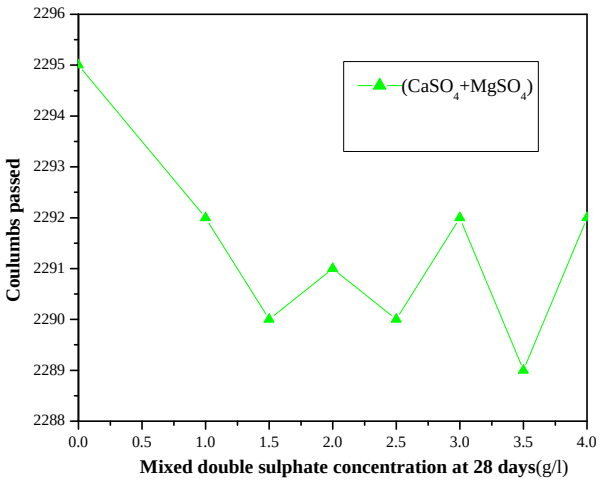


Fig. 6. Couloumbs passed vs Mixed double sulphate concentration of 2.5g/l at 28 days.

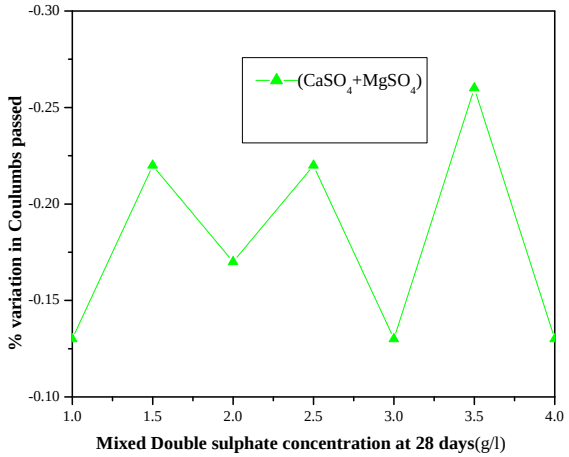


Fig.7 Percentage variation in Couloumbs passed vs Mixed double sulphate concentration of 2.5g/l at 28 days.

6.0 CONCLUSIONS

Based on the results obtained in the present investigation the following conclusions can be drawn.

- The permissible limit of double mixed sulphate ($CaSO_4$+$MgSO_4$) concentration in water increases the initial and final setting times of blended cement.
- When the concentration of the mixed double sulphate is 2.5g/l (maximum), the difference in the initial and final setting times is 37 minutes and 38 minutes considered to be significant as per IS:456 code.
- The percentage increase of Initial setting time of FBC with double mixed sulphate chemical is 11.76% to 58.82% and that of Final setting time is 5.77% to 23.08%.
- Compressive strength of FBCM cubes, had shown that strength loss/gain is marginal compared to control sample.
- The maximum permissible limit of mixed double sulphate concentration was considered as 2500 mg/l.
- The percentage compressive strength variation of FBCM for mixed double sulphate is in the range of 0.43to1.95%, for 7days and 0.2to2.99% for 28days, 0.04to1.69% for 90days and 0.28 to 2.76% for 180 days on comparison with the control specimen.
- Chloride ion permeability trend followed more or less same variation with reference sample.

7.0 References

[1] Rasheeduzzafar, Al-Amoudi OSB, S N Abduljawad, M, Maslehuddin, Magnesium –sodium sulphate attack in plain and blended cements, J Mater Civil Eng 6 (2), 1994, 201-22.

[2] Al-Amoudi OSB, M, Maslehuddin, M M Saadi, Effect of magnesium sulphate sodium on the durability performance of plain and blended cements ACI Mater J 92 (1), 1995, 15-24.

[3] MD Cohen, B Mather, sulphate attack on concrete research needs, ACI Mater J 88 (1), 1991, 62-69.

[4] S.M.Torres,J.H.Sharp, R.N.Swamy, C.J. Lynsdale and S.A. Huntley, Long term durability of Portland limestone cement mortar exposed to magnesium sulphate attack," Cement Concrete Composites, 25, 2003, 8047-8054.

[5] Y.Senhadji, M.Mouli, H.Khelafi, and A.S Benosman, Comportment Des Mortiers Des Ciments De I Outest Algerien En Environments Acids" 3rd colloque Internationale deRheologie CIR 05 Bejata. Algeria. November 2005, 12-14.

[6] N.J.Crammond and M.A.Halliwell, "The Thaumasite form of sulphate attack in concretes containing a source of carbonate ions," Second InternationalSymposiumAdvancesin Concrete.Tech ACI (CANMET) Las Vegas Nevada. SP-154, 1995, 357-380.

[7] ASTM C94 – 1992. Standard specification for ready-mixed concrete, American society for testing and materials, Philadelphia.

[8] IS 456- 2000. Plain and reinforced concrete-code of practice, New Delhi: Bureau of Indian Standards.

[9] AS 1379, Specification and supply of concrete Standards Australia, 2007NZS 3121, Specification for Water and Aggregate for Concrete,New Zealand Standards 2002 SANS 51008, Mixing water for concrete, South African National Standards 2006

[10] BS- EN 1008, Mixing water for concrete. Specification for sampling, testing and Assessing The suitability of water, including water recovered from processes in the Concrete industry, as mixing water for concrete, 2002.

[11] K.K.Veiga,A.L.G. Gastaldini, Sulfate attack on a white Portland cement with activated slag, Construction and Building Materials 34 (2012) 494–503.

[12] E. Rozière, A. Loukili, R. El Hachem, F. Grondin, Durability of concrete exposed to leaching and external sulphate attacks, Cement and Concrete Research 39 (2009) 1188–1198

[13] P.Chindaprasirt, S.Rukzon,V.Sirivivatnanon, Resistance to chloride penetration of blended Portland cement mortar containing palm oil fuel ash, rice husk ash and fly ash, Construction and Building Materials 22 (2008) 932–938.

[14] Laure Pelletier-Chaignat, Frank Winnefeld, Barbara Lothenbach, Gwenn Le Saout Christian Jörg Müller, Charlotte Famy, Influence of the calcium sulphate source on the hydration mechanism of Portland cement–calcium sulphoaluminate clinker–calcium sulphate binders, Cement & Concrete Composites 33 (2011) 551–561

BIOGRAPHIES:

G.Narasimhulu, presently working as Lecturer(selection grade), Civil(PHEE) dept.,Kasturba Institute of technology, Pitampura, Delhi-88. Pursuing Ph.D from Department of Civil Engineering, JNTUA, Anantapuramu. He received M.E from, UVCE, Jnanabharathi campus, Banglore and B.Tech in civil Engineering from V.R.Siddhartha Engineering college, Nagarjuna University, Vijayawada. He has more than 15 years of teaching experience.

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. Presently working as controller of examinations in JNTUA University, Ananthapuramu, Andhra Pradesh, India.