International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || Volume 03 - Issue 02(S) || PP.86-94

Concrete Experimental Study on Elastic Constants of Hybrid Geopolymer

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Abstract: In this project low calcium fly ash with GGBS were used as the source material in concrete to fully replace of cement is known as Geopolymer concrete. Additionally Steel, Polypropylene, and coir are incorporated to improve its strength aspects in the concrete are called as hybrid geopolymer concrete at low volume fraction of 0.5. The manufacturing of geopolymer concrete was carried out using the usual concrete technology methods. The silicon and the aluminium are the source material to activate by a combination of sodium hydroxide and sodium silicate solutions to form the geopolymer paste that binds the aggregate sand other un-reacted materials. This paper aims to study about the elastic constants of hybrid geopolymer concrete for the different molarities of NaOH. The molarities of NaOH solution used in this work were 8M, 10M & 12M.
Keywords: Fly ash, GGBS, Geopolymer Concrete, Steel, Polypropylene, coir s, hybrid geopolymer concrete, elastic constants, molarities of NaOH

Introduction

Concrete is conventionally formed by using the ordinary Portland cement as the primary ring binder. Cement developed causes environmental impacts at all stages of the process. The manufacturing of Portland cement releases carbon dioxide (CO_2) that is a significant provider of the greenhouse gas emissions to the atmosphere. The amount of CO_2 emitted by the cement industry is nearly 900 kg of CO_2 for every 1000 kg of cement producedTo reduce the environmental impact of the concrete industry, Mehta (2002) suggests two approaches, a short term and a long term approach. The short term approach would be to practise "industrial ecology" which involves the use of industrial by-products as cement surrogate materials. According to the report of Central Electricity Authority of India (CEA), the total fly ash generation from April 2014 to March 2015 is 184.14 Million Tonnes. The use of Ground Granulated Blast-furnace Slag (GGBS) will increase the strength as well as enhance the mechanical properties of the concrete.

In 1978, Davidovits (1999) projected that binders might be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminium in source materials of geological origin or by-product materials such as fly ash and rice husk ash. He termed these binders as geopolymer.

Concrete is the largest part broadly used construction substance in the world due to its high compressive strength, long service life, and low cost. However, concrete has inbuilt disadvantages of low tensile strength and crack resistance. To perk up such weaknesses of the material, numerous studies on reinforced have been performed by Sung Bae Kim et al 2012.

The variation of two or more fibres in the concrete is called as Hybrid Fibre Reinforced Concrete. The function of short-cut fibres as secondary reinforcement in concrete is primarily to reduce crack instigation and transmission (Hsie et al., 2008).

The large and the strong fibres control large cracks. The small and soft fibres control crack initiation and propagation of small cracks (Sivakumar and Santhanam, 2007).

In this experimental work the cement is replaced by low calcium fly ash and Ground Granulated Blast-furnace Slag (GGBS). Low calcium fly ash and GGBS is activated by alkaline activator solution for binding. The bond between the materials in concrete is achieved by the process of polymerization. Additionally s have been added in 0.5% of volume fraction by keeping the steel as permanent and adding other s as partial. The manufacture of hybrid geopolymer concrete (H_yGPC) is carried out using the usual concrete technology methods.

Materials Used:

Fly Ash: Fly ash used in this experimental work was collected from Tuticorin Thermal Power Station located in Tamil Nadu, India. The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 7%lime (CaO) is used.

GGBS: Ground Granulated Blast-Furnace Slag is a waste material generated in iron or slags Industries have significant impact on Strength and Durability of Geopolymer Concrete. It also continues to gain strength over a longer period of time. It also reduces the damages caused by alkali-silica reaction, reinforcement corrosion and high resistance to sulphate attacks.

Fig 1: Fly ash and GGBS

Alkaline Activator Solution:

Sodium Hydroxide: Generally sodium hydroxide (NaOH) is available in market in pellets or flakes form with 96% to 98% purity. The solution of NaOH was formed by dissolving it in water in different quantities to obtain different molarities (8M, 10M and 12M).

