ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Experimental Investigation on Strength and Durability Properties of Ternary Blended Geopolymer Bricks

M.Seshalalitha
PG Student,
Department of Civil Engineering,
Siddartha Educational Academy Group of Institutions, Tirupati, A.P, India.

Dr K.Rajasekhar
Head and Professor,
Department of Civil Engineering,
Siddartha Educational Academy Group of Institutions, Tirupati, A.P, India.

ABSTRACT:

The major problem that the world facing today is Environmental pollution. In the construction industry mainly the production of Ordinary Portland Cement will cause the emission of pollutants which results in environmental pollution. The emission of carbon dioxide during the production of ordinary Portland cement is tremendous because the production of one ton of Portland cement emits approximately one ton of Carbon dioxide into the atmosphere. Hence to reduce this problemin India it is becoming inevitable to use of alternative materials for cement in concrete which include Fly ash, Red mud, Ground Granulated Blast furnace Slag, crushed rock powder etc. The use of such materials not only results in conservation of natural resources but also helps in maintaining good environmental conditions. The geopolymer technology shows considerable promise for application in concrete industry as a alternative binder to the Portland cement. Research is shifting from the chemistry domain to engineering applications and commercial production of geopolymer materials. In this experimental investigation, An effort is made for an alternate approach in manufacturing of bricks which was accomplished by using the materials like Fly ash, Ground Granulated Blast furnace Slag and Clay as key ingredients. We have also replaced the regular sand with the Quarry dust as fine aggregate. This project report includes studies on Compressive strength and Durability characteristics of ternary blended geopolymer bricks using alkaline solutionfor different molarities of 4M, 6M and 8M.

Key words:

Fly ash,Ground Granulated Blast furnace Slag, alkaline solution, Compressive strength.

1.0 INTRODUCTION:

The development of civilization and social progress has been greatly influenced by the application of concrete in establishing infrastructural facilities.

The global usage of concrete is second only to water. Annual worldwide production of concrete is estimated to be around one cubic meter for every person on earth. Given the fact that, at present, there is no practically feasible alternative to conventional concrete composites, the demand for traditional concrete is bound to increase in spite of some of its shortcomings. The increased demand for concrete calls for increased production of cement, undisputedly the most widely used single binder ingredient of traditional concrete. The annual rate of increase of cement production is about 3%. The three major concerns associated with the cement production are environ-eco issues, Sustainability issues and intense energy needs. The production of cement releases approximately an equal amount of CO2 into atmosphere due to the calcinations of limestone and combustion of fossil fuel.

It is estimated that with the demographic growth and industrialization, the pollution generated by cement production could reach an alarming 17% of global CO2 emissions which is currently about 7%. Also Industrialization and urbanization are the two worldwide phenomena. Though these are the necessity of the society and are mostly inevitable, one has to look into their negative impacts on the global environment and social life. The major ill effect of these global processes is the production of large quantities of industrial wastes and the problems related with their safe management and disposal. Second problem is the scarcity of land, materials and resources for ongoing developmental activities, including infrastructure.

Hence Cement Replacement Materials (CRMs) or Supplementary Cementing Materials (SCMs) were introduced into the construction sector which helps to reduce the global environmental problems. Supplementary Cementing Materials (SCMs) such as Flyash, Ground Granulate Blast Furnace Slag, Clay, Silica Fume and Metakaoline etc., either in singly or in combination, is used for the development of alternate binder systems which is thus of economic and ecological significance.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

As we know, no construction is possible without bricks. Bricks play a major role in construction field. Hence this technique is applied to the bricks to get geopolymer bricks.Although geopolymer technology is considered new, the technology has ancient roots and has been postulated as the building material used in the construction of the pyramids at Giza as well as in other ancient constructions. More¬over, alkali-activated slag cement is a type of geopolymer that has been in use since the mid-20th century. In 1978, Davidovits proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminium (Al) in a source material of geological origin or in by product materials such as Fly ash and Rice Husk Ash to produce binders[1].

