EXPERIMENTAL INVESTIGATION ON PACKING DENSITY OF DIFFERENT FINE AGGREGATE IN GEOPOLYMER CONCRETE

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Abstract: The production of Ordinary Portland Cement (OPC) causes havoc to the environment due to the emission of CO_2 as well mining also results in unrecoverable loss to nature. Estimated carbon This Project deals with the details of optimized Mix Design for normal strength concrete using packing density method. Dredged Marine Sand (DMS) which is produced during the operation of dredging. DMS is mixed with M-Sand in different ratios & Packing density is obtained using sieve analysis experimentally. This ratio's of different fine aggregate is introduced into the geopolymer concrete is the concrete in which alternate material for cement is used also alkali activated solution is used and Concrete made up of cement, aggregates, water & additives is the world's most consumed construction material since it is found to be more versatile, durable and reliable. Concrete is the second most consumed material after water which required large quantities of Portland cementemissions from cement production in 1994 were 307 MtC, 160 MtC from calcination, and 147 MtC from energy use which account for 5% of 1994 global anthropogenic CO_2 emissions. Hence, it is the need of hour to find an alternative material to the existing most expensive cement-concrete. The result for packing density has been obtained by taking inference on particle distribution curve. The compressive strength of the respective concrete grade is obtained. The fines content (particles finer than 75 µm) in aggregate has substantial effects on the performance of concrete. Since the fines content has large surface area that would increase the water demand, maximum limits are often imposed. However, the fines content would also fill into the voids between larger particles to increase the packing density and thus reduce the volume of voids to be filled with cement paste. Hence, the fines content is not entirely undesirable and it has been suggested to raise the limits on the fines content.

Key words: Packing density, M-Sand, Dredged Marine Sand (DMS), Geopolymer concrete

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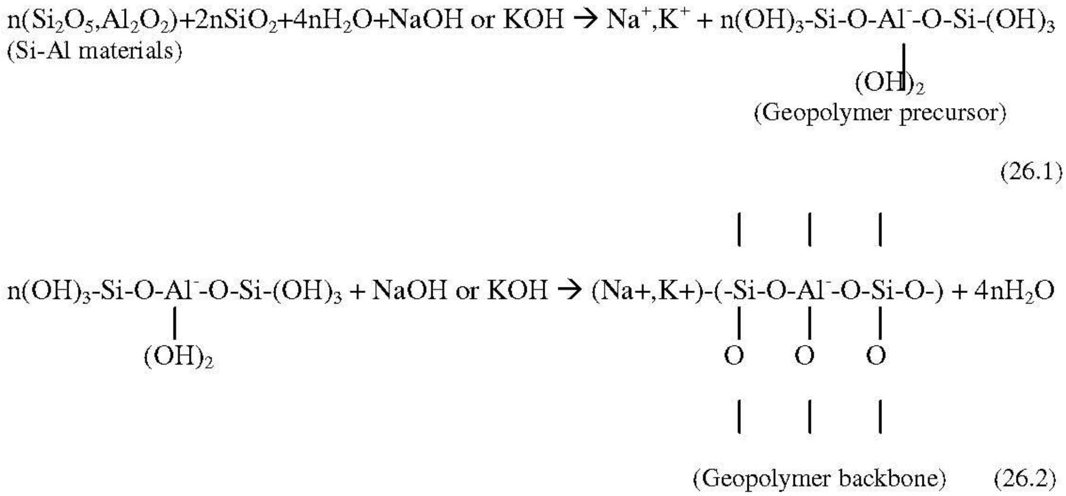
Introduction:

GEO POLYMER CONCRETE:

Concrete usage around the world is second only 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. In addition, the extent of energy required to produce OPC is only next to steel and aluminium. 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. 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 this work, low-calcium (ASTM Class F) fly ash-based geopolymer is used as the 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 un-reacted materials together to form the geopolymer concrete, with or without the presence of admixtures. The manufacture of geopolymer concrete is carried out using the usual concrete technology methods.

Davidovits (1988; 1994) proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminum (Al) in a source material of geological origin or in by-product materials such as fly ash and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is a polymerization process, he coined the term 'Geopolymer' to represent these binders. Geopolymers are members of the family of inorganic polymers. The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous. The polymerization process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals, that results in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds (Davidovits, 1994). The schematic formation of geopolymer material can be shown as described by Equations (26.1) and (26.2) (Davidovits, 1994; van Jaarsveld et al., 1997): The last term in Equation 26.2 reveals that water is released during the chemical reaction that occurs in the formation of geopolymers. This water, expelled from the geopolymer matrix during the curing and further drying periods, leaves behind discontinuous nano-pores in the matrix, which provide benefits to the performance of geopolymers. The water in a geopolymer mixture, therefore, plays no role in the chemical reaction that takes place; it merely provides the workability to the mixture duringhandling. This