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An Experimental Study on Geopolymer Concrete with Varying Proportion of Manufactured Sand

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ABSTRACT: Geo –Polymer concrete utilizes an alternate material called fly ash as binding material instead of cement. Fly ash reacts with alkaline solution (e.g. NaOH) and sodium silicate (Na_2SiO_3 to form a gel which binds the fine and coarse aggregates. Another artificial material called as manufactured sand (M-Sand) is also used as the fine aggregate against the normal river sand in varying proportion. In this paper the strength parameters for Geo- Polymer concrete with varying proportion of manufactured sand was tested and analysed. The strength of ordinary Geo – Polymer concrete with varying proportion of M- Sand and found the strength of Geo – Polymer Concrete with M-Sand can be an alternative to ordinary Portland cement concrete.

I. INTRODUCTION

Concrete is one of the most widely used materials in the world. Ordinary Portland Cement (OPC) is conventionally used as the primary binder to produce concrete. The amount of the carbon dioxide released during the manufacture of OPC due to the calcination of lime stone and combustion of fossil fuel is in the order of one ton for every ton of OPC Produced. On the other hand, the abundant availability of fly ash worldwide creates opportunity to utilize this by product of burning coal, as a substitute for OPC to manufacture concrete. Low calcium fly ash based Geo – Polymer is used as a binder, instead of Portland or other hydraulic cement paste, to produce concrete. The fly ash reacted materials together to form the Geo – Polymer concrete, with or without the presence of admixtures. The silicon and the aluminium in the fly ashreacted with an alkaline liquid that is a combination of sodium silicate and sodium hydroxide solutions to form the Geo – Polymer paste that binds the aggregates and the other un –reacted materials environment pressures to reduce extraction of sand from rivers, the use of manufactured sand as a replacement is increasing. There is a need for clean sand in the construction from the point of view of durability of structures. As the demand for natural river sand is exceeding the availability, it has resulted in fast diminution of natural sand sources. Hence, river sand is replaced by manufactured sand to overcome the demand.

Concrete usage around the world is next to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calcination of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced.

On the other hand, the abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for OPC to manufacture concrete. As the demand for concrete as a construction material increases, so also the demand for Portland cement. It is estimated that the production of cement will increase from about from 1.5 billion tons in 1995 to 2.2 billion tons in 2010 (Malhotra, 1999).

With the world wide decline in the availability of construction sands When used as a partial replacement of OPC, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate

(C-S-H) gel. The development and application of high volume fly ash concrete, which enabled the replacement of OPC up to 60% by mass, is a significant development. In 1988, Davidovits proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminum in source materials of geological origin or by-product materials such as fly ash rice husk ash. He termed these binders as geopolymer

With the world wide decline in the availabilityof construction sands along with the environmental pressures to reduce extraction of sand from rivers, the use of manufactured sand as a replacement is increasing. There is a need for 'clean sand' in the construction from the point of view of durability of structures. As the demand for Natural River sand is surpassing the availability, has resulted in fast depletion of natural sand sources

The technology developed for rock-based geopolymer cements reduces co_2 emission by 80%.geopolymeric cements are manufactured in a different manner than Portland cement. geopolymers do not rely on the calcination of $caco_3$ and therefore do not release bounded co_2.they also do not require extreme high temperature kilns ,with large expenditure of fuel, nor do geopolymers require such a large capital investment in plants and equipment.the mechanical properties of these novel geopolymeric cements are similar to those of regular Portland cement.

Appropriate geological resources are available on all continents for providing suitable raw materials.the issue of long term durability was studied in relation with archaeological analogues,namely ancient roman cements.

A new linguistic study of the latin author Vitruvius 'famous book << De Architecture >> (1stcentury BC) outlines unique properties of a "carbunculus" cement,which was manufactured by calcining geological materials (see in archaeo-analogues and in a paper #E searching for" carbunculus".

During cement manufacture this recreated ancient roman cement reduces co_2 emissions by 55-60%. introducing low co_2 rock based geopolymer cements would ,on one hand, allow unlimited development of concrete infrastructures for the global economy and ,on the other hand ,dramatically mitigate co_2 greenhouse gas emissions.the European industrial research consortium GEOCYSTEM (European multidisciplinary brite euram industrial research project funded by the European commission) developed rock – based geopolymer cements that mitigate co_2 emissions by 80%.seeing the results on GEOCISTEM.successfull accomplishment of the GEOCISTEM exemplifies the theoretical studies of the background knowledge (see the research project global warming and in global warming and also for example #21 geopolymer cement review 2013) and demonstrates that it is possible to manufacture new cements with low-co_2 emission during their fabrication, to minimize the green house <<Green House>> Global-warming. The table and figure show interesting data on energy cost and co_2 emission for Portland cement and for three types of geopolymeric cements developed during the GEOCISTEM project glass cement and two CARBUNCULUS cements

II. FLYASH BASED POLYMER

In this project, fly ash based geopolymer is used as binder ,instead of Portland or other hydraulic cement paste ,to produce concrete .the fly ash based geopolymer paste binds the loose coarse aggregates ,fine aggregates and other unreacted materials together to form geopolymer concrete ,with or without presence of admixtures.

The manufacture of geo-polymer concrete is carried out using the usual concrete technology methods. As in the case of OPC concrete, the aggregates occupy about 75-80% by mass, in concrete. The silicon and the aluminium in the fly ash reacted with an alkaline liquid that is a combination of sodium silicate and sodium hydroxide solutions to form the geo-polymer paste that binds the aggregates and other un-reacted materials.

Fly ash based geopolymer cements reduce CO2 emissions by 90% when compared to Portland cement. The GEOASH (2004-2007) project was carried out with a financial grant from the Research fund for coal and steel of the European community. The GEOASH project is known under the contract number RFC-CR-04005. It involves: Antennuci D.,ISSeP, Liege, Belgium; Nugteren H.and Butselaar-Orthlieb V., Delft University of Technology, Delft, The Netherlands; Davidovits J., Cordi-Geopolymere Sarl, Saint-Quentin, France; Fernandez-Pereira c. and Luna Y., University of Seville, School of Industrial Engineering,Sevilla, Spain; Izquierdo M. and Querol X., CSIC, Institute of Earth sciences "Jaume Almera", Barcelona, Spain.

Seventeen samples of co-combustion European fly ashes were tested on their suitability for geopolymeric cements. Normally,curing of flyash –based matrices is done at temperatures between 60 and 90^{o}C

In this project ,since the idea is to use the geopolymer as a cement,curing takesplace at ambient temperature ,with a modified (Ca,K)based geopolymeric system .the final technical and report was presented mid 2008.detailed information found in technical paper # 22 at GEOASH :fly ash –based geopolymer cements as well as in updated 3rd edition of davidovitis book geopolymer chemistry & applications chapter 12

Two methods were used and compared it one classical method or conventional method ,relies on alkali –activation and pure NAOH (8M,12M) i.e user-hostile conditions the geopolymeric method was developed for the implementation of all kind of geological materials ,eg .Rock –based geopolymers .the (K,Na,Ca) poly(sialate-siloxo) process is based on the system of flyash /slag/ksil/ H_2O reacting at room temperature.the ashes, 60-80% by weight of the mix,were mixed with geopolymeric slurry containing alkali-silicate solution (molar SiO_2:M_2O > 1.40),blast furnace slag and water ,and cured at room temperature

The investigations by palomo and his team (Fernandez-jimenez and palomo,2003),are often taken in literature as the reference.they claim that the pure NAOH based zeolitic system should be considered as the reference in the determination of the chemical parameters leading to a material with optimal binding properties .

According to these standard criteria ,any flyash with a mullite content higher than 5% is not suitable and may not be used .six flyashes were selected and submitted to this criteria.results were shown below.only two flyashes ,CSIC-4 and CSIC-5 have mullite content lower than 5% and might work with alkali - activation.the results of (Ca,K) based geopolymeric method, it shows 28day compressive strength abstained in relation with mullite content. All values are higher than 50mpa ,the majority reaching strengths higher than 70mpa.it is therefore important to notice that practically all class fly ash types,i.e those with low free CaO,can be used with this user friendly system.

It has also been measured that for a given flyash the conventional alkali-activation (zeolitic method) provides lower compressive strength than the (Ca,K,Na)-based geopolymeric Procedure. The Geopolymeric method yields higher strengths as well as lower costs (no thermal activation needed) and safer and easier handling treatment i.e user friendly.

III. SCOPE OF PRESENT INVESTIGATION

The sand from river due to natural process of attrition tends to possess smoother surface texture and better shape. It also carries moisture that is trapped in between the particles. These characters make concrete workability better. However, silt and clay carried by river sand can be harmful to the concrete.

Another issue associated with river sand is that of obtaining required grading with a fineness modulus of 2.4 to 3.1.It has been verified and found, at various locations across south India, that it has become increasingly difficult to get riversand of consistent quality in terms of grading requirements and limited silt / clay content. It is because we do not have any control over the natural process.

In case of manufactured sand, the process of attrition through VSI and washing makes the crushed stone sand particles good enough to be compared shape and surface texture of natural sand. With well-designed screening system the required grading (Zone II) and fineness modulus (2.4 to 3.1) can also be achieved consistently in the case of manufactured sand.

It must be noted that properly processed manufactured sand can improve both compressive strength and flexural strength through better bond compared to river sand

The study of geo-polymer concrete provides an alternative for ordinary Portland cement which reduces CO_2 emission and produce eco-friendly concrete. It provides high strength concrete than ordinary Portland cement.