Because the chemical reaction that takes place in this case is a polymerisation process, Davidovits coined the term 'Geopolymer' to represent these binders.Palomo et al (1999) concluded that the type of alkaline liquid plays an important role in the polymerisation process. Reactions occur at a high rate when the alkaline liquid contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxide[2].Xu and van Deventer (2000) confirmed that the addition of sodium silicate solution to the sodium hydroxide solution as the alkaline liquid enhanced the reaction between the source material and the solution[3].

2.0 OBJECTIVES:

The aim of the research is to evaluate the effect of fluid to binder ratio on compressive strength and durability of ternary blended (Fly Ash, Clay and GGBS) geopolymer compressed bricks under different molarities.

3.0 CHARACTERIZATION OF MATERIALS

3.1 GROUND GRANULATED BLAST FURNACE SLAG:

Ground granulated blast furnace slag is the granular material formed when molten iron blast furnace slag is rapidly chilled by immersion in water. It is a granular product with very limited crystal formation, is highly cementitious in nature and, ground to cement fines, and hydrates like Portland cement. It has been supplied by M/S ThosilaPvt Limited in Vizag and the physical & chemical properties are listed below in the Table 1.

Table 1: Physical & Chemical Composition of GGBS:

Chemical & Physical properties	GGBS
Fineness(m^2/kg)	275
Soundness(mm)	10
Initial setting time(min)	230
Insoluble residue	1.5%
Magnesia	14%
Sulphur	2.50%
Loss of ignition	3%
Manganese	2%
Chloride	0.1%
Moisture	1%
Glass	67%
Compressive strength at 7 days (MPa)	12
Compressive strength at 28 days (MPa)	32.5

3.2 FLYASH:

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. In an industrial context, fly ash usually refers to ash produced during combustion of coal. In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release.

In the US , Fly Ash is generally stored at coal power plants or placed in landfills. About 43% is recycled, often used to supplement Portland cement in concrete production. Fly ash used in this experiment is brought from Sri DamodaramSanjeevaiah Thermal Power Station (SDSTPS) and the chemical compositions of the Fly Ash are listed in Table 2.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

TABLE 2: CHEMICAL COMPOSION OF FLYASH

S. No.	CONSTITUENTS	% BY WEIGHT
1.	Silica	64.22
2.	Aluminium	20.37
3.	Iron oxide	4.44
4.	Manganese	0.12
5.	Titanium oxide	0.49
6.	Potassium oxide	2.35
7.	Calcium oxide	4.32
8.	Magnesium oxide	0.40
9.	Phosphorus	0.37
10.	Sulphur trioxide	1.25
11.	Sodium oxide	0.80
12.	Loss on ignition	0.89

3.3 CLAY:

Clayobtained from local brick manufacturing unit Gudur is used for the manufacturing of bricks. The physical and chemical properties of clay material are listed in Table 3 and 4 respectively.

TABLE 3 :PHYSICAL PROPERTIES OFCLAY

PHYSICAL PROPERTIES	CLAY
Specificgravity	2.62
Maximum dry densitykN/m^3	14.65
Optimum moisture content	24.5
Water absorption (%)	2.33
Plastic Limit (%)	30
Liquid Limit(%)	61
Plastic Index (%)	31

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

TABLE 4: CHEMICAL COMPOSITION OF CLAY

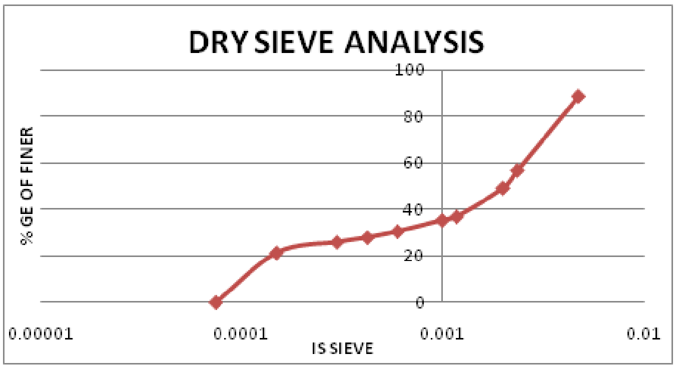
CHEMICAL COMPOSITION	CLAY(%)
SiO2	20.10
Al2O3	7.55
Fe_2O_3	32.89
CaO	26.15
MgO	0.47
SO_3	4.92
Na_2O	NA
K_2O	3.17
LOI	3.44

3.4QUARRY DUST

Quarry dust is the sand manufactured in the stone quarries. It is a substitute for the river sand used in the construction. Quarry dust obtained from local granite crushers was used as partial replacement of fine aggregate in the present investigation to cast the geopolymer bricks. It was brought from Local stone crushing industry- KANDRA, GUDUR. Sieve analysis is conducted on the quarry dust and is represented in Table 5. The dry sieve analysis is shown in Graph 1.

