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Experimental Investigation of Geo Polymer Concrete with Pebbles as Coarse Aggregate

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ABSTRACT: This study deals with the different properties of Geo Polymer concrete using fly ash and pebbles as coarse aggregate. Potassium hydroxide and sodium hydroxide solution are used as alkali activators. The strength is compared with Geo polymer concrete and conventional concrete. Fly ash-based Geo polymer concrete is a new material that does not need the Portland cement as a binder. There are two main constituents of geo polymers, namely the source materials and the alkaline liquids. The source material for geo polymers is based on alumina-silicate which should be rich in silicon (Si) and aluminium (Al). These could be natural minerals such as kaolinite, clays, etc. Alternatively, by-product materials such as fly ash could be used as source materials. Fly ash is a by-product from the coal industry, which is widely available in the world. Fly ash is rich in silicate and alumina, it reacts with alkaline solution to produce alumino silicate gel. This gel binds the loose aggregates and other unreacted materials in the mixture to form the geo polymer concrete. Hence, fly ash-based geo polymer concrete is a good alternative to overcome the abundant of fly ash. They have very high earlier strength. Fly ash based geo polymer also provided better resistance against aggressive environment and at high temperature compared to normal concrete.

KEYWORDS: pebbles; concrete; fly ash;Sodium silicate; alumina-silicate ;cracks.

I. INTRODUCTION

1.1 General

The production of cement causes pollution to the environment. The production of one ton of cement emits approximately one ton of carbon dioxide to the atmosphere.

The manufacturing of Ordinary Portland cement requires the burning of large quantities of fuel and decomposition of limestone, resulting in emissions of carbon di oxide. In spite of that the Concrete usage in the world is very important, thus Ordinary Portland cement is conventionally used as one of the primary binder to produce concrete.The demand for Portland cement is increasing day by day and hence we need an alternatematerial binders in concrete.Fly ash-based Geo polymer concrete is a new material that does not need the Portland cement as a binder. There are two main constituents of geo polymers, namely the source materials and the alkaline liquids. The sourcematerials for geo polymers isbased on alumina-silicate which should be rich in silicon and aluminium. Fly ash is rich in silicate and alumina, it reacts with alkaline solution to produce alumino silicate gel. This gel binds the loose aggregates and other unreacted materials in the mixture to form the geo polymer concrete[S.E.Wallah and B. V. Rangan 2006].

1.2 Need for this study

The Concrete usage in the world is very important. The production of cement causes pollution to the environment.The production of one ton of cement emits approximately one ton of carbon dioxide to the atmosphere. Fly ash-based Geo polymer concrete is a new material that does not need the Portland cement as a binder. The by-product materials such as fly ash could be used as source materials. They have very high earlier strength when compared to conventional concrete.

Fly ash based geo polymer also provided better resistance against aggressive environment and at high temperature compared to normal concrete. Due to depletion of natural blue granite stone, Pebbles can be used as an alternative material for coarse aggregate.

II. MATERIALS AND METHOD

2.1Pebbles as Coarse aggregate

Pebbles are rounded stone worn smooth by the action of water.The nominal size of pebbles used are 20 mm. The specific gravity of pebbles used is 2.82. The below given fig 1 represents pebbles aggregate. It is significant that earlier days the British people used pebbles for their construction (river pebbles) which were suitable for their work. And after the blue granite stones were introduced the usage of pebbles were dropped down. The scare in

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availability of pebbles also paved way for blue granite stones to over rule. But pebbled can also be used in construction when they have rough surface. Such a kind of a rough surface pebble (river pebble) is used in this experiment. Fig 1 shows the image of the pebbles.

Fig. 1 Pebble aggregate

III. FLY ASH

Fly ash is of coal fire by-product material from coal fired power station. The fly ash is conforming to Indian Standard IS 3812 (Part 1).The below given Fig 2 represents the sample of fly ash used in the concrete.
Specific gravity of fly ash = 2.20

Fig.2 Fly ash

3.1 Alkali activator solution

The alkali activator solution used consisted of a mixture of NaOH and Na2SiO3 solution. NaOH pellets of 98% purity were used to make NaOH solution of desired molarity.The below given Fig 3 and 4 represents sodium hydroxide pellets and sodium silicate solution respectively.

