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Geopolymer Brick by using Flyash, GGBS, Silica Fume and Kadapa Slab Dust

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Abstract*: Brick is the former construction material, a standard-sized non load bearing building component. The ancient bricks manufactured by clay, earth or mud. By 2007 the new 'fly-ash' brick made up of cement and flyash which is reliable, weather & acid resistant. The cement is a hugely used building material and liberates CO2 leading to pollution. To minimize pollution and a step to advancement in sustainable development. The current research results to geo polymer brick, where the cement is replaced with GGBS, silica fume and Kadapa slab dust. For bonding, polymers were used with limited water content. Hence produced brick is a hybrid geo polymer brick with multi material combination. Fly ash 75%- GGBS 25% as a base material. GGBS is partially replaced with silica fume and Kadapa slab dust by 2 to 5%. Evaluated through compressive strength results in which we found three optimum proportions such as FA 75%-GGBS22%-SF3% & 75% FA-22% GGBS -3% KSP.

Index Terms*: Flyash (FA), Ground granulated blast furnace slag (GGBS), Silica fume (SF)

I. INTRODUCTION

A brick is a building material, used to construct walls, pavements and other elements. Traditionally, A brick is composition of clayey soil, fine aggregate, and lime(calcium carbonate). Bricks are classified in to various types based on geometry and composition of materials which vary with region. Initially in 7000 BC sun-dried mud bricks were introduced, later kiln-dried clay bricks are introduced which are more weather-resistant.

Dr. Bhanumathidas and Kalidas in 1991 has developed and got petent on Flyash, Lime &Gypsum for achieving high early strength due to the conversion of calcium aluminates into calcium alumino sulphates. Leads to reduction in cost by 20%. Even though in the present scenario, a well known fact that cement is universal constructional material made of clay & lime stone a naural resource, because of its continuous usage soon they may exhaust. In order to protect the natural resource and to reduce pollution as an alternate material for sustainable development Geo-polymers-NACL & NAOH is introduced as a binding material. The materials flyash, kadapa slab dust & GGBS are used in the manufacture

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II. LITERATURE REVIEW

Hardjito and Rangan studied fly ash based Geo-polymer Concrete. The material used are fly ash-class F acquired from Thermal power station. Fly ash contains calcium by 2 percent by mass. They observed the compressive strength data and concluded that fly ash based geo-polymer concrete has good strength, fit for structural application. **Davidovit's** the poly condensation of geo-polymer occurs at lower temperatures less than 100°C and the chemical reaction involved in their formation. **Hardjito et al.** concluded water to geo-polymer solids ratio has considerable effect on compressive strength of geo-polymer concrete, where as **Fongjan and Ludger** observed that potential properties of geo-polymeric mortar has many key factors like, physical properties, oxide-mole ratios, curing conditions and morphologies of solid materials,. **Rangan et al.** concluded that fly ash geo-polymer concrete has magnificiant resistance to durability properties like creep, shrinkage and chemical attacks. **Hardjito et al.** found that effects of the concoction time and the strength gaining time. **Sumajouw et al.** studied the mechanical properties of geo-polymer concrete columns and beams. **Barbosa et al.** observed the effect of the oxides molar composition and polymerization process- water content. **van Jaarsveld et al.** studied that the properties of geopolymer is affected by water content. **Ranganath and Mohammed** analysed the effect of materials, water content, polymer proprtioning, and the time interval of accelerated curing on the properties of geo-polymer concrete, whereas **Mustafa Al Bakri et al. and Jamkar et al.** analysed the fineness of fly ash leads to increase in workability and compressive strength **Chindaprasirt et al (2007)** found that, to produce a higher strength geo-polymer the optimum sodium silicate to sodium hydroxide ratio was in range of 0.67 to 1.00. Alternatively, the concentration of NaOH between 10M and 20M give small effect on the strength

III. ENGINEERING SIGNIFICANCE

Portland cement emits carbon dioxide majorly leads to global warming. Among the greenhouse gases; carbon dioxide contributes about 65% of global warming also to secure the natural resources.