TABLE 5: DRY SIEVE ANALYSIS FOR QUARRY DUST

IS SIEVE SIZE(mm)	PERCENTAGE OF FINER
4.75	88.756
2.36	56.828
2	49.2
1.18	36.95
1	35.342
0.6	30.521
0.425	27.912
0.3	25.904
0.15	21.29
0.075	7.84



GRAPH 1: DRY SIEVE ANALYSIS OF QUARRY DUST:

3.5 ALKALINE SOLUTION:

The Alkaline solution used for experimental investigation is a combination of Sodium silicate solution and Sodium Hydroxide solution. It is seen that the Geopolymers with Sodium Hydroxide solution exhibit better Zeolitic properties than Potassium Hydroxide activated geopolymers. Also it has been confirmed that addition of Sodium Silicate Solution to Sodium Hydroxide enhanced the reaction rate between Source material and the alkaline solution. The Sodium Hydroxide is in flakes and pellet form with about 98% puritywith a molecular weight of 40 was used. These pellets were mixed with potable water to obtain the sodium hydroxide solution of required molarity. In the present study, the molarities of the solution were kept as 4M, 6M and 8M. Sodium Hydroxide flakes (caustic soda) are obtained from Bros Chemical industry, Tirupati. Sodium silicate solution is obtained from laboratory reagents and fine chemical, from Meena Enterprises, Mudinepally(md), Vijayawada.The chemical composition of sodium hydroxide flakes is listed in Table 6.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The chemical composition of aqueous solution of sodium silicate with SiO2 / Na2O ratio of 3.36 and pH 10.4 has listed in Table 7.

TABLE 6: CHEMICAL COMPOSITION OF SODIUM HYDROXIDE FLAKES

Minimum Assay(Acidimetric) Maximum Limits Of Impurities	96%
Carbonate	2%
Chloride	0.1%
Phosphate	0.001%
Silicate	0.02%
Sulphate	0.01%
Arsenic	0.0001%
Iron	0.005%
Lead	0.001%
Zinc	0.02%

TABLE 7: CHEMICAL COMPOSITION OF SODIUM SILICATE

Sp.Gravity	Viscosity	Na_2O %	SiO_2 %	Water %
1.385	68 Seconds	8.35	28.12	63.53

4. MIX PROPORTIONING:

In the present investigation three Cement Replacement Materials namely Fly Ash (FA), Ground Granulated Blast Furnace slag (GGBS), and Clay comprises as the major ingredients and Fine aggregate was replaced by Quary dust and was planned to conduct lab investigation using alkaline solutions with different molarities. The various molarities and mix proportions of GGBS, FA and Clay is shown in Table 8.

TABLE 8: VARIOUS MIX PROPORTIONS

Mix Trails	Fly Ash	GGBS	Clay	Molarity
M-1	80	10	10	4
M-2	70	15	15	4
M-3	80	10	10	6
M-4	70	15	15	6
M-5	80	10	10	8
M-6	70	15	15	8

4.1 PREPERATION OF ALKALINE SOLUTION

Potable water was used to prepare alkaline solution to avoid any mineral interference. The alkali solution has to be prepared 24 hours in advance before the use. The sodium hydroxide is available in small flakes and sodium silicate is available in gel form. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, NaOH solution with a concentration of 6M consisted of 6x40 = 240 grams of NaOH solids (in flake or pellet form) per liter of the solution, where 40 is the molecular weight of NaOH. Note that the mass of NaOH solids was only a fraction of the mass of the NaOH solution, and water is the major component..