Fig. 3 Sodium hydroxide pellets

Fig. 4 Sodium silicate solution

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3.2MIX PROPOTION

The mix proportions that is to be carried out in this research project for the manufacture of geo polymer concrete are given in Table 1

Table 1 Mix proportions

S.no	Mix	Mix proportions
1	1	25 % Geo polymer + 75 % Cement mortor(pebbles)
2	2	50 % Geo polymer + 50 % Cement mortor(pebbles)
3	3	25 % Geo polymer + 75 % Cement mortor(blue granite)
4	4	50 Geo polymer + 50 % Cement mortor(blue granite)

IV. EXPERIMENTAL RESULTS

4.1General

This investigation deals with the test on concrete specimens for different mixtures of fly ash with blue granite stones and pebbles. The compression test, split tensile test and flexure test were carried out respectively of M25 grade of concrete. The Eoung's modulus was compared between blue granite stone and pebble with geopolymer concrete. The investigated parameters under this study were concrete strength and the percentage of replacement of geo polymer instead of cement. Further details of concrete specimens are as follows.

4.1.1 Geo polymer concrete

The primary difference between geo polymer concrete and Portland cement concrete is the binder. The silicon and aluminium oxides in the low-calcium fly ash reacts with the alkaline liquid to form the geo polymer paste that binds the loose coarse aggregates, fine aggregates, and other un-reacted materials together to form the geo polymer concrete. As in the case of Portland cement concrete, the coarse and fine aggregates occupy about 75 to 80% of the mass of geo polymer concrete. The influence of aggregates, such as grading, angularity and strength, are considered to be the same as in the case of Portland cement concrete.

4.1.2 Alkaline solutions

The common materials used as alkaline solution in producing fly ash-based geopolymer are sodium hydroxide and sodium silicate. Usually both the material was mixed to produce the alkaline solution and the molarity (M) of alkaline solution is 8 to 12 M. The alkaline solution was prepared a day before it is mixed with fly ash. Then, the materials are mixed together with fine aggregate and coarse aggregate toform concrete.

4.1.3 Curing of specimens

The curing of specimens is carried out using steam curing which accelerates the curing. Setting time of geo polymer depend on many factors such as composition of alkaline solution and ratio of alkaline liquid to fly ash by mass. However, the curing temperature is the most important factor for geo polymer. As the curing temperature increases the setting time of concrete decreases.

During curing process, the geo polymer concrete experience polymerization process. Due to the increasing of temperature, polymerization become more rapid and the concrete can gain 70% of it strength within 3 to 4 h of curing.The temperature for curing is takes as 60 °c. The remaining days are curing is done using ordinary water curing. The below given Fig5 represents steam curing.

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Fig. 5 Steam curing tank

4.2 specimen tests

4.2.1 Compression test

Concrete is primarily meant to withstand compressive stresses.Cubes, cylinders and prisms are the three types of compression test specimens used to determine the compressive strength.Cubes of size 100 × 100 × 100 mm are used in the present work.

The specimens are casted as follows

Apply the oil to mould for lubrication.Concrete is laid in the mould in a three layer and each layer is compacted with tamping rod.In this way, the concrete is laid in three layers and the procedure is repeated.The next step is vibration on a vibrating machine.

The cubes are cured for 28 days. After 28 days of curing, the cubes are tested in a Compression Testing Machine (CTM). The Fig 6 given below represents compression test for cube specimen.The unit for compressive strength is measured in N/mm^2

Fig. 6 Compression test for cube

4.2.2 Split Tensile Test

This is to determine the split tensile strength of concrete.Cylinders are the test specimens used to determine the tensile strength.Cylinders of size 100 mm diameter and length 200 mm are used in the present work.

The specimens are casted as follows

Apply oil to the moulds for lubrication.Concrete is laid in the mould in a three layer and compacted with tamping rod.The next step is vibration on a vibrating machine.

The cylinders are cured for 28 days.After 28 days of curing, the cylinders are tested in a Compression Testing Machine (CTM). The Fig 7 given below represents the split tensile test for cylinder.

Fig. 7 split tensile test for cylinder

4.2.3 Flexure Test

Concrete is likely to withstand little bending stresses.Beams are the bending test specimens used to determine the flexural strength.Beams of size 100 × 100 × 500 mm are used in the present work.

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The specimens are casted as follows
Apply oil for the moulds for lubrication.Concrete is laid in the mould in three layers and each layer is compacted with tamping rod.In this way, the concrete is laid in and the procedure is repeated.The next step is vibration on a vibrating machine.The beams are cured for 28 days. After 28 days of curing, the beams are tested for flexural test under two point loading.The Fig 8 given below represents the flexural test for beam specimens.