Numerous researches are undergoing to decrease Portland cement utility in bricks and concrete. Leads to utilization of sustainable mineral admixtures like granulated blast furnace slag , fly ash, rice-husk ash, silica fume and Kadapa slab dust, resulting different binders alternative to Portland cement.

To decrease the global warming, the geo-polymer technology is best suiting.

In this project, the effort was made to study the strength parameters of geo-polymer brick. In order to total replacement of cement and water. The geo-polymer brick in our project is having

- ✓ More strength when compared to normal brick. Here the geo-polymer brick that we prepared will gain the strength 10.2 N/mm^2 at only in 7 days. Normal brick will doesn't gain this much of strength even in 28 days also. The strength of the normal fly ash brick at 28 days is 8.1 N/mm^2 only.
- ✓ Nearly less cost when compared to normal fly ash brick.
- ✓ It doesn't require stream curing. When it placed in 60^0C, it will gain the maximum strength in 24 hours after demoulding.
- ✓ Time reduces.
- ✓ It doesn't have any soluble salts in it.
- ✓ It is weather resistant and fire resistant.

IV. MATERIALS

Fly Ash

It is extremely fine ash 'flying' along with flue gases is trapped in electro-static precipitators (ESP) and is collected as dangerous pollutant precipitate. The coarser ash is mixed with water at the bottom, made into slurry and pumped into fill sites called 'ash ponds'. The another ingredient in ash which is generated from TPP is termed as **'POND ASH'**. Depending on efficiency, design and capacity, the ratio of pond ash to fly ash lies from 20:80 & 30:70.

Ground-granulated blast -furnace slag (GGBS)

GGBS is obtained by dampen down liquified slag of iron (a secondary product of iron and steel manufacturing units) from a blast furnace in steam, to furnish a glassy coarse material which is required to dry and ground to fine particulate matter comprises mainly of calcium oxide, silicon di-oxide, aluminium oxide, magnesium oxide. It has the same main chemical constituents as ordinary Portland cement but in different proportions.

Silica fume

Silica fume is a secondary-product snuffed out from the alloy of silica and iron. One of the most beneficial uses for silica fume is in concrete. Because of its characterization in both physically and chemically, its proved to be very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable. Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide (SiO2). The individual particles are extremely small, approximately 1/100th the size of an average cement particle.

Geo-polymers

Geo-polymers is inorganic, typically ceramic material, that forms long range chemically double bonded, but not crystalline. polymers-sodium hydroxide, sodium silicate respectively.The alkaline liquid used was a combination of sodium silicate solution and sodium hydroxide solution. The sodium hydroxide pellets were dissolved in water to produce the solution . The mass of NaOH pellets in a solution indicates concentration of the polymers and they are expressed as Molar (M). NaOH solution with a concentration of 8 M consisted of 8 x 40 = 320 gms of sodium hydroxide pellets per litre of polymer, where 40 is the molarity of sodium hydroxide . The mass of NaOH solids was measured as 262 gms/kg of NaOH solution of 8M concentration. Similarly, the mass of NaOH pellets per kg of the solution for 14M congregation is computed as 404 grams and for 16M mass of NaOH pellets is 444 gms.

Water (H2O):

The main reason of using water in this experiment is, in general normal fly ash bricks get the strength due to the formation of C-S-H gel it forms due to the mixing of cement, sand and water. But the geo-polymer brick get the strength due to the formation of N-A-S-H gel it forms due to the mixing of polymers, fly ash and water. So without water the N-A-S-H gel doesn't forms. That's why we are using water from 8 to 15% in this experiment.

Table-1Propeties of geo polymers

S.No	Property	Magnitude
1.	Specific gravity	1.46 to 1.50
2.	N_2O	13.5 to 14.5
3.	SiO_2	27.0 to 29.0
4.	Weight ratio	1:2.00 to 1:2.4
5.	Mole ratio	1:2.06 to 1:2.47

Coarse Aggregate:

The coarse aggregate from a local crushing granite stone of angular type having 06 mm minimum size well graded aggregate according to IS-383 is used in this investigation. The coarse aggregate procured from quarry was sieved through 12.5mm, 10mm and 4.75mm sieves.