The sodium silicate is taken in the same weight as that of sodium hydroxide for preparing the solution as we are considering the ratio of sodium hydroxide to sodium silicate as 1. The solution is normally soapy in nature and even a drop of solution falls on the skin, it may cause skin irritation etc.., hence proper care and precautions should be taken while handling the solution. The solution should be stored in closed containers with proper labeling.

4.2 MIXING, CASTING AND CURING:

The required quantities are weighed for a given proportion and are mixed in a 'Pan mixer' with rollers of 200 liters capacity with fixed blades., in which it is efficiently used for kneeding of materials. All the dry materials are mixed for about 3 minutes in a pan mixer and the wet mixing after adding the solution is continued for another 4 minutes.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The mortar is prepared by taking required quantities of raw materials (Fly ash, GGBS and Clay) into the Pan mixer. Dry mixing and wet mixing is done for specified time period till the total kneeding process is done. The resultant brick motor is poured in machine mould specimens (23 cm × 9 cm × 11 cm) and the bricks are compacted. The curing process is the most crucial aspect and plays an important role in geopolymerization reaction because water content and humidity has an effect to the performance and properties of geopolymer materials. Curing at elevated temperature generally starting from 27°C to 100°C tend to increase the compressive strength of geopolymer materials depending on the raw materials used. In this the curing is done ambiently i.e., air dried curing at a temperature on the ground in a particular place of 30-400¬C.

5 RESULTS AND DISCUSSIONS:

5.1COMPRESSIVE STRENGTH TEST:

The bricks specimens prepared are allowed to self curing under ambient conditions and the compressive strength is found out for 1, 3, 7 and 28 days. The bricks are tested in digital compression testing machine. Three bricks are tested at a time and the results presented here is the mean of the three values. The compressive strength values for different sets for different fluid binder ratios were listed in Table 9.

TABLE 9: COMPRESSIVE STRENGTH TEST RESULTS

SET NO.	F/B	FLY ASH %	GGBFS %	CLAY %	COMPRESSIVE STRENGTH IN Mpa				Molarity
					1 DAY	3 DAYS	7 DAYS	28 DAYS	
SET-1	0.20				0.6	1.5	2.7	3.2	
SET-2	0.25	70	15	15	1.0	2.1	3.3	4.4	
SET-3	0.30				1.0	1.6	2.7	3.9	4
SET-4	0.20				1.3	2.2	2.9	3.5	
SET-5	0.25	80	10	10	1.4	2.4	3.7	4.8	
SET-6	0.30				1.3	2.3	3.1	4.0	
SET-7	0.20				1.4	2.5	3.1	3.6	
SET-8	0.25	70	15	15	2.1	3.3	4.1	5.0	
SET-9	0.30				1.6	2.7	3.4	4.2	6
SET-10	0.20				1.5	2.6	3.2	3.8	
SET-11	0.25	80	10	10	1.7	3.2	4.3	5.3	
SET-12	0.30				1.6	2.8	3.6	4.5	
SET-13	0.20				1.7	2.3	3.4	4.1	
SET-14	0.25	70	15	15	2.1	3.6	4.5	5.5	
SET-15	0.30				2.0	2.9	3.5	4.6	8
SET-16	0.20				1.9	2.6	3.7	4.7	
SET-17	0.25	80	10	10	3.7	4.2	5.9	7.5	
SET-18	0.30				2.9	3.2	3.8	4.9	

5.2 WATER ABSORPTION TEST:

Geopolymer brick absorbed only very small quantity of water when compared with Ordinary bricks, almost less than ten percent and it should be appreciable for nonporous structures. Thus the geopolymer brick satisfies all the requirements.