Fig.8 Flexural test for beam

The parameters for geopolymerconcreteis given in Table 2. This shows the quantity of ingredients used in this experiment with blue granite stones and pebbles.

Table 2 parameters for geopolymer concrete

Mix	**Aggregate (kg/m^3)**	**Cement (kg/m^3)**	**Fly Ash (kg/m^3)**	**Fa (kg/m^3)**	**Ca (kg/m^3)**	**Water (kg/m^3)**	**Total alkali activator Solution (kg/m^3)**	**Sodium hydroxide Solution (kg/m^3)**	**Sodium silicate Solution (kg/m^3)**
25%GP 75%CM	PEBBLES	358	120	656.5	1140	143.2	47.75	13.64	34.11
50%GP 50%CM	PEBBLES	238.7	238.7	656.5	1140	95.5	95.50	27.28	68.21
25%GP 75%CM	BLUE GRANITE	358	120	656.5	1107	143.2	47.75	13.64	34.11
50%GP 50%CM	BLUE GRANITE	235.7	238.7	656.5	1107	95.5	95.50	27.28	68.21

4.3 Test results

4.3.1 Compressive strength for cube

The compression test was carried out in the cube specimens in various mixes. It was found that 50 % replacement of cement with geo polymer gives good compressive strength using blue granite as coarse aggregate than compared to 50 % replacement of cement with geo polymer using pebbles as coarse aggregate because the fly ash bonding with pebbles aggregate is less due to the smooth surface.Fig 6 and Table 3 given below represents compression test for cube specimen.

Table 3 compressive strength results for cubes

S.no	**Description**	**Compressive strength (N/mm^2)**		
		3 days	**7 days**	**28 days**
1	Conventional (B.G)	15.10	21.50	28.30
2	Conventional (pebbles)	17.63	19.16	28.60
3	25% GP + 75 % CM (8M)(B.G) (steam curing)	16.20	22.05	28.32
		16.68	22.76	28.40

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4	25% GP + 75 % CM (10M)(B.G) (steam curing)			
5	25% GP + 75 % CM (12M)(B.G) (steam curing)	15.65	21.15	28.50
6	50% GP + 50 % CM (8M)(B.G) (steam curing)	15.80	21.55	28.54
7	50% GP + 50 % CM (10M)(B.G) (steam curing)	16.20	22.25	28.60
8	50% GP + 50 % CM (12M)(B.G) (steam curing)	16.28	23.73	**28.90 ***
9	25% GP + 75 % CM (8M) (PEB) (steam curing)	14.40	16.40	27.03
10	25% GP + 75 % CM (10M)(PEB) (steam curing)	14.03	16.43	27.23
11	25% GP + 75 % CM (12M)(PEB) (steam curing)	14.73	17.20	27.50
12	50% GP + 50 % CM (8M) (PEB) (steam curing)	15.30	20.03	28.30
13	50% GP + 50 % CM (10M)(PEB) (Steam curing)	15.43	20.20	28.37
14	50% GP + 50 % CM (12M)(PEB) (Steam curing)	15.85	20.4	28.40

4.3.2 Split tensile strength

The Split tensile test was carried out in the cube specimens in various mixes. It was found that 50 % replacement of cement with geo polymer gives good tensile strength using blue granite as coarse aggregate than compared to 50 % replacement of cement with geo polymer using pebbles as coarse aggregate because the fly ash bonding with pebbles aggregate is less due to the smooth surface.

Fig7 and Table 4 given below represents split tensile test on cylinder specimen and split tensile strength results respectively.

Table 4 spilt tensile results for cylinders

S.no	Description	Split Tensile strength (N/mm^2)		
		3 days	7 days	28 days
1	Conventional (B.G)	1.50	1.90	2.92
2	Conventional (pebbles)	1.52	1.95	2.90
3	25% GP + 75 % CM (8M)(B.G) (steam curing)	1.46	2.85	2.80
4	25% GP + 75 % CM (10M)(B.G) (steam curing)	1.48	1.76	2.84
5	25% GP + 75 % CM (12M)(B.G) (steam curing)	1.46	1.78	2.90
6	50% GP + 50 % CM (8M)(B.G) (steam curing)	1.43	1.82	2.94
7	50% GP + 50 % CM (10M)(B.G) (steam curing)	1.50	1.82	2.90
8	50% GP + 50 % CM (12M)(B.G) (steam curing)	1.65	1.96	**3.0 ***
9	25% GP + 75 % CM (8M) (PEB) (steam curing)	1.40	1.80	2.70
10	25% GP + 75 % CM (10M)(PEB) (steam curing)	1.20	1.67	2.65
11	25% GP + 75 % CM (12M)(PEB) (steam curing)	1.25	1.66	2.54
12	50% GP + 50 % CM (8M) (PEB) (steam curing)	1.27	1.76	2.86
13	50% GP + 50 % CM (10M)(PEB) (Steam curing)	1.36	1.76	2.83
14	50% GP + 50 % CM (12M)(PEB) (Steam curing)	1.28	1.71	2.95