Sodium Silicate: It is also known as waterglass which is available in the market in gel form. The ratio of SiO_2 and Na_2O in sodium silicate gel highly affects the strength of geopolymer concrete. Mainly it is seen that a ratio ranging from 2 to 2.5 gives a satisfactory result.

Coir : Coconut Coir is a 100-percent natural by-product of harvesting coconut. Coir consists of the coarse s extracted from the husk on the outer shell of a coconut. Because of its superior water holding capacity, excellent air space and drainage, coir is a useful soil amendment for potted plants, containers and garCoir fibres are found between the hard, internal shell and the outer coat of a coconut.

Steel : Steel fibres are made of cold-drawn steel wire with low content of carbon or stainless steel wire. Steel fibres in Concrete can improve crack, impact and fatigue resistance, shrinkage reduction and toughness by preventing or delaying crack propogation from micro-cracks to macro-cracks. Crimped steel fibre was used.

Polypropylene : The polypropylene s have good ductility, fineness, and spreading so they can restrain the plastic cracks (Yao et al., 2003). Therefore, proper mixture of these two matching s can make better emotionless properties of concrete.

Table 1 - Properties of Fibers

Specification	Coir Fibre (CF)	Steel Fibre (ST)	Polypropylene Fibre (PP)
Length	72 mm	50 mm	38 mm
Diameter	0.05 mm	1 mm	0.02 mm
Aspect Ratio	1440	50	1900
Specific Gravity	1.18	7.46	0.9

Aggregates

Coarse aggregate: It was collected from the local crusher with the nominal size and it was sieved for 12.5mm i.e. the aggregates passing through 12.5mm sieve were taken for casting. It doesn't have moisture content.

Fine aggregates: It was collected from the college site having the size of 4.75mm after sieving.

The Properties of Aggregates were listed in Table 2.

Table 2 Properties of aggregates

S.NO	Physical properties	Coarse Aggregate	Fine Aggregate
1	Type	Crushed	River Sand
2	Size	12.5mm (passing)	4.75mm
3	Moisture Content	Nil	Nil

Super Plasticiser: It is added for the workability of the concrete. In this work the super plasticiser added was conplast SP430 from the local suppliers.

Water: Water used for mixing concrete was potable water.

Mix Proportion:

The primary difference between a geopolymer concrete and Portland cement concrete is the binder. As in the case of later one, the coarse and fine aggregate occupy 77% of the mass of geopolymer concrete. While arriving the mix parameters like the alkaline liquid to fly ash ratio by mass, sodium silicate to sodium hydroxide by mass we fixed. Based on the literature review, trial and error method the following mix proportion was obtained and it was charted in table 3.

has been taken as 0.5% from fine aggregate. From the low volume fraction of fibres, steel fibre plays the regular role and the other fibres namely Coir and Polyprop ylene were added in the following form (0.25% S T + 0.25% CF) is named as HyGPC-1 and (0. 25% ST + 0.25% PP) is named as HyGPC-2.

Table 3 Mix proportion

Fly Ash	GGBS	Fin e aggregate	Coarse Aggregate	Super plasticiser	Water
(Kg/m^3)	**(Kg/m^3)**	**(Kg/m^3)**	**(Kg/m^3)**	**(Kg/m^3)**	**(Kg/m^3)**
354.87	39.43	555	1295	11.829	39.43

Methodology:

The cylinders of size 300mm height and 150mm diameter are casted for three different molarities (8M, 10M and 12M) of NaOH solution was shown in fig.2, the cylinder. T he freshly mixed geopolymer concrete with the s was placed manually in three layers into the cylinder mould. Before casting, machine oil wa s tarnished on the inner surfaces of the cast ir on mould. After thorough compaction, the top surrface was leveled using a smooth trowel. The moulds were left at room temperature for ambient air curing. After one day of casting the concrete cylinders are removed from the mould was sh own in fig 3 & 4. It is kept for ambient air curin g for 28 days.