The Table 10 shows a statistical comparison of water absorption of geopolymer bricks. The geopolymer brick having maximum compressive strength was chosen in each molarity and the water absorption test was conducted and variations in weight were calculated. It was also compared with country bricks.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

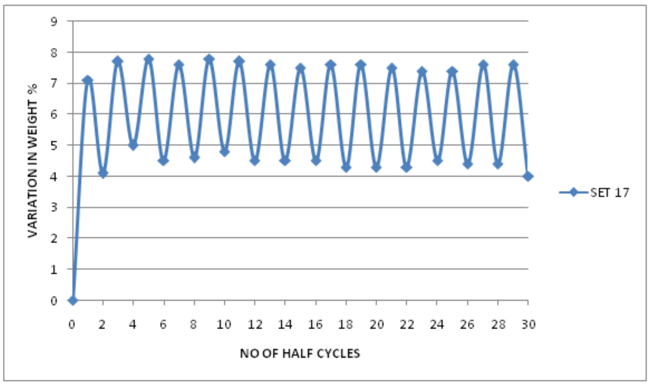
TABLE 10: WATER ABSORPTION RESULTS FOR BOTH ALKALINE SOLUTIONS.

S No	Type of Brick		Percentage increase in weight
1	Country Bricks		10.754
2	Geopolymer bricks of different molarities	4M	6.8
		6M	7.0
		8M	7.1

5.3 DURABILITY TEST RESULTS

5.3.1 ALTERNATE WETTING AND DRYING

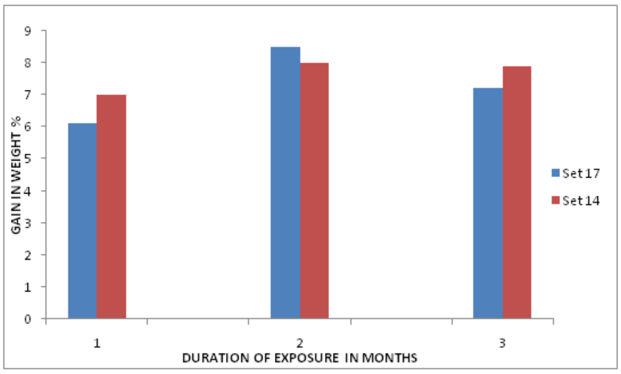
For this test set 17 brick with 8M is chosen as the compressive strength of this brick is very high. The initial weight of the set 17 brick is 4.727 Kgs. After conducting alternate wet and drying the percentage variations is shown in Graph 2.



GRAPH 2: TYPICAL VARIATION OF WEIGHT IN ALTERNATIVE WET AND DRY CYCLES

The changes in the weight of the bricks subjected to alternate wet and dry condition indicates that, during the first wet cycle, the weight gain of about 7.1 % corresponds to 24 hours water absorption test results; thereafter, throughout the test, the change in the weight during each wet and dry cycle is around 3 % for geopolymer bricks. This implies that the geopolymer bricks behave consistently with regard to weight change under alternate wet and dry cycles. After 15 alternate wet and dry cycles, the average residual compressive strength of the bricks of the set 17 is found to be 70 %.

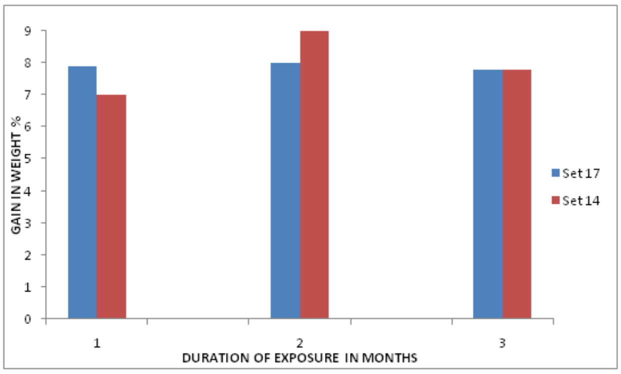
5.3.2 ACID ATTACK: In this test set 17 and set 14 bricks was chosen as the compressive strength of the bricks were high. The bricks when immersed in 5% sulphuric acid solution for different duration's up to three months the variations and the gain in percentage of weight of the bricks were shown in Graph 3.



GRAPH 3: VARIATION IN WEIGHT GAIN OF GEOPOLYMER BRICKS UNDER ACID ATTACK

6.3.3 SULPHATE ATTACK

In this test set 17 and set 14 bricks was chosen as the compressive strength of the bricks was high. The bricks when immersed in 5% Magnesium sulphate solution for different duration's up to three months the variations and the gain in percentage of weight of the bricks were shown in Graph 4.