- To study the different strength properties of geo-polymer concrete with percentage replacement of manufactured sand.
- To compare the cost variation of geo-polymer concrete with normal concrete
- The incorporation of geo-polymer concrete in construction field has led to the total elimination of cement from concrete which ultimately becomes

"GREEN CONCRETE"

- Increase the efficiency of the construction while at the same time maintaining the highest levels of product quality under the conduction of natural sand shortage.

3.1MATERIALS USED

Materials used for manufacturing geopolymer concrete are as follows:

- Fly ash

- Ordinary Portland Cement
- Alkaline solutions
- Aggregates
- Super plasticizer
- Water

3.1.1 Fly ash

Fly ash is one of the most abundant materials on the Earth. It is also a crucial ingredient in the creation of geopolymer concrete due to its role in the geopolymerization process. Fly ash is a powdery pozzolan. A pozzolan is a material that exhibits cementitious properties when combined with calcium hydroxide. Fly ash is the main byproduct created from the combustion of coal in coal-fired power plants. There are two “classes” of fly ash, Class F and Class C. Each class of fly ash has its own unique properties. Class F fly ash is created from the burning of either anthracite or bituminous coal. This Class of fly ash has little to no self-cementing properties and contains very little calcium oxide (also known as lime). In order to apply Class F fly ash in concrete, it must be combined with some type of cementing agent, such as Portland cement, and must also be combined with an air-entraining admixture. This is not a very economic process if it is going to be made into ordinary concrete. Class C fly ash, on the other hand, is produced through the combustion of lignite or subbituminous coal. Unlike Class F fly ash, it has self-cementing properties and a much higher lime concentration which makes it ideal for use in ordinary Portland cement based concrete.

Table 4.1.Chemical composition of fly ash

Oxides	Percentage
Sio_2	52.0
Al_2O_3	33.9
Fe_2O_3	4.0
CaO	1.2
K_2O	0.83
Na_2O	0.27
MgO	0.81
SO_3	0.28
LOI	6.23
SiO_2/Al_2O_3	1.5

The specific gravity of fly ash is given below.

The Le-chatelier flask was dried carefully and filled with kerosene or naphtha to a point on the stem between zero and 1 ml. Record the level of the liquid in the flask as initial reading. Put a quantity of fly ash (about 60 gm) into the flask so that level of kerosene rise to about 22 ml mark, care being taken to avoid splashing and to see that cement does not adhere to the sides of the above the liquid. After putting all the fly ash to the flask, roll the flask gently in an inclined position to expel air until no further air bubble rises to the surface of the liquid. Note down the new liquid level as final reading.

Weight of fly ash = 60gm
Initial reading of flask = 0ml
Final reading of flask = 24.48ml
Volume of fly ash = Final reading- Initial reading
= 24.48ml
Weight of equal volume of water = 24.48gm
Specific weight of fly ash = wt. of fly ash used /wt.of equal volume of water
=60/24.48
Specific gravity of cement = **2.45**

3.1.2. Ordinary Portland cement

Portland cement is by far the most common type of cement in general use around the world. This cement is made by heating limestone(calcium carbonate) with small quantities of other materials (such as clay) to 1450 °C in a kiln, in a process known as calcination, whereby a molecule of carbon dioxide is liberated from the calcium carbonate to form calcium oxide, or quicklime, which is then blended with the other materials that have been included in the mix. The resulting hard substance, called 'clinker', is then ground with a small amount of gypsum into a powder to make 'Ordinary Portland Cement', the most commonly used type of cement (often referred to as OPC).Portland cement is a basic ingredient of concrete, mortar and most non-specialty grout. The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. Portland cement may be grey or white.

Table 4.2 Chemical composition of ordinary Portland cement

Compound	**Formula**	**Shorthand form**	**Percentage by weight**
Tricalcium aluminate	$Ca_3Al_2O_6$	C_3A	10
Tetracalciumluminoferrite	$Ca_4Al_2Fe_2O_{10}$	C_4AF	8
Belite or dicalcium silicate	Ca_2SiO_5	C_2S	20
Alite or tricalcium silicate	Ca_3SiO_4	C_3S	55
Sodium oxide	Na_2O	N	Upto 2
Potassium oxide	K_2O	K	
Gypsum	$CaSO_4.2H_2O$	$C\underline{S}H_2$	5

The Le-chatelier flask was dried carefully and filled with kerosene or naphtha to a point on the stem between zero and 1 ml. Record the level of the liquid in the flask as initial reading. Put a quantity of cement (about 60 gm) into the flask so that level of kerosene rise to about 22 ml mark, care being taken to avoid splashing and to see that cement does not adhere to the sides of the above the liquid. After putting all the cement to the flask, roll the flask gently in an inclined position to expel air until no further air bubble rises to the surface of the liquid. Note down the new liquid level as final reading.

Weight of cement= 60gm
Initial reading of flask = 0ml
Final reading of flask = 19ml
Volume of cement = Final reading- Initial reading
= 19ml
Weight of equal volume of water = 19gm
Specific weight of cement = weight of cement used / weight of equal volume of water
Specific gravity of cement = **3.15**

Fineness of cement is given below.

Cement was weighed accurately for 100gms and placed on IS: sieve 90micron.Air lumps are broken using fingers. Allow gentle sieving is done continuously for 15 minutes. The residue left is weighed. The residue left is weighed this shall not exceed 10% by weight of sample of cement .Repeat the procedure for two more samples.The fineness of cement sample - **98.03%**

3.1.3 Alkaline Solutions

Sodium based alkaline solution were used to react with the source materials to produce the binder. Sodium-silicate solution was used for the concrete production. Sodium hydroxide solution (NaOH) was prepared by dissolving NaOH pellets in water. The pellets are commercial grade with 97% purity. Physical appearance of alkaline solutions are shown in the figures.

The sodium hydroxide solution was prepared one to two days prior to the concrete batching to allow the exothermically heated liquid to cool to room temperature. The Na_2Sio_3 and NaOH solution were mixed just prior to the concrete batching. This is a different process to that which had been employed previously at Curtin University where the two alkaline solutions were mixed 24 hour prior to casting.

In this study the compressive strength of geo-polymer concrete is examined for the mixes of varying molarities of NaOH solution (5M,8M and 11M). The molecular weight of NaOH is 40. For example to prepare 3M of NaOH solution 120g of NaOH flakes are weighted and they can be dissolved in distilled water to form 1 litre solution. For this, volumetric flask of 1 litre capacity is taken, NaOH flakes are added slowly to distilled water to prepare 1litre solution. Commercial grade of Na_2SiO_3 solution was used which had a chemical composition of 8% NaO,26% SiO_2 and 64% water by mass. The ratio of Na_2siO_3 to NaOH was kept as 2.5.The sodium silicate properties are shown in table 3.3.

Table 4.3. Sodium Silicate Properties

Chemical composition	**Nao×sio$_2$ colour less**
Na_2O	15.9%
SiO_2	31.4%
H_2O	52.7%
Appearance	Liquid(gel)
Colour	Light yellow

Molecular weight	184.04
Specific gravity	2.6

3.1.4. Aggregate

Coarse aggregate of size 20mm and fine aggregate taken for the study. Sieve analysis is done to find the particle distribution of the aggregates Fineness Modulus of aggregate is an index to find the fineness of aggregates. Fineness Modulus is also found using an empirical formula obtained by adding cumulative percentages of aggregate retained on each of the standard sieves and dividing this sum by an arbitrary number 100.

Specific gravity test of fine aggregate is found using pycnometer .The pycnometer is washed, cleaned and dried. The pycnometer with brass cap and washer is weighed (w_1). 200 gms. of oven dried sand is taken in the pycnometer and is weighed with its cap and washer (w_2).The pycnometer is filled to half of its height with water and mixed thoroughly with glass rod .Add more water and stir it . Replace the screw top and fill the pycnometer with water through the hole in the conical cap and weigh (w_3). Empty the pycnometer, clean it thoroughly and fill it with water to the .whole of conical cap and weigh it with (w_4)

Specific gravity was calculated by the formula = (w2-w1)/[(w4-w1)-(w3-w2)]
Empty weight w1 = 0.6303gm
Weight of pycnometer +sand w2 = 1.3640gm
Weight of pycnometer +sand +water w3 = 2.0410gm
Weight of pycnometer+ water w4 = 1.5440gm
Specific gravity of fine aggregate = (w2-w1)/[(w4-w1)-(w3-w2)]= (1.3960-0.6323)/[(1.5440-0.6323) - (2.0410- 1.3640)]
Specific gravity of fine aggregate = 2.66

Manufactured sand is crushed aggregates produced from hard granite stone, gravel or slag which is cubically shaped with grounded edges, washed and graded with consistency to be used as a substitute of river sand. In this project we are replacing fine aggregate (river sand) by manufactured sand. Specific gravity of manufactured sand was also found using the same procedure and calculation.

Specific gravity of manufactured sand = 2.07
Specific gravity test: - Course aggregate

Coarse aggregate of 500g is taken. Empty clean water bucket is taken and weighed w1.Weighed 500gm of coarse aggregate is taken in the water b and weight of water bucket with coarse aggregate is weighed w2.The bucket with coarse aggregate is immersed in water and weighed w4.And then the aggregates are removed from the water bucket and the plain water bucket is immersed in water and weighed w4.
Specific gravity was calculated by the formula = (w2-w1)/[(w4-w1)-(w3-w2)]
Specific gravity of coarse aggregate = 2.770

Sieve analysis for aggregates. A two kg air dry sample of fine aggregate was taken. The set of sieves were arranged in order of the aperture size such that the sieve having smaller opening comes at the bottom. The aggregate was poured into the top sieve was placed on the sieve shaker and shaken for 10 mins. The weight of aggregates retained on each sieve was measured and noted. The procedure was repeated for 5kg sample of air-dry coarse aggregate with a different set of sieves

Table 4.4 Properties of aggregate

S.no	Property	Coarse aggregate	Fine aggregate
1	Specific gravity	2.77	2.66
2	Fineness modulus	2.1	2.708
3	Zone	-	II

3.1.5 Manufactured Sand

Manufactured sand is crushed aggregates produced from hard granite stone, gravel or slag which is cubically shaped with grounded edges, washed and graded with consistency to be used as a substitute of river sand. In this project we are replacing fine aggregate (river sand) by manufactured sand in the ratio of 0%,20%, 40%, 60%, 80%, 100%.