Table-2 Propeties of coarse aggregate:

S.No.	Property	magnitude
1.	**Size**	**6mm**
2.	Specific gravity	2.80

3.	Bulk density (dense)	1520 kg/m^3
4.	Bulk density (loose)	1330 kg/m^3
5.	Fineness modulus	6.9

Fine Aggregate:

The fine aggregate that falls in zone-II was obtained from a nearby Cheyyeru river course at Nandalur. The sand obtained i.e., retained in the following sieves (i.e.4.75mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm).

Table-3 Properties of fine aggregate:

S.No.	Property	Magnitude
1.	Specific gravity	2.50
2.	Bulk density (dense)	1715 kg/cum
3.	Bulk density (loose)	1633 kg/cum
4.	Fineness modulus	3.20
5.	Grade	Zone II

V. MIX DESIGN

Table-2 Mix Proportions: M_{20} grade concrete

Binder	Coarse aggregate	Fine aggregate	Water / cement (W / C)
1	3.79	1.82	0.55

- Weight of cement = 330 kg/m^3, Here Cement is totally replaced by Fly ash and GGBS with 75% and 25% respectively.
- Weight of water = 180 kg/m^3, Here water is totally replaced by chemicals which are NaOH and Na_2SiO_3 with 1:2.5 proportions.
- Weight of NaOH = 51.42 lit (or) kg/m^3 ,
- Weight of Na_2SiO_3 = 128.58 lit (or) kg/m^3
- 6mm size crushed aggregates of 30% and remaining 70% of fine aggregate is used in over all aggregates.

VI. HELPFUL HINTS

COMPRESSIVE STRENGTH: IS: 3495 – P (1)-1992- Load is applied axially at a uniform rate of 14 N/mm^2 per minute till failure occurs. The maximum load at failure is noted down. from the compression testing machine.

Table-2 Compressive strength of by varying KSP &H_2O

S.No	FA	GGBS	KSP	H_2O	Compressive strength-N/mm^2
5.	75	20	5	8	7.6
6.	75	22	3	8	9.7
7.	75	23	2	8	7.8
8.	75	20	5	12	8.1
9.	75	22	3	12	9.5
10.	75	23	2	12	7.4
11.	75	20	5	15	7.9
12.	75	22	3	15	8.5
13.	75	23	2	15	7.7

S.No	FA	GGBS	H_2O	Compressive strength-N/mm^2
1.	75	25	0	1.7
2.	75	25	5	9.4
3.	75	25	8	9.6
4.	75	25	15	10.2

S.No	FA	GGBS	SF	H_2O	Compressive strength-N/mm^2
1.	75%	20%	5%	0	3.3
2.	75%	20%	5%	8	5.8
3.	75%	22%	3%	15	10.3
4.	75%	23%	2%	15	9.9

S.No	FA	GGBS	RHA	H_2O	Compressive strength N/mm^2
1.	75%	20%	5	15	8.8
3.	75%	22%	3%	15	5.8
4.	75%	23%	2%	15	5.5

Water absorption:

Fly ash	GGBS	Silica fume	Kadapa slab powder	Water (H_2O)	Avg. % of water absorption for 2 bricks

75%	25%	0%	0%	8%	6
75%	22%	3%	0%	15%	6.6
75%	22%	0%	3%	8%	5.7

Fig.1.Specimen after demoulding

VII. COST ANALYSIS

In general, the normal fly ash bricks with 85% fly ash and 15% cement are sold by Rs. 7/- each based on that we are analyzing the cost of one geo-polymer brick.