Fig.2 Alkaline Activator


Fi g.3 Concrete Preparation


Fig.4 Curing of Specimens

Tests for Elastic Constants

The experimental work, modulus of elasticity and Poisson's ratio of geo polymer concrete were tested in Compression testing machine (CTM). The cylindrical specime ns were used to determine the elastic constants. The size of specimens that is used for testing is 150mm diameter and 300mm height. The readings for both the parameters (modulus of elasticity and Poisson's ratio) are taken simultaneously in the CTM shown in Fig.5.

The elastic modulus of an object is defined as the slope of its stress–strain curve in the elastic deformation region.

$$\text{Modulus of elasticity, } E = \frac{\text{Stress}}{\text{Strain}}$$

Poisson's ratio (μ)

Poisson's ratio is the negative ratio of transverse to axial strain. When a material is compressed in one direction, it usually tends to expand in the other two directions perpendicular to the direction of compression. Poisson's ratio is a measure of this effect. It is also known as the coefficient of expansion.

$$\text{Poisson's ratio } (\mu) = \frac{\text{Lateral strain}}{\text{Linear Strain}}$$

Fig.5 Specimen with lateral extensometer

Results:

Compressive strength

The compressive strength of the hybrid geopolymer **(**H_YGPC) of different molarities has the following values

Table 4 Weight and Compressive strength of H_YGPC specimens at 28 days

Molarity of GPC cylinder	**Avg. Weight of HyGPC cylinder (kg)**		**Avg. Compressive strength of GPC at 28 days (N/mm^2)**	
	HYGPC 1	**HYGPC 2**	**HYGPC 1**	**HYGPC 2**
8M	10.56	10.85	38.25	40.25
10M	9.89	11.02	42.56	44.14
12M	10.88	10.36	36.80	42.15

Modulus of Elasticity
The data for calculating modulus of elasticity of different molarities of hybrid geopolymer **(**H_YGPC) (8M, 10M and 12M) was resulted below (Table 6).

Table 5 Linear strain and Stress for H_yGPC - 1 specimen

Molarity	8 M		10 M		12 M	
S.No	Linear Strain (no unit)	Stress (N/mm2)	Linear Strain (no unit)	Stress (N/mm2)	Linear Strain (no unit)	Stress (N/mm2)
1	0	0	0	0	0	0
2	0.0001	1.92265	0.00011	1.92678	0.000155	1.244409
3	0.00015	3.28023	0.00015	3.28436	0.000198	2.54542
4	0.00019	4.29841	0.0002	4.30254	0.000242	3.959561
5	0.00023	5.54285	0.00023	5.54698	0.000285	5.486834
6	0.00026	6.73073	0.00027	6.73504	0.000325	6.900975
7	0.00029	7.69235	0.00029	7.69665	0.000365	8.315117
8	0.00032	8.82366	0.00032	8.82797	0.000402	9.672692
9	0.00035	9.78528	0.00034	9.78958	0.000428	10.860575
10	0.00037	10.5776	0.00037	10.5815	0.000445	11.709055
11	0.00039	11.426	0.00039	11.43	0.000468	12.896935

12	0.00041	12.2745	0.00041	12.2846	0.000488	13.858555
13	0.00043	13.0665	0.00043	13.0765	0.000512	14.989865
14	0.00045	13.9715	0.00047	13.9815	0.000538	16.121175
15	0.00047	14.7634	0.00049	14.7734	0.000568	17.365625
16	0.00049	15.3856	0.00051	15.3957	-	-
17	0.00052	16.2341	-	-	-	-
18	0.00054	16.9129	-	-	-	-