Specific gravity of manufactured sand was also found using the same procedure and calculation.Specific gravity of manufactured sand =2.07 concrete mix proportions chosen should be such that the concrete is of adequate workability for the placing condition of the concrete and we can properly be compacted with the means available. In hardened state concrete shall have required strength, durability and surface finish Fine aggregate is one of the important constituents of

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concrete. As natural sand deposits becomes depleted near some areas of metropolitan growth, the use of manufactured sands as a replacement fine aggregate in concrete receiving increased attention. Designers, specifiers, contractors and material suppliers need to understand the effects of manufactured sand characteristics on concrete water demand and concrete durability. IS 383–1970 (reaffirmed 2007) recognize manufacture sand as 'Crushed stone sand' under clause2

3.1.6 Superplasticizer

Superplasticizers, also known as high range water reducers, are chemical admixtures used where well-dispersed particle suspension is required. These polymers are used as dispersants to avoid particle segregation (gravel, coarse and fine sands), and to improve the flow characteristics (rheology) of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture, and enables the production of self-consolidating concrete and high performance concrete. This effect drastically improves the performance of the hardening fresh paste. If we need in order to improve the workability of fresh concrete, high range water reducing thermos plasticizers were used.

3.1.7 Water

A properly designed mixture possesses the desired workability for the fresh concrete and the required durability and strength for the hardened concrete. Typically, a mix is about 10 to 15 percent.Extra water nearly 10% of binder is added to increase the workability of the concrete.The water used for the experimentation confirms to the standards available in table 1 of IS-456-2000

IV. RESULTS AND DISCUSSION

4.1 GENERAL

Strength properties of geo-polymer concrete were studied, 6 different mixes were prepared by replacing river sand by manufactured sand in varying proportion such as 0%, 20%, 40%, 60%, 80%, 100% are shown in the table 5.1.

Constituents	GPC1 (kg/m^3)	GPC2 (kg/m^3)	GPC3 (kg/m^3)	GPC4 (kg/m^3)	GPC4 (kg/m^3)	GPC5 (kg/m^3)
Fly ash	408	408	408	408	408	408
Coarse aggregate	1294	1294	1294	1294	1294	1294
Fine aggregate	554	443.2	332.4	221.6	110.8	-
Manufactured sand	-	110.8 (20%)	221.6 (40%)	332.4 (60%)	443.2 (80%)	554 (100%)
Sodium silicate	103	103	103	103	103	103
Sodium hydroide	41	41	41	41	41	41

Table 5.1 Mix proportion of GPC with M-sand

4.2 COMPRESSIVE STRENGTH TEST

In the study of properties of materials, the compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine.

Compressive strength is one of the most important properties of concrete cubes of size 150mmx150mmx150mm were cast with varying proportion of manufactured sand and oven dried for 24hours at 60°c and compressive strength for 3, 7, 14, 21 and 28 days were tested. Compressive strength of geopolymer concrete with manufactured sand is shown in table 5.2

Table 5.2 Compressive strength of geo-polymer concrete with manufactured sand

Mix	**Cube strength (N/mm^2)**				
	3 days	7days	14 days	21 days	28days
GPC1	13.83	24.44	28.17	31.45	34.22
GPC2	13.97	24.66	28.48	31.80	34.60
GPC3	14.20	25.11	28.90	32.27	35.11
GPC4	14.6	25.77	29.63	33.09	36
GPC5	14.75	26.44	30.17	33.69	36.66
GPC6	15.08	27	30.73	34.31	37.33

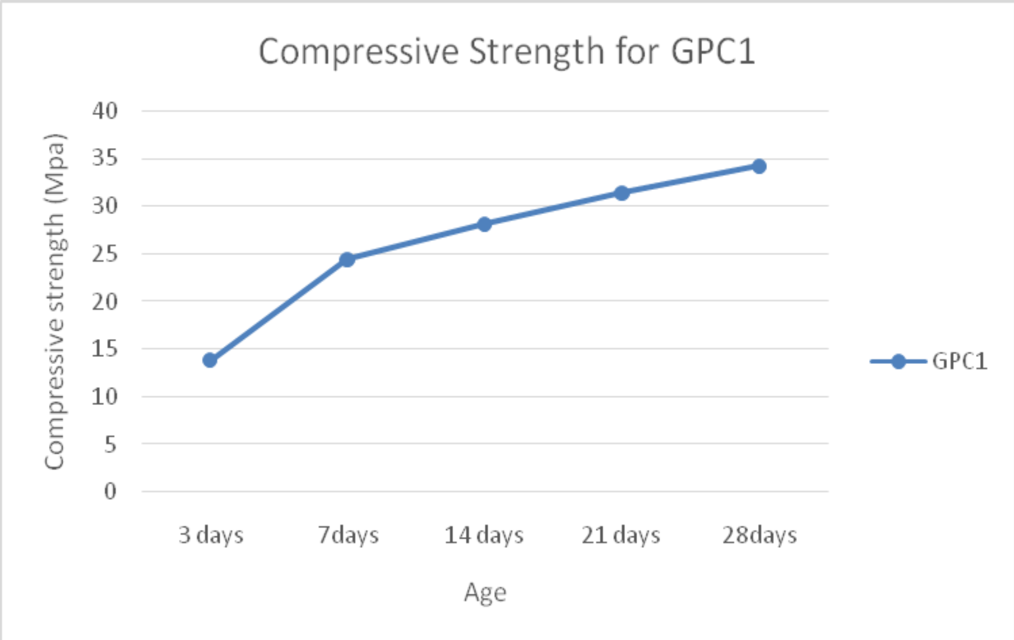

Fig. 5.2 Variation of Compressive strength of GPC 1 with the age

From above figure 5.2we can access that the compression strength at 28days is 35mpa and it is maximum compressive strength obtained at geopolymer concrete at mix 1

International Journal of Advances in Engineering and Management (IJAEM)
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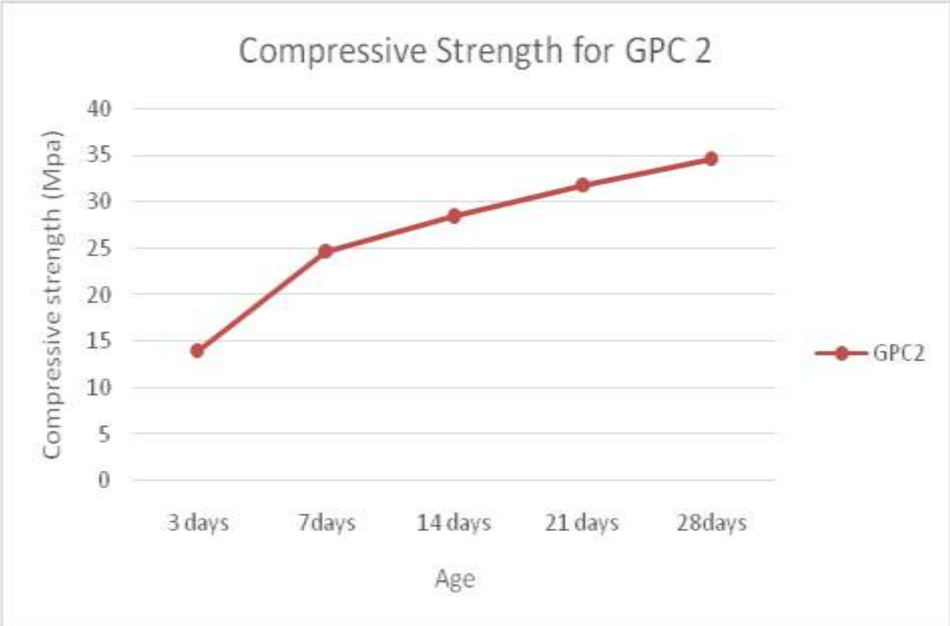

Fig. 5.3 Variation of Compressive strength of GPC 2 with the different age

From above figure 5.3we can access that the compression strength at 28days is 35mpa and it is maximum compressive strength obtained at geopolymer concrete at mix 2

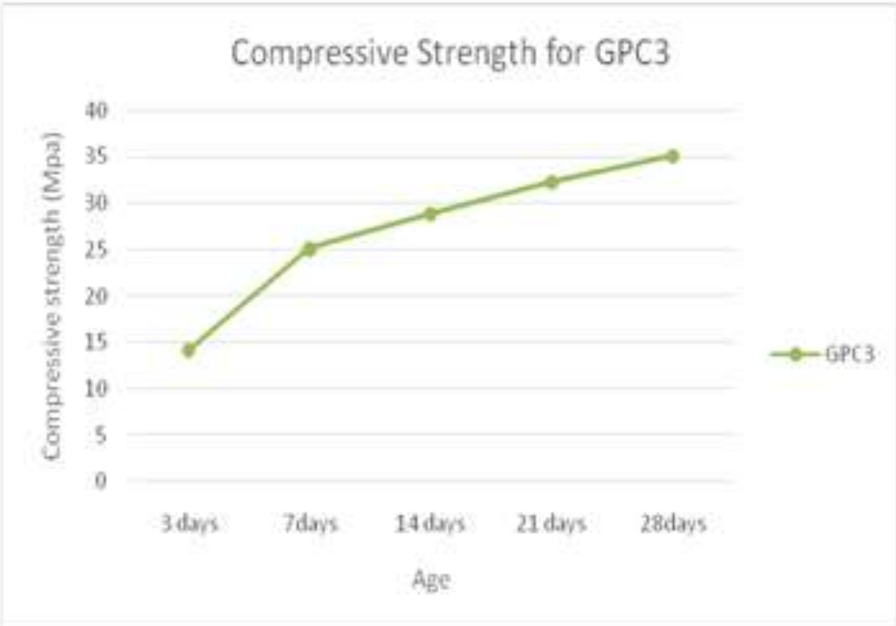

Fig. 5.4 Variation of Compressive strength of GPC 3 with the different age

From above figure 5.4we can access that the compression strength at 28days is 35mpa and it is maximum compressive strength obtained at geopolymer concrete at mix 3