GRAPH 4: VARIATION OF WEIGHT GAIN OF GEOPOLYMER BRICKS UNDER SULPHATE ATTACK

The above graphs demonstrate that the geopolymer bricks in general gain weight when immersed in 5 % solutions of sulphuric acid and magnesium sulphate, more likely due to absorption much similar to water absorption.

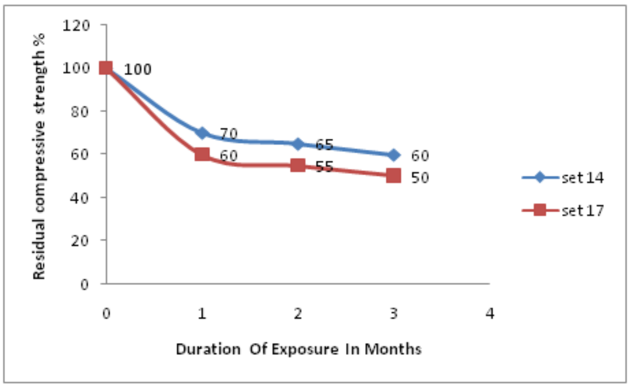
ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

In both the cases, the weight gain slightly increases between 1 and 3 months of exposure, but the weight gain after 3 months of immersion is marginally less when compared to that after 2 months of immersion. This apparent loss in weight suggests that there is some deterioration in the form of material loss from the matrix under acid/ sulphate attack. The weight gain, both in acidic and sulphate environments for different brick series are nearly the same. Further, the weight gain is close to 24 hours water absorption, though the period of immersion is much higher. This indicates that due to degradation, some material might have been lost under chemical attack. Further, binder to aggregate ratio does not seem to significantly influence the outcome of this test.

5.4 COMPRESSIVE STRENGTH VARIATIONS:

5.4.1 ACID ATTACK:

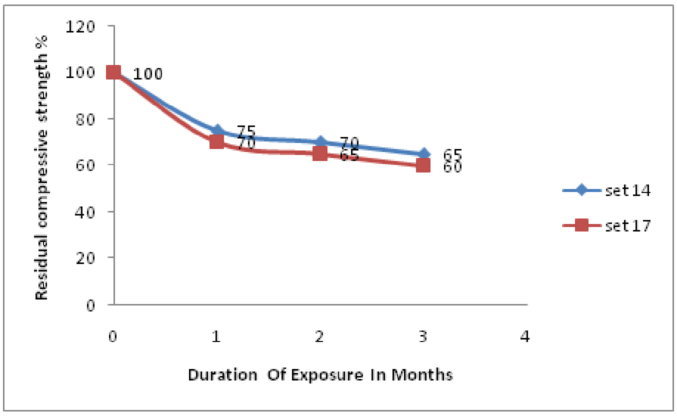
The compressive strength of geopolymer bricks of set 17 and 14 in the end of third month were 7.0 and 5.7 respectively. Comparing their strengths with the same sets when immersed in 5 % of sulphuric acid, there is a reduction in compressive strength for 1, 2 and 3 monthsand the variation of the residual compressive strength is shown in Graph 5.



GRAPH 5: VARIATION OF RESIDUAL COMPRESSIVE STRENGTH UNDER ACID ATTACK

5.4.2SULPHATE ATTACK:

Comparing the strengths of the same sets when immersed in 5 % magnesium sulphate solution, there is a reduction in compressive strength for 1, 2 and 3 monthsand the variation of the residual compressive strength is shown in Graph 6.



GRAPH 6: VARIATION OF RESIDUAL COMPRESSIVE STRENGTH UNDER SULPHATE ATTACK

From the Graphs it is evident that the geopolymer bricks undergo strength deterioration when exposed to 5 % solution of sulphuric acid. The major strength loss (up to approximately 40 % for set 17 and 30 % for set 14) occurs during the first month of immersion; the strength loss continues further up to 3 months at slower rate. After 3 months of immersion, the geopolymer bricks of the series set 14 and set 17 still possess 60 % (≈ 3.42 MPa) and 50 % (≈ 3.5 MPa) of their respective initial ultimate compressive strengths which are comparatively higher than the strengths of conventional Indian bricks unexposed to acid attack. The bricks of the set 17 appear to suffer slightly greater strength loss compared to that of the brick set 14. However, because of its higher initial compressive strength, it possesses higher strength even after acid attack.