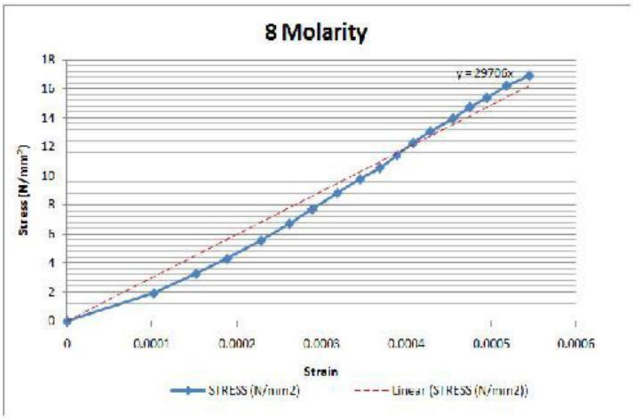

Fig.7 Stress - Strain Curve 8M H_yGPC -1

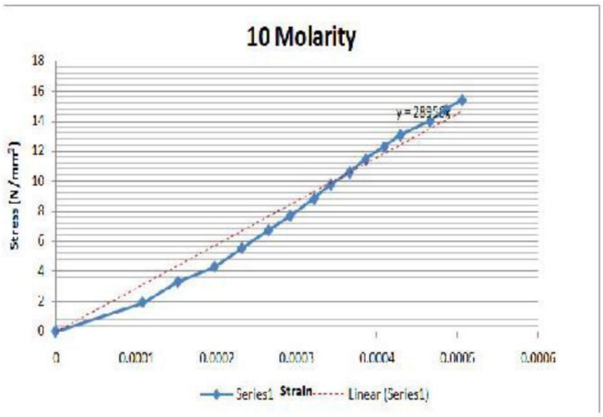

Fig.8 Stress strain curve 10M H_yGPC – 1

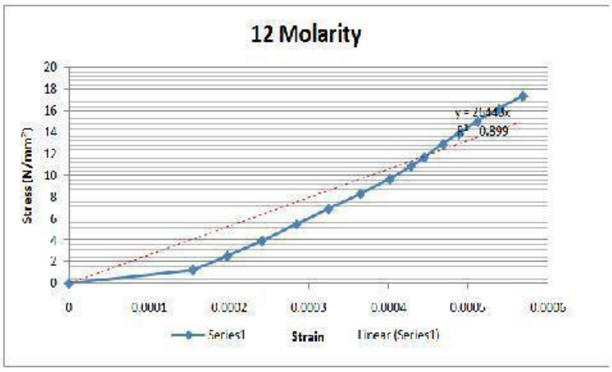

Fig.9 Stress strain curve 12M H_yGPC -1

Molarity	8 M		10 M		12 M	
S.No	Linear Strain (no unit)	Stress (N/mm2)	Linear Strain (no unit)	Stress (N/mm2)	Linear Strain (no unit)	Stress (N/mm2)
1	0	0	0	0	0	0

2	0.000038	1.920832	0.000101	1.813232	0.000058	1.24799
3	0.000158	3.278408	0.000151	3.170808	0.000095	2.54901
4	0.0001947	4.29659	0.000187	4.18899	0.000148	3.96315
5	0.0002347	5.541034	0.000227	5.433434	0.000185	5.49042
6	0.000268	6.728913	0.000261	6.621313	0.000225	6.90474
7	0.0002947	7.690529	0.000287	7.582929	0.000265	8.31888
8	0.0003247	8.821842	0.000317	8.714242	0.000302	9.67645
9	0.0003513	9.783459	0.000344	9.675859	0.000322	10.8643
10	0.0003747	10.57538	0.000367	10.46778	0.000339	11.7128
11	0.0003947	11.42386	0.000387	11.31626	0.000362	12.9007
12	0.000418	12.27235	0.000411	12.16475	0.000382	13.8684
13	0.000438	13.06427	0.000431	12.95667	0.000406	14.9997
14	0.0004647	13.96932	0.000457	13.86172	0.000442	16.131
15	0.0004847	14.76124	0.000477	14.65364	0.000472	17.3755
16	0.0005047	15.38346	0.000497	15.27586	-	-
17	0.000528	16.23194	0.000521	16.12434	-	-
18	0.0005547	16.91073	0.000547	16.80313	-	-