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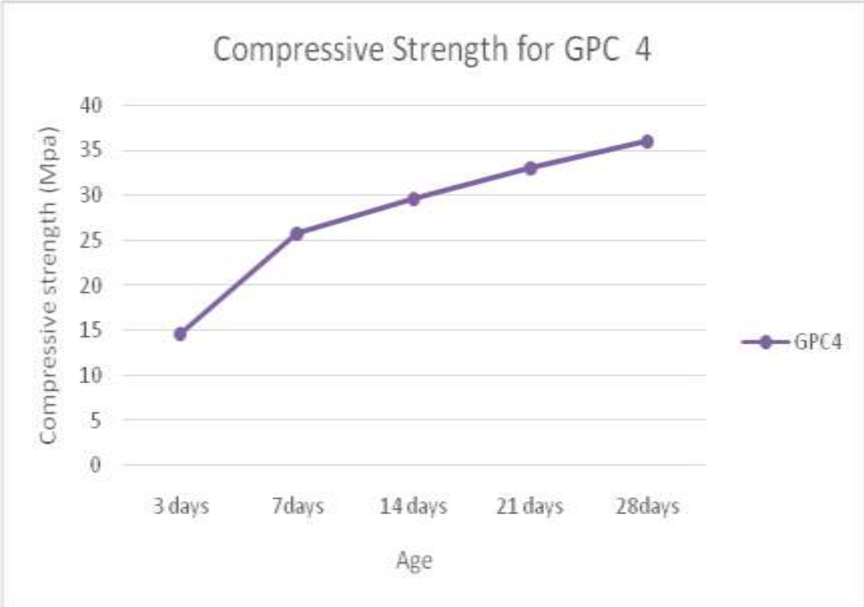

Fig. 5.5 Variation of Compressive strength of GPC 4 with the different age

From above figure 5.5we can access that the compression strength at 28days is 35mpa and it is maximum compressive strength obtained at geopolymer concrete at mix 4

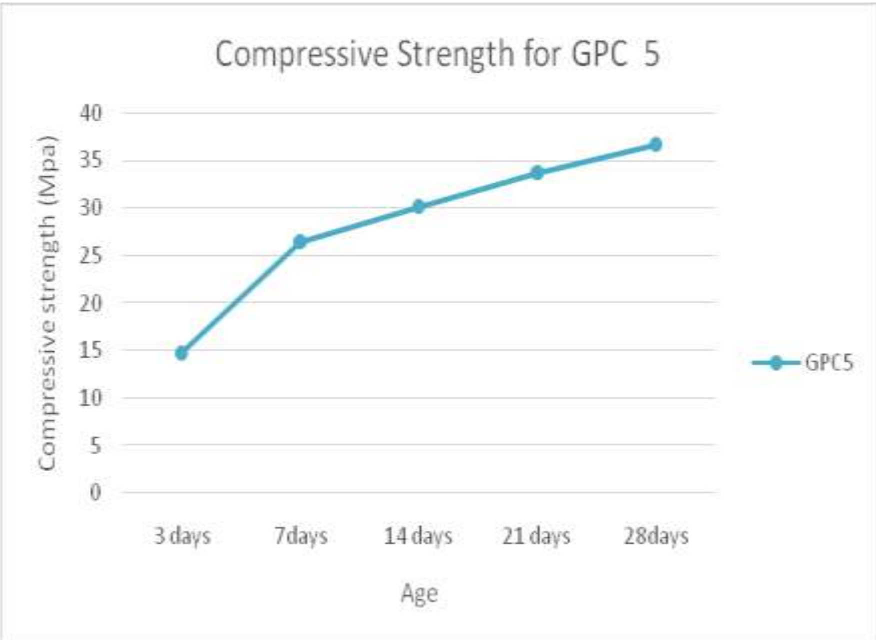

Fig. 5.6 Variation of Compressive strength of GPC 5 with the different age

From above figure 5.6we can access that the compression strength at 28days is 37mpa and it is maximum compressive strength obtained at geopolymer concrete at mix 5

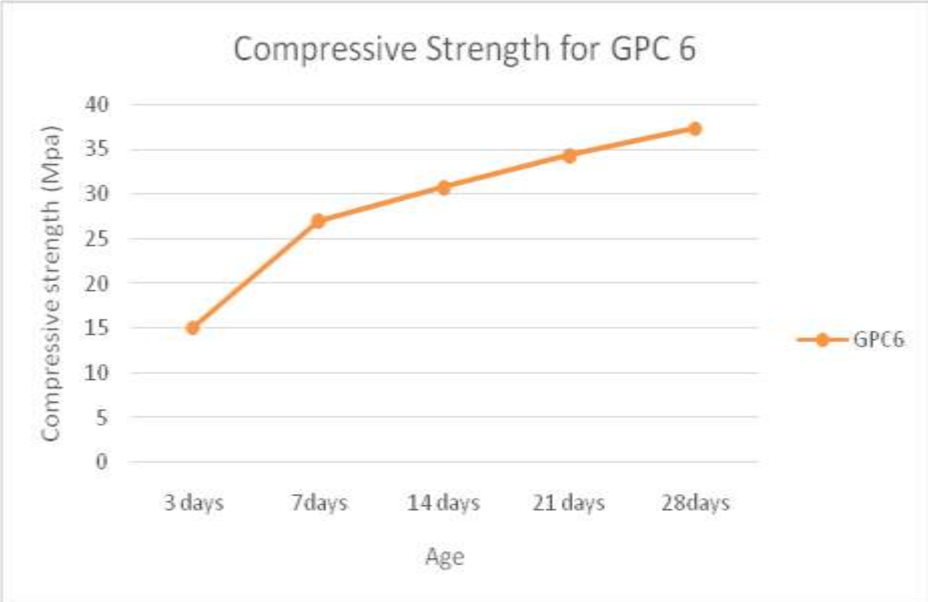

Fig. 5.7 Variation of Compressive strength of GPC 6 with the different age

From above figure 5.7we can access that the compression strength at 28days i37mpa and is maximum compressive strength obtained at GPC 6

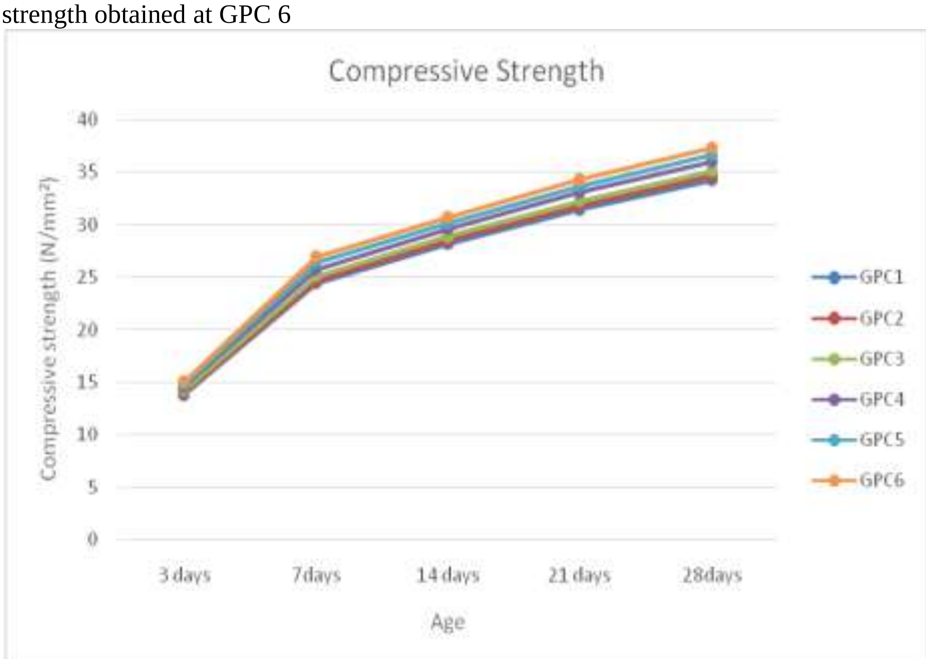

fig 5.8 Compressive strength vs age

As per the standards ,the percentage variation in strength is more than 10% with that of reference mix ,it is considered as significant.if the variation is less than 10%,it is considered as in significant.