Conti…

4.3.3 Flexural strength

The flexural strengthtest was carried out in the cube specimens in various mixes. It was found that 50 % replacement of cement with geo polymer gives good tensile strength using blue granite as coarse aggregate than compared to 50 % replacement of cement with geo polymer using pebbles as coarse aggregate because the bonding with pebbles aggregate is less due to the smooth surface and the flexural strength is greatly reduced in pebbles aggregate.

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Fig 8 and Table 5 given below represents split tensile test on cylinder specimen and split tensile strength results respectively.

Table 5 flexural strength results for beams

S.no	Description	Flexural strength (N/mm^2)		
		3 days	7 days	28 days
1	Conventional (B.G)	1.40	2.12	3.80
2	Conventional (pebbles)	1.48	2.48	3.60
3	25% GP + 75 % CM (8M)(B.G) (steam curing)	1.40	2.60	3.60
4	25% GP + 75 % CM (10M)(B.G) (steam curing)	1.60	2.80	4.00
5	25% GP + 75 % CM (12M)(B.G) (steam curing)	1.80	3.00	4.00
6	50% GP + 50 % CM (8M)(B.G) (steam curing)	2.00	3.20	4.00
7	50% GP + 50 % CM (10M)(B.G) (steam curing)	2.20	3.20	4.40
8	50% GP + 50 % CM (12M)(B.G) (steam curing)	2.40	3.2	**4.40 ***
9	25% GP + 75 % CM (8M) (PEB) (steam curing)	1.40	2.60	3.70
10	25% GP + 75 % CM (10M)(PEB) (steam curing)	1.20	2.92	3.84
11	25% GP + 75 % CM (12M)(PEB) (steam curing)	1.25	2.20	3.40
12	50% GP + 50 % CM (8M) (PEB) (steam curing)	1.27	3.00	3.80
13	50% GP + 50 % CM (10M)(PEB) (Steam curing)	1.36	3.20	3.60
14	50% GP + 50 % CM (12M)(PEB) (Steam curing)	1.28	2.80	3.60

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V. RESULTS AND DISCUSSIONS

5.1 Compressive strength comparison

The fig 9 given below represents comparison of compressive strength between blue granite stones and pebbles with geopolymer concrete. This shows the proportion of geopolymer concrete (50% fly ash) + 12 molarity + blue granite stones have the higher compressive strength (28.90 N/mm^2) than geopolymer concrete (50% fly ash) + 12 molarity + pebbles (28.40N/mm^2) for M 25 grade concrete which is given in Table 3.

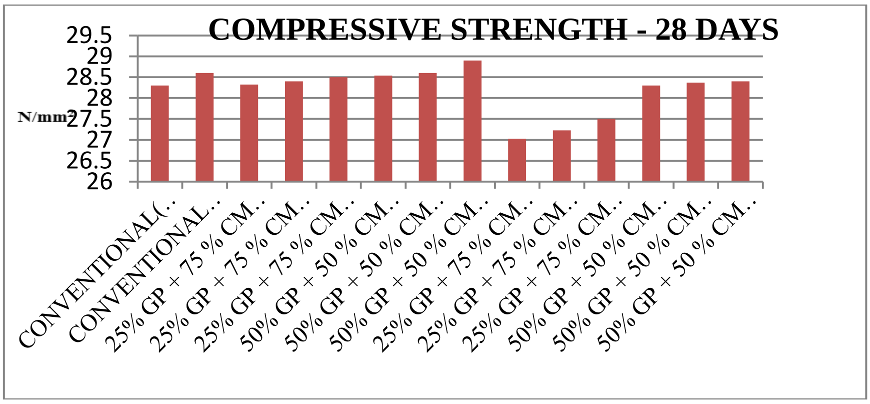

Fig. 9 Compressive strength comparison

5.2 Split tensile strength comparison

The fig 10 given below represents comparison of compressive strength between blue granite stones and pebbles with geopolymer concrete. This shows the proportion of geopolymer concrete (50% fly ash) + 12 molarity + blue granite stones have the higher split tensile strength (3.0 N/mm^2) than geopolymer concrete (50% fly ash) + 12 molarity + pebbles (2.95N/mm^2) for M 25 grade concrete which is given in Table 4.