The variations of the percentage residual strength of geopolymer bricks in sulphate environment are very much similar to that in acid environment. In case of sulphate attack, the deterioration is less severe than in the case of acid attack. Again, the major loss in strength (up to approximately 30 % for set 17 and 25 % for set 14 bricks) is observed during the first month of exposure. The absolute residual strength after 3 months of immersion is in the range of 4.2 MPa for set 17 and 3.7 for set 14 which is comparatively higher than that of conventional Indian bricks unexposed to sulphate attack.

6CONCLUSIONS:

Based on experimental study, following conclusions can be drawn regarding the strength behaviour and durability studies of Ternary blended Geopolymer bricks.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

* The experimental results show that the maximum compressive strength for geopolymer bricks was attained at 80 % Fly ash, 10 % GGBS and 10 % Clay.
* Maximum compressive strength was attained for a Fluid binder ratio of 0.25
* The maximum compressive strength of geopolymer brick was obtained as 7.5 Mpa for 28days curing period.
* Maximum compressive strength was achieved at 8M due to increase in pH value it increases the compressive strength of mortar. Another reason is F/B 0.25 in which mortar mix is moderately workable.
* The geopolymer bricks behave consistently with regard to weight change under alternate wet and dry cycles.
* The geopolymer bricks were resisted against the acid and sulphate attack as the changes were less comparative.
* Water absorption capacity of these bricks is relatively lower when compared to country bricks.
* Comparing the residual strength of the bricksit is clear that acid environment is more severe than sulphate environment for geopolymer composites.
* The geopolymer bricks proved to be energy efficient and aim towards a greener eco-friendly brick for construction.
* Hazardous effects and disposal problems of waste materials can be reduced through this investigation.
* It proves that the used cement replacement materials are used for the manufacturing of bricks based on experimental results.

REFERENCES:

1. Ashish Kumar Parashar*, RinkuParashar “Comparative Study of Compressive Strength of Bricks Made With Various Materials to Clay Bricks” International Journal of Scientific and Research Publications, Volume 2, Issue 7, July 2012.

2. Davidovits, J. (1994b). Properties of Geopolymer Cements. In Kiev (Ed.), First International Conference on Alkaline Cements and Concretes (pp. 131-149).Kiev, Ukraine: Kiev State Technical University.

3. DhavalVaviya, J JBhavsar, JayeshPitroda “Literature Review On Comparing Clay Bricks Nomograms With Fly Ash Bricks” published in National Conference on Recent Trends In Engineering & Technology, (NCRTET-2011) B.V.M. Engg. College, V.V.Nagar, Gujarat on 13TH - 14TH May 2011.

4.Garth V Taylor, William daidon “The use of bottom ash in the manufacturing of clay face brick” World of coal ash conference in Denver” May(2011).

5.J. N. Akhtar, J. Alam and M. N. Akhtar “An experimental study on fibre reinforced fly ash based lime bricks” Internationa l Journal of the Physical Sciences Vol. 5(11), pp. 1688-1695, 18 September 2010.

6.Obadakayali “High performance Bricks from fly ash” World Of Coal Ash (WOCA), Lexington, Kentucky, USA (2005).

7.Palomo A. et al (1999), “Alkali-acivated fly ash cement for future”, Cement and Concrete Research, Vol.29, pp.1323-1329.

8.Tabinrushad, Abhishekkumar, Duggal S.K, Mehta P.K “Experimental study on lime_soil_fly ash bricks” International journal of civil and structural engineering Volume 1, no 4, (2011).

9.Xu, H., &Deventer, J. S. J. V. (2000). The geopolymerisation of alumino-meta silicateminerals. International Journal of Mineral Processing, 59(3), 247-266.

10.B.I.S brick testing code IS:516:1959 compressive strength.

11.IS: 3495-1992 (Part 1 to 4), “Methods of Tests for Burnt Clay Bricks”, Bureau of Indian Standards, Third Revision, New Delhi.