For GPC1 mix wrt GPC2 mix below values obtained:-

At 3days ,the compressive strength of reference mix (i.e with 0% replacement) observed is 13.83,the variation of other mixes with M-sand and replacement is observed to be insignificant. the maximum variation i.e increase in compressive strength observed is 1.01%

At 7days,the compressive strength of reference mix (i.e with 20% replacement)observed is 24.44,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 0.9%

At 14days ,the compressive strength of reference mix (i.e with 40% replacement)observed is 28.17,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed as 1.10%

At 21days ,the compressive strength of reference mix (i.e with 60% replacement)observed is 31.45,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 1.11%

At 28days ,the compressive strength of reference mix (i.e with 80% replacement)observed is 34.22,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 1.11%

For GPC1 mix wrt GPC3 mix below values obtained:-

At 3days ,the compressive strength of reference mix (i.e with 0% replacement) observed is 13.83,the variation of other mixes with M-sand and replacement is observed to be insignificant. the maximum variation i.e increase in compressive strength observed is 2.67%

At 7days,the compressive strength of reference mix (i.e with 20% replacement)observed is 24.44,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 2.74%

At 14days ,the compressive strength of reference mix (i.e with 40% replacement)observed is 28.17,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed as 2.59%

At 21days ,the compressive strength of reference mix (i.e with 60% replacement)observed is 31.45,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 2.60%

At 28days ,the compressive strength of reference mix (i.e with 80% replacement)observed is 34.22,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 2.60%

For GPC1 mix wrt GPC4 mix below values obtained:-

At 3days ,the compressive strength of reference mix (i.e with 0% replacement) observed is 13.83,the variation of other mixes with M-sand and replacement is observed to be insignificant. the maximum variation i.e increase in compressive strength observed is 5.56%

At 7days,the compressive strength of reference mix (i.e with 20% replacement)observed is 24.44,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 5.44%

At 14days ,the compressive strength of reference mix (i.e with 40% replacement)observed is 28.17,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed as 5.18%

At 21days ,the compressive strength of reference mix (i.e with 60% replacement)observed is 31.45,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 5.21%

At 28days ,the compressive strength of reference mix (i.e with 80% replacement)observed is 34.22,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 5.20%

For GPC1 mix wrt GPC5 mix below values obtained:-

At 3days ,the compressive strength of reference mix (i.e with 0% replacement) observed is 13.83,the variation of other mixes with M-sand and replacement is observed to be insignificant. the maximum variation i.e increase in compressive strength observed is 6.65%

At 7days,the compressive strength of reference mix (i.e with 20% replacement)observed is 24.44,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 8.18%

At 14days ,the compressive strength of reference mix (i.e with 40% replacement)observed is 28.17,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed as 7.09%

At 21days ,the compressive strength of reference mix (i.e with 60% replacement)observed is 31.45,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 7.1%

At 28days ,the compressive strength of reference mix (i.e with 80% replacement)observed is 34.22,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 7.13%

For GPC1 mix wrt to GPC6 mix below values obtained:-

At 3days ,the compressive strength of reference mix (i.e with 0% replacement) observed is 13.97,the variation of other mixes with M-sand and replacement is observed to be insignificant. the maximum variation i.e increase in compressive strength observed is 9.03%

At 7days,the compressive strength of reference mix (i.e with 20% replacement)observed is 24.66,the variation of other mixes with M-sand and replacement is observed to be significant .the maximum variation ie increase in compressive strength observed is 10.47%

At 14days, the compressive strength of reference mix (i.e with 40% replacement)observed is 28.17,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 9.08%

At 21days, the compressive strength of reference mix (i.e with 60% replacement)observed is 31.45,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 9.09%At 28days ,the compressive strength of reference mix (i.e with 80% replacement)observed is 34.60,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 9.08%

4.3 TENSILE STRENGTH

Tensile strength is a measurement of the force required to pull something such as rope, wire, or a structural beam to the point where it breaks. The tensile strength of a material is the maximum amount of tensile stress that it can take before failure, for example breaking.150 mm x 300 mm cylinders were casted and oven dried for 24hours at 60°c and compressive strength for 3, 7, 14, 21 and 28 days were tested. Manufactured sand is varied in 0%, 20%, 40%,60%,80%,100% for river sand. Tensile strength of geo-polymer concrete with manufactured sand is shown in table

Mix	Tensile strength (N/mm^2)				
	3days	7days	14days	21days	28days
GPC1	0.83	1.43	1.97	2.22	2.47
GPC2	0.86	1.46	2.02	2.27	2.53
GPC3	0.88	1.5	2.07	2.33	2.59
GPC4	0.90	1.53	2.12	2.38	2.65
GPC5	0.91	1.56	2.16	2.43	2.7
GPC6	0.93	1.59	2.20	2.47	2.75

Table 5.3Compressive strength of geo-polymer concrete with manufactured sand

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 10 Oct 2023, pp: 16-39 www.ijaem.net ISSN: 2395-5252

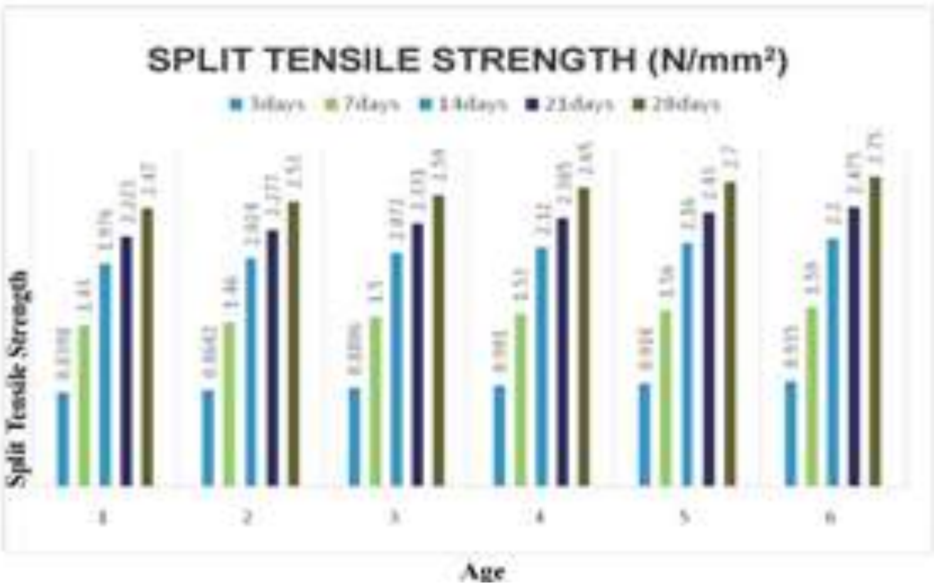

Fig. 5.8 Split tensile strength of geo-polymer concrete with manufactured sand

from the above figure 5.8,split tensile strength of geopolymer concrete is plotted between split tensile strength and age in days
At 3 days,7days ,14days,21 days,28 days the split tensile strengths are calculated

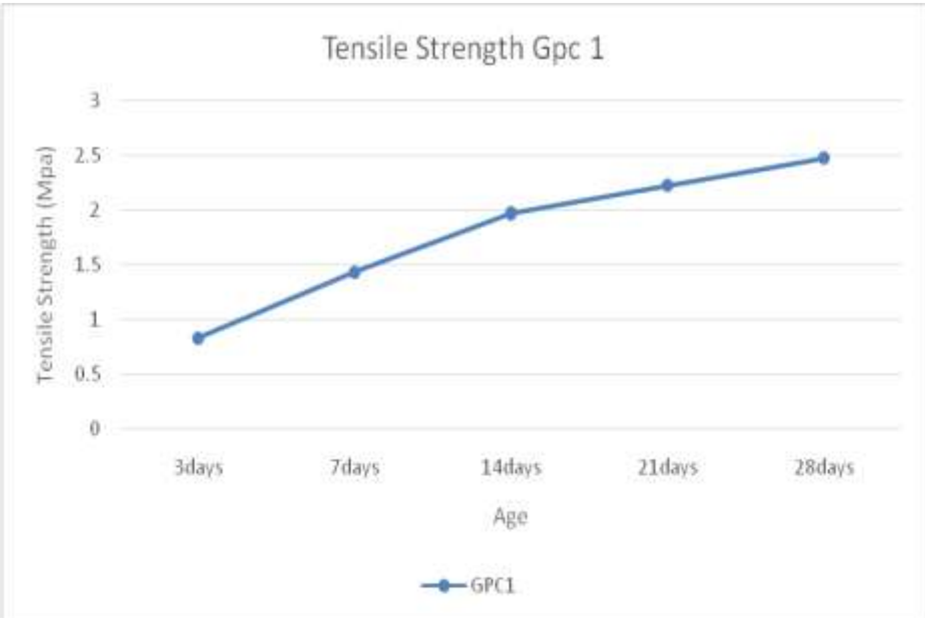

Fig. 5.9 Variation of Split tensile strength of GPC 1 with the different age

From above figure 5.9we can access that the split tensile strength at 28days is maximum strength 2.5Mpa obtained at geopolymer concrete at mix 1,the split tensile strengths are calculated for 3,7,14,21,28 days

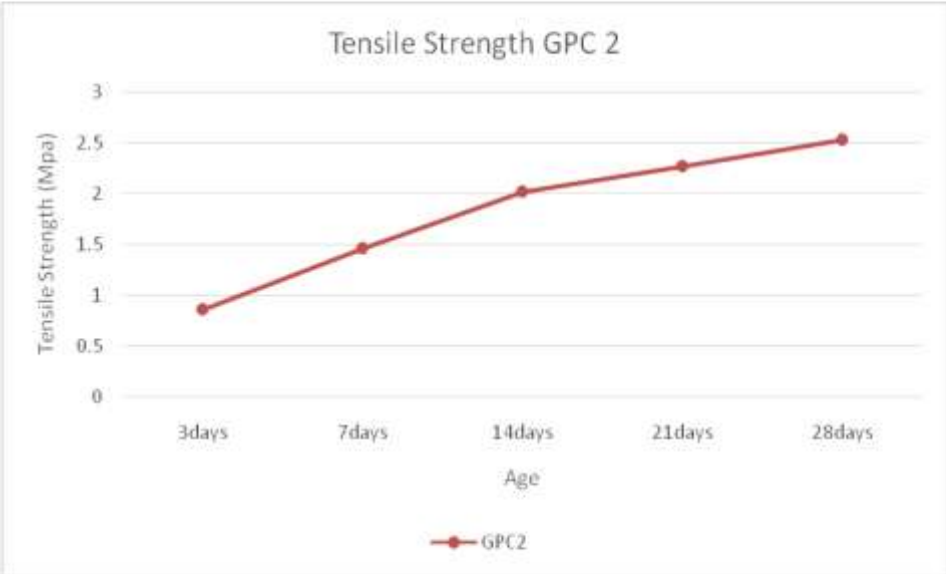

Fig. 5.10 Variation of Split tensile strength of GPC 2 with the different age

From above figure 5.10we can access that the split tensile strength at 28days is maximum strength of 2.5Mpa is obtained at geopolymer concrete at mix 2