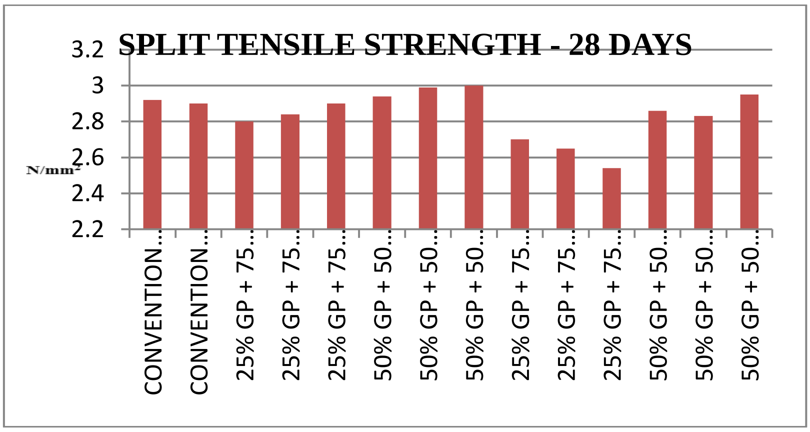

Fig. 10Split tensile strength comparison

5.3Flexural strength comparison

The fig 11 given below represents comparison of compressive strength between blue granite stones and pebbles with geopolymer concrete. This shows the proportion of geopolymer concrete (50% fly ash) + 12 molarity + blue granite stones have the higher flexural strength (4.40 N/mm^2) than geopolymer concrete (50% fly ash) + 12 molarity + pebbles (3.60N/mm^2) for M 25 grade concrete which is given in Table 5.

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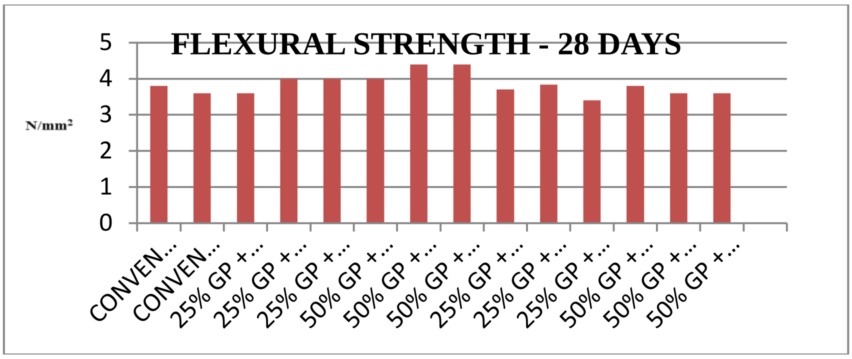

Fig. 11Flexural strength comparison

5.4 Fresh age density test

The fresh age density test is carried out in order to find out the fresh slump of concrete. The freash age density is carried out for the optimum molarityand maximum percentage of geopolymer concrete. Therefore it is experimented forgeopolymer concrete (50% fly ash) + 12 molarity + blue granite stones and geopolymer concrete (50% fly ash) + 12 molarity + pebbles.The below given fig 12 represents fresh age density test and the Table 6 shows the valve of fresh age density of 50% of geopolymer concrete between blue granite stones and pebbles. The pebbles has high fresh age density (86 mm).

Fig. 12 Fresh age Test

The fresh age density of geopolymer concrete (50% fly ash) between blue granite stones and pebbles is given Table 6.

Table 6 Fresh Age Density

Fresh age density	
50% fly ash 50 % cm (blue granite aggregate)	**50% fly ash 50 % cm (pebble aggregate)**
Fresh age density = 75 mm	Fresh age density = 86 mm

5.5 Young's modulus test

The Young's modulus is the measure of the stiffness of an elastic isotropic material .It is defined as the ratio of the stress along an axis over the strain along that axis in the range of stress . The slope of the stress–strain curve at any point is called the tangent modulus. The tangent modulus of the initial, linear portion of a stress–strain curve is called Young's modulus. The below given fig 13 represents the compressometer test.