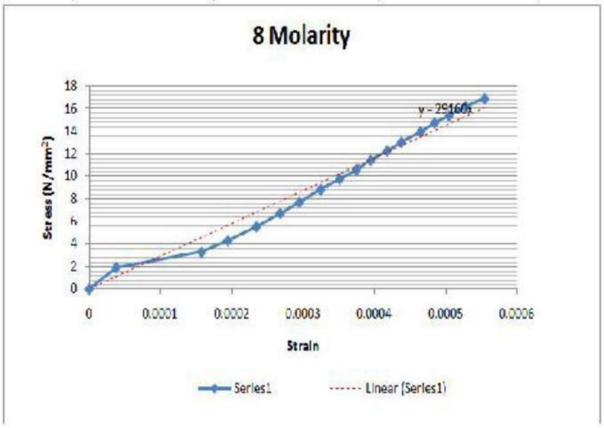

Fig.10 Stress - Strain Curve 8M H_yGPC -2

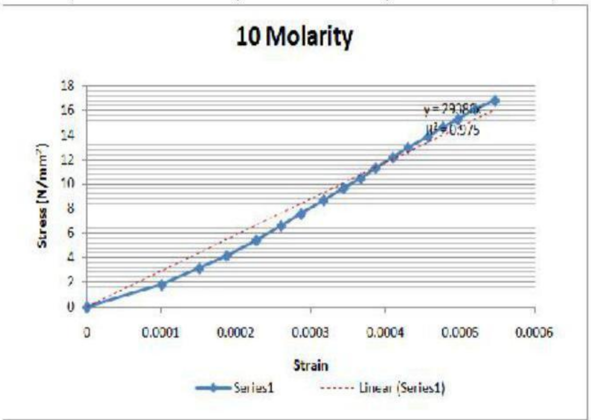

Fig.11 Stress strain curve 10M H_yGPC – 2

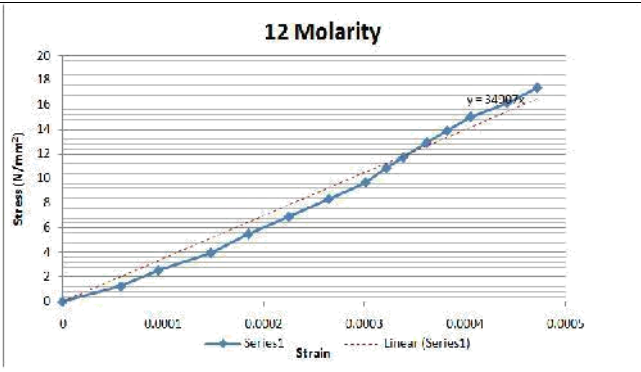

Fig.12 Stress strain curve 12M H_yGPC -2

Table 7 Modulus of elasticity - H_yGPC -1 & H_yGPC -2

Specimen	Modulus of elasticity	
8 M	29706 N/mm2	29160 N/mm2
10 M	28956 N/mm2	29836 N/mm2
12 M	26443 N/mm2	34907 N/mm2

Poisson's Ratio

The data for calculating Poisson's ratio of different molarities of geopolymer concrete (8M, 10M and 12M) were taken from CTM corresponding to each deformation on lateral extensometer result was tabulated below.

Table 8 Modulus of elasticity

Specimen	Poisson's ratio - HyGPC -1	Poisson's ratio - HyGPC -2
8 M	0.2105 at 40% of elastic range load	0.220 at 40% of elastic range load
10 M	0.221 at 40% of elastic range load	0.211 at 40% of elastic range load
12 M	0.207 at 40% of elastic range load	0.247 at 40% of elastic range load

Conclusion

- The compressive strength of the hybrid geopolymer concrete corresponding to 10M NaOH was higher compared to 8M and 12M NaOH GPC.
- The combination of steel and polypropylene with 10 M achieved higher compressive strength.
- Modulus of elasticity (E) of the geopolymer with the combination of steel and polypropylene concrete corresponding to 12M NaOH was higher compared to 8M and 10M NaOH GPC.
- Poisson's ratio of the geopolymer with the combination of steel and polypropylene concrete corresponding to 12M NaOH was higher compared to 8M and 10M NaOH GPC.
- From the above points, it is conclude that the 12M NaOH solution proves to be optimum for geopolymer concrete preparation with steel and polypropylene combination.
- Apart from the strength characteristics the coir didn't allow the geopolymer binder as wet mix, the absorption of water is little bit higher than the steel and polypropylene mix.
- But there is no much more deviation in absorbing the modulus of elasticity because the coir with the combination of steel archive good modulus of elasticity at 8M of NaOH when the molarity improves its get regrets a slight.

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