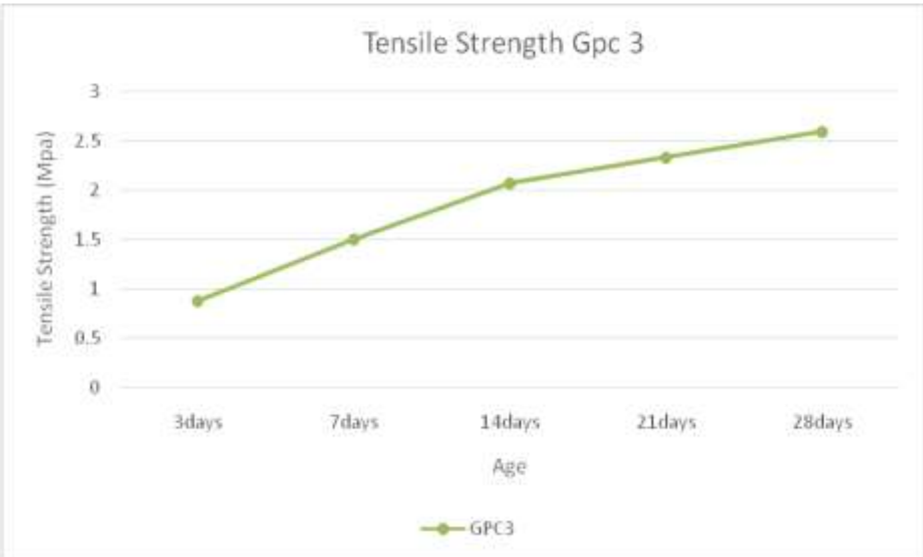

fig 5.11 Variation of Split tensile strength of GPC 3 with the different age

From above figure 5.11we can access that the split tensile strength at 28days is maximum strength of 2.7Mpa obtained at geopolymer concrete at mix 3

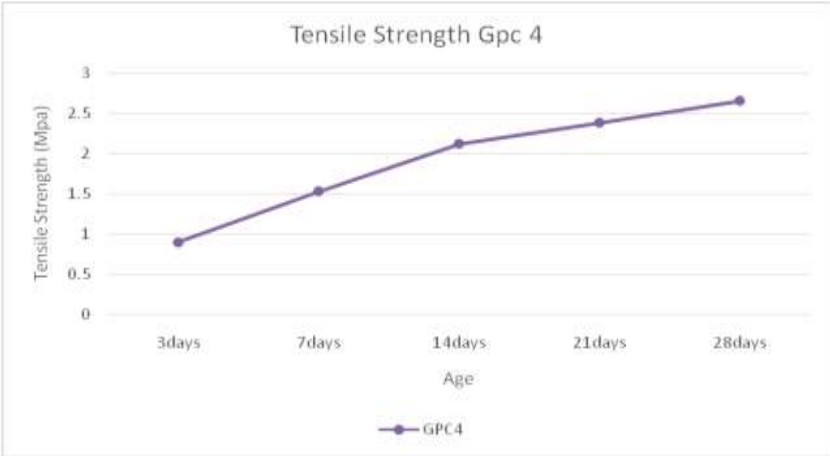

Fig. 5.12 Variation of Split tensile strength of GPC 4 with the different age

From above figure 5.12we can access that the split tensile strength at 28days is maximum of 2.5Mpa strength obtained at geopolymer concrete at mix 4

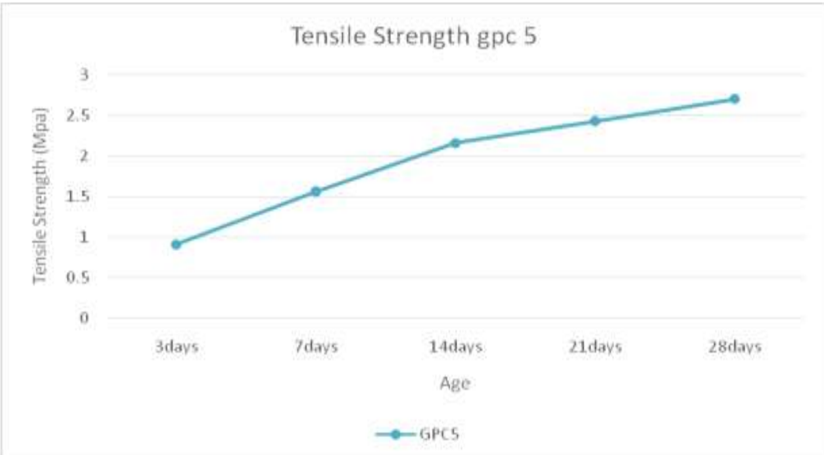

Fig. 5.13 Variation of Split tensile strength of GPC 5 with the different age

From above figure 5.13we can access that the split tensile strength at 28days is maximum strength of 2.7Mpa obtained at geopolymer concrete at mix 5

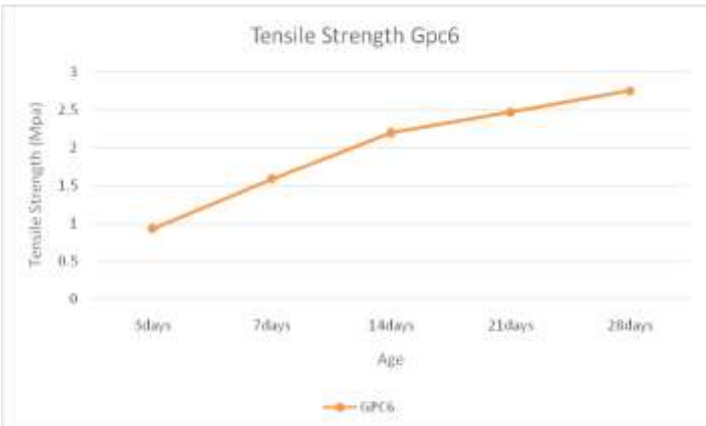

Fig. 5.14 Variation of Split tensile strength of GPC 6 with the different age

From above figure 5.14we can access that the split tensile strength at 28days is maximum strength of 2.5mpa obtained at geopolymer concrete at mix

From the test results obtained from above for tensile strength, shows that there is 12% increase in strength when manufactured sand is fully replaced by river sand

Fig. 5.15 Tensile strength vs age

As per the standards ,the percentage variation in strength is more than 10% with that of reference mix,it is considered as significant. if the variation is less than 10%,it is considered as insignificant

For GPC1 mix wrt GPC2 mix below values obtained:-

At 3days ,the split tensile strength of reference mix (i.e with 0% replacement) observed is 0.83,the variation of other mixes with M-sand and replacement is observed to be insignificant. the maximum variation i.e increase in split tensile strength observed is 3.61%

At 7days,the split tensile strength of reference mix (i.e with 20% replacement)observed is 1.43,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in split tensile strength observed is 2.09%

At 14days , the split tensile strength of reference mix (i.e with 40% replacement)observed is 1.97,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in split tensile strength observed as 2.53%

At 21days,the split tensile strength of reference mix (i.e with 60% replacement)observed is 2.22 ,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in split tensile strength observed is 2.25%

At 28days ,the split tensile strength of reference mix (i.e with 80% replacement)observed is 2.47,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in split tensile strength observed is 2.42%

GPC1 mix wrt GPC3 mix below values obtained:-

At 3days ,the split tensile strength of reference mix (i.e with 0% replacement) observed is 0.83,the variation of other mixes with M-sand and replacement is observed to be insignificant. the maximum variation i.e increase in split tensile strength observed is 6.03%

At 7days,the split tensile strength of reference mix (i.e with 20% replacement)observed is 1.43,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in split tensile strength observed is 4.89%

At 14days ,the split tensile strength of reference mix (i.e with 40% replacement)observed is 1.97 ,the variation of other mixes with M-sand and replacement is observed to be significant .the maximum variation ie increase in split tensile strength observed as 5.07%

At 21days ,the split tensile strength of reference mix (i.e with 60% replacement)observed is 2.22,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in split tensile strength observed is 4.95%

At 28days ,the split tensile strength of reference mix (i.e with 80% replacement)observed is 2.47,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in split tensile strength observed is 4.85%

GPC1 mix wrt GPC4 mix below values obtained:-

At 3days ,the split tensile strength of reference mix (i.e with 0% replacement) observed is 0.83,the variation of other mixes with M-sand and replacement is observed to be insignificant. the maximum variation i.e increase in split tensile strength observed is 8.4%

At 7days,the split tensile strength of reference mix (i.e with 20% replacement)observed is 1.43,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in split tensile strength observed is 6.99%

At 14days ,the split tensile strength of reference mix (i.e with 40% replacement)observed is 1.97 ,the variation of other mixes with M-sand and replacement is observed to be significant .the maximum variation ie increase in split tensile strength observed as 7.61%