Young's modulus is found for geo polymer concrete with 12 M molarity and 50% fly ash using blue granite aggregate and pebbles. The graph is drawn for young's modulus valve which is shown in Fig14 and 15 for the proportiongeopolymer concrete (50% fly ash) + 12 molarity + blue granite stones and geopolymer concrete (50% fly ash) + 12 molarity + pebblesrespectively. The valves are listed in the Table 7 for blue granite stones and pebbles

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Fig. 13Compressometer Test

The table shows Young's Modulus forgeopolymer concrete (50% fly ash) + 12 molarity + blue granite stones and pebbles.

Table 7 Young's Modulus result

Material	Young's modulus
50% FLY ASH 50 % CM (Blue granite aggregate)	E=2.578 X10^4 N/mm^2
50% FLY ASH 50 % CM (Pebble aggregate)	E=2.198 X10^4 N/mm^2

The fig 14 and 15 shows gragh of Young's Modulus for blue granite stones and pebbles respectively. The young's modulus of geopolymer concrete (50% fly ash) + 12 molarity + blue granite stones have higher valve (E =2.578 X10^4) than geopolymer concrete (50% fly ash) + 12 molarity + pebbles (E =2.198 X10^4).

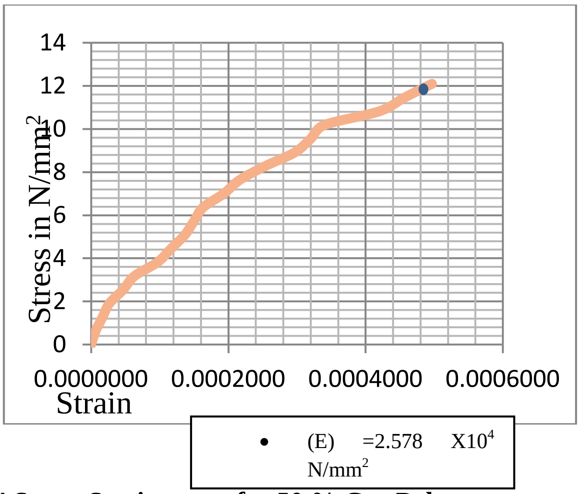

Fig. 14 Stress Strain curve for 50 % Geo Polymer concrete using pebbles aggregate

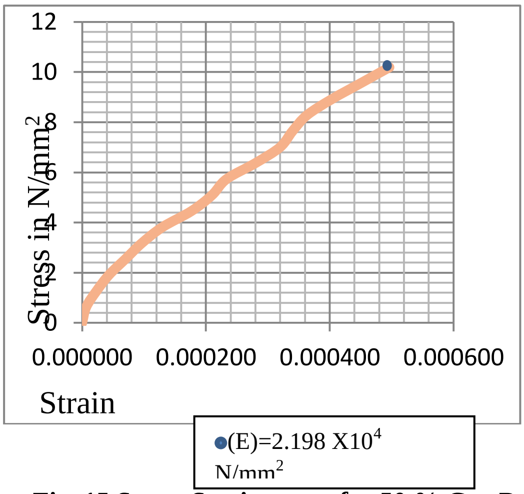

Fig. 15 Stress Strain curve for 50 % Geo Polymer concrete using Blue granite aggregate..

VI. CONCLUSIONS

Fly ash-based geo polymer is better than normal concrete in many aspects such as strength, exposure to aggressive environment, workability and exposure to high temperature.Compressive strength of GPC using blue granite stone increases over GPC using Pebbles concrete by 1.02 times with 12 molarity. Split Tensile Strength of GPC using blue granite stone increases over GPC using Pebbles concrete by 1.02 times with 12 molarity. Flexural Strength of GPC using blue granite stone increases over GPC using Pebbles concrete by 1.22 times with 12molarity.The Fresh age density of geo polymer concrete using pebbles increases 1.15 times than blue granite aggregate.Young's modulus of geo polymer concrete using blue granite aggregate increases 1.2 times than pebbles aggregate

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The Stress Strain curve were compared for conventional blue granite aggregate and pebbles .It was found that the Stress Strain curve for Geo polymer concrete (50% fly ash) with B.G aggregate was better than Geo polymer oncrete (50 % fly ash) with pebbles as given in table 5.10 and 5.11 respectively..

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