- ✓ Generally, the cost of NaOH is Rs.100/- per kg. We can prepare this 1kg of powder into 3 lit of solution with 8M; in this experiment every brick wants 80ml of NaOH solution. Then by using 1 lit of NaOH solution we can prepare nearly 13 bricks. Similarly, by using 1kg of NaOH, we can prepare nearly 40 bricks. Then the cost of NaOH in one brick is 100/40 = Rs. 2.5/-.
- ✓ Similarly, the cost of Na2SiO3 is Rs. 15/- per kg. We can prepare this 1kg of powder into 8ltr of solution; in this experiment every brick wants 200ml of solution. Then by using 1lit of Na_2SiO_3 solution we can prepare nearly 5 bricks. Similarly, by using 1kg of Na_2SiO_3, we can prepare nearly 40 bricks. So the cost of Na_2SiO_3 in one brick is 15/40 = Rs. 0.375/-.
- ✓ Similarly, the cost of silica fume is Rs. 18/- per kg. In this experiment each brick wants 50g of silica fume, so by using 1kg of silica fume we can prepare 20 bricks. Then the cost of silica fume in one brick is 18/20 = Rs.0.9/-.
- ✓ All the other materials are waste materials which are available at free cost, but the transportation cost and labor cost are additional. Based on normal fly ash brick analysis the labor and transportation costs are Rs. 1/- and Rs. 0.5/- respectively.

Finally, the cost of a geo-polymer brick = Rs.2.5 + Rs.0.375 + Rs.0.9 + Rs.1.5 = **Rs.5.275/-.**

"WHEN COMPARED TO NORMAL FLY ASH BRICK THE COST OF GEO-POLYMER BRICK IS NEARLY LESS"

VIII. CONCLUSION

Comparatively with normal fly ash bricks the hybrid geo-polymer bricks had better properties and economy. The alternating stuff practiced in this work is 75% waste materials (flyash, GGBS & Kadapa slab dust) and Silica fume, a bit costlier. In current work flyash of 75% and GGBS of 20% were made constant, remaining 5%, 2% & 3% filled with silica fume, rice husk ash & Kadapa stone dust.

1.Firstly Geo polymer bricks, fly ash-75% and GGBS-25% with polymers of 1:2.5 ratio of 0.55 and coming to traditional flyash bricks, fly ash-85% & cement-15% with W/C ratio of 0.6. Both of these proportions are considered as referenced base for comparison. Fly ash and GGBS of 75% and 25% with alkaline activators of 1:2.5 ratio. Casted cubes without water, but the strength is undesirable. In order to attain better strength, water is added in certain proportions i.e. from 5 to 15%, for 8% of water the max strength of 9.6 N/mm2is attained. Considering this as optimum proportion.

2. Secondly, we will go for new material i.e. RHA of 1 to 5% along with fly ash of 75%, GGBS of 20 to 24% and water of 8 to 15% by this we get the compressive stress value from minimum 1.5 N/mm2 to maximum 6.5 N/mm2 at 7days. When compared to normal fly ash brick it doesn't give the expected results. So we were neglecting this material in our investigation.

3. Similarly, we will go for an another new material i.e. Silica fume with same 1 to 5% along with fly ash as 75%, GGBS as 20 to 24% and water as 8 to 15%. In this for one proportion we get the compressive stress of 10.3 N/mm2 at 7days this is the max stress that we expected, so we can take it as the optimum proportion and that proportion is fly ash 75%, GGBS 22%, silica fume 3% and water is 15%.

4. Finally, we will go for an another new material l i.e. Kadapa slab powder with the same 1 to 5% along with fly ash as 75%, GGBS as 20 to 24% and water as 8 to 15%. In this for one proportion we get the compressive stress of 9.5 N/mm2 at 7days this is also a better result that we expected, so we can take it as the optimum proportion and that proportion is fly ash 75%, GGBS 22%, Kadapa slab powder 3% and water is 15%.

"FROM THE ABOVE OPTIMUM RESULTS, WE CAN ACHIEVE BETTER ECONOMY AND SUSTAINABILITY IN THE GROWTH OF BRICK CULTURE"

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