At 21days ,the split tensile strength of reference mix (i.e with 60% replacement)observed is 2.22,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in split tensile strength observed is 7.20%

At 28days ,the split tensile strength of reference mix (i.e with 80% replacement)observed is 2.47,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 7.28%

GPC1 mix wrt GPC5 mix below values obtained:-

At 3days ,the split tensile strength of reference mix (i.e with 0% replacement) observed is 0.83,the variation of other mixes with M-sand and replacement is observed to be insignificant. the maximum variation i.e increase in split tensile strength observed is 9.63%

At 7days,the split tensile strength of reference mix (i.e with 20% replacement)observed is 1.43,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in split tensile strength observed is 9.09%

At 14days ,the split tensile strength of reference mix (i.e with 40% replacement)observed is 1.97 ,the variation of other mixes with M-sand and replacement is observed to be significant .the maximum variation ie increase in split tensile strength observed as 9.64%

At 21days ,the split tensile strength of reference mix (i.e with 60% replacement)observed is 2.22,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in split tensile strength observed is 9.45%

At 28days ,the split tensile strength of reference mix (i.e with 80% replacement)observed is 2.47,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in compressive strength observed is 9.31%

For GPC1 mix wrt to GPC6 mix below values obtained:-

At 3days ,the split tensile strength of reference mix (i.e with 0% replacement) observed is 0.83,the variation of other mixes with M-sand and replacement is observed to be significant. the maximum variation i.e increase in split tensile strength observed is 12.04%

At 7days,the split tensile strength of reference mix (i.e with 20% replacement)observed is 1.43,the variation of other mixes with M-sand and replacement is observed to be significant .the maximum variation ie increase in split tensile strength observed is 11.18%

At 14days, the split tensile strength of reference mix (i.e with 40% replacement)observed is 1.97,the variation of other mixes with M-sand and replacement is observed to be significant .the maximum variation ie increase in split tensile strength observed is 11.67%

At 21days, the split tensile strength of reference mix (i.e with 60% replacement)observed is 2.22,the variation of other mixes with M-sand and replacement is observed to be significant .the maximum variation ie increase in split tensile strength observed is 11.26%

At 28days ,the split tensile strength of reference mix (i.e with 80% replacement)observed is 2.47,the variation of other mixes with M-sand and replacement is observed to be significant .the maximum variation ie increase in split tensile strength observed is 11.33%

4.4 FLEXURAL STRENGTH

Concrete specimen for flexural strength has cross sectional area of 100mm width with 100mm depth and length of 500mm concrete beam was casted and oven dried for 24hours at 60°c and compressive strength for 7 and 28 days were tested. The manufactured sand is varied in 0%,20%, 40%, 60%, 80%, 100%.for river sand.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 10 Oct 2023, pp: 16-39 www.ijaem.net ISSN: 2395-5252

Results are tabulated below table

Mix	Flexural strength (N/mm^2)		
	7days	14days	28days
GPC1	4.24	5.25	5.9
GPC2	4.32	5.34	6
GPC3	4.44	5.50	6.18
GPC4	4.53	5.60	6.3
GPC5	4.57	5.66	6.36
GPC6	4.66	5.76	6.48

Table 5.4 Flexural strength of geo-polymer concrete with manufactured Sand

Figure 5.16 Flexural strength of geo-polymer concrete with manufactured sand

From the test results obtained from above for flexural strength, shows that there is 10% increase in strength when manufactured sand is fully replaced by river sand.

International Journal of Advances in Engineering and Management (IJAEM)
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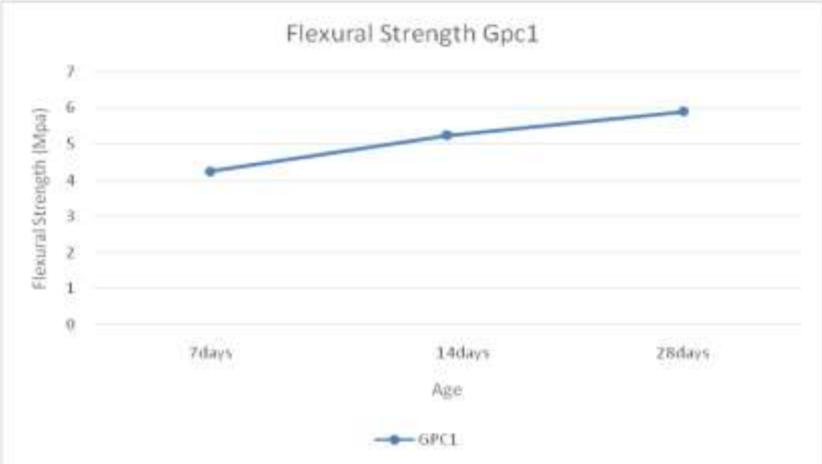

Fig. 5.17 Variation of Flexural strength of GPC 1 with the different age

From above figure 5.17we can access that the flexural strength at 28days is maximum strength of 6Mpa obtained at geopolymer concrete at mix 1

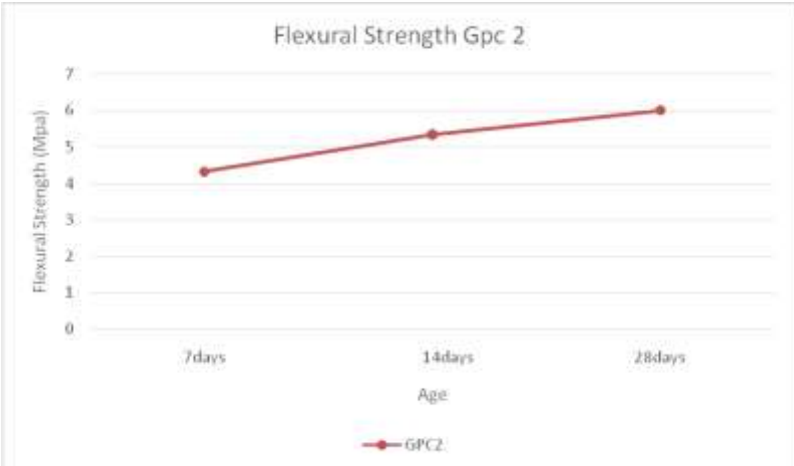

Fig. 5.18 Variation of Flexural strength of GPC2 with the different age

From above figure 5.18we can access that the flexural strength at 28days is maximum strength of 6Mpa obtained at geopolymer concrete at mix 2

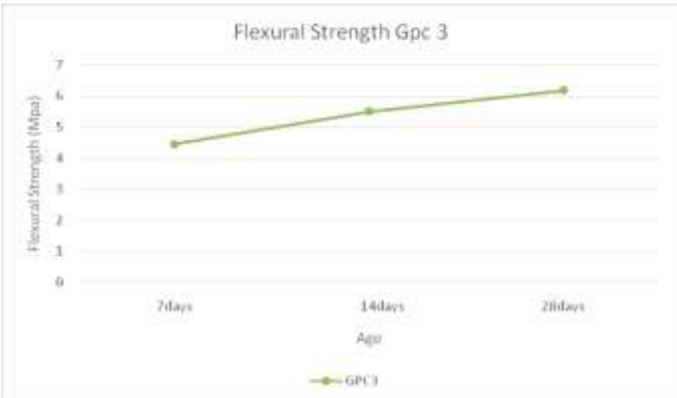

Fig. 5.19 Variation of Flexural strength of GPC3 with the different age

From above figure 5.19we can access that the flexural strength at 28days is maximum strength of 6.1Mpa obtained at geopolymer concrete at mix 3

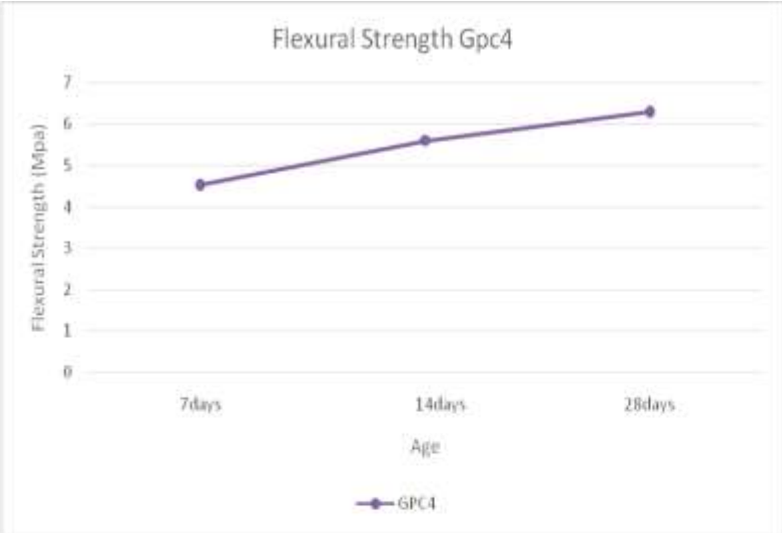

Fig. 5.20 Variation of Flexural strength of GPC4 with the different age

From above figure 5.20we can access that the flexural strength at 28days is maximum strength 6.1Mpa obtained at geopolymer concrete at mix 4

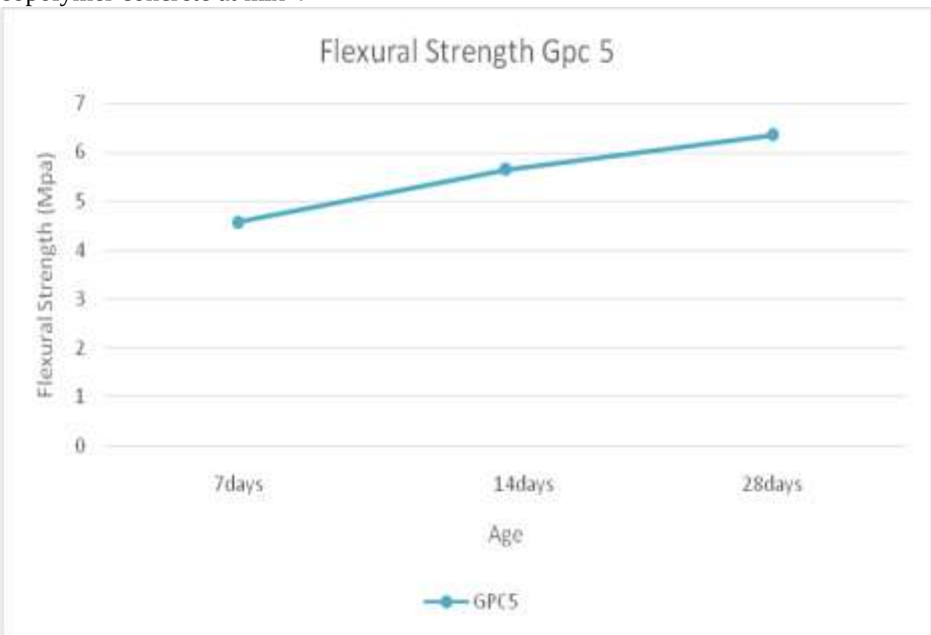

Fig. 5.21 Variation of Flexural strength of GPC5 with the different age

From above figure 5.21we can access that the flexural strength at 28days is maximum strength 6.2Mpa obtained at geopolymer concrete at mix 5

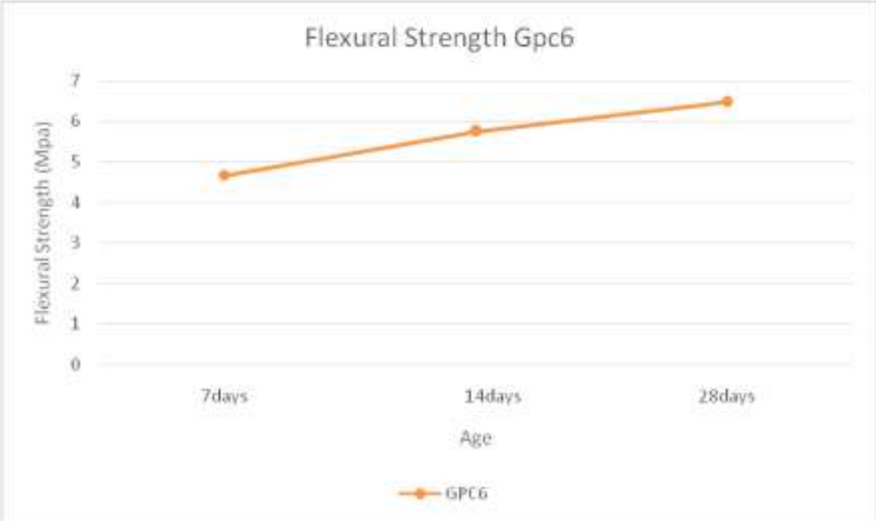

Fig. 5.21 Variation of Flexural strength of GPC6 with the different age

From above figure 5.21we can access that the flexural strength at 28days is maximum strength 6.3Mpa obtained at geopolymer concrete at mix 6

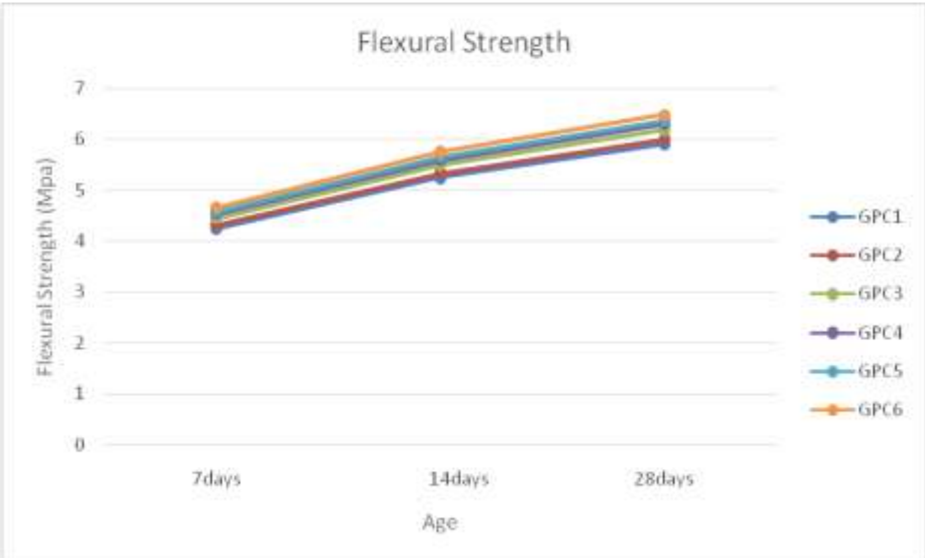

Fig. 5.22 Flexural strength vs age

For GPC1 mix wrt to GPC2 mix below values obtained

At 7days,the flexural strength of reference mix (i.e with 20% replacement)observed is 4.24,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 1.88%

At 14days, the flexural strength of reference mix (i.e with 40% replacement)observed is 5.25,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 1.71%

At 28days ,the flexural strength of reference mix (i.e with 80% replacement)observed is 5.9,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 1.61%

For GPC1 mix wrt to GPC3 mix below values obtained

At 7days,the flexural strength of reference mix (i.e with 20% replacement)observed is 4.24,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 4.71%

At 14days, the flexural strength of reference mix (i.e with 40% replacement)observed is 5.25,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 4.76%

At 28days ,the flexural strength of reference mix (i.e with 80% replacement)observed is 5.9,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 4.74%

For GPC1 mix wrt to GPC4 mix below values obtained

At 7days,the flexural strength of reference mix (i.e with 20% replacement)observed is 4.24,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 6.83%

At 14days, the flexural strength of reference mix (i.e with 40% replacement)observed is 5.25,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 6.67%

At 28days ,the flexural strength of reference mix (i.e with 80% replacement)observed is 5.9,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 6.77%

For GPC1 mix wrt to GPC5 mix below values obtained

At 7days,the flexural strength of reference mix (i.e with 20% replacement)observed is 4.24,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 7.78%

At 14days, the flexural strength of reference mix (i.e with 40% replacement)observed is 5.25,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 7.8%

At 28days ,the flexural strength of reference mix (i.e with 80% replacement)observed is 5.9,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 9.83%

For GPC1 mix wrt to GPC6 mix below values obtained:-

At 7days,the flexural strength of reference mix (i.e with 20% replacement)observed is 4.24,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 9.9%

At 14days, the flexural strength of reference mix (i.e with 40% replacement)observed is 5.25,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 9.71%

At 28days ,the flexural strength of reference mix (i.e with 80% replacement)observed is 5.9,the variation of other mixes with M-sand and replacement is observed to be insignificant .the maximum variation ie increase in flexural strength observed is 9.83%

V. CONCLUSIONS & SCOPE FOR FURTHER STUDY

Based on experimental investigation , the following conclusions arrived

- The test results of compressive strength show that there is an increase in strength when manufactured sand is replaced by river sand ,but the strength of mix is not significant at 28days for the further studies
- The test results of split tensile strength shows that there is increase in strength when manufactured sand is fully replaced by river sand
- The test results of flexural strength shows that there is increase in strength when manufactured sand is fully replaced by river sand

From the results obtained it proves that geopolymer concrete using manufactured sand can be an alternative to ordinary Portland cement concrete.since no cement is used in geopolymer concrete .lot of energy which interm reduces the production of OPC.the use of waste material like flyash helps in reducing the pollution of atmosphere which adds to pollution free environment

SCOPE FOR FURTHER STUDY

- Similar studies can be carried with varying proportion of M.sand

- Similar investigations can be carried out for GGBS & metakoline and microsilica replacements
- Durability studies can be carried for different combination of geopolymer concrete

REFERENCES

[1]. Abdul Aleem M.I,P.D. Arumairaj,S. Vairam, "Chemical Formulation of Geopolymer Concrete with M-Sand" International Journal of Research in Civil Engineering, Architecture & Design Volume 1, Issue 2, October-December, 2013

[2]. Abdul Aleem M. I,P. D. Arumairaj, "geopolymer concrete-a review", International Journal of Engineering Sciences & Emerging Technologies, Feb 2012. Indian standard serial number : 2231 – 6604 Volume 1, Issue 2.

[3]. Djwantoro Hardjito, Steenie E. Wallah, Dody M.J. Sumajouw, and B.V. Rangan. "factors influencing the compressive strength of Fly ash-based geopolymer concrete" Civil Engineering Dimension, Volume 6, No. 2, 88–93, September 2

[4]. "Concrete technology "textbook by MS shetty

[5]. "Geopolymers:structures,processing,properties & applications "a text book by JSJ van Deventer

[6]. "Green building with concrete" a text book byy Gajanan M.Sabnis

[7]. www.reasearch.gate .net

[8]. petra.ac.id

[9]. www.google.co.in

[10]. www.cipremia.com

[11]. science direct.com

[12]. IS 10262-2009 Recommended guidelines for concrete mix design.

[13]. IS 516 -1959 Methods of tests for strength of concrete.

[14]. Xu H, Lukey GC, van Deventer JSJ. The activation of class C, class F fly ash and blast furnace slag using geopolymer, Fly ash, Silica Fume, Slag, and Natural Pozzolans in Concrete, Proceedings Eighth International Conference, V.M. Malhotra editors, Las Vegas, USA., 2004, pp. 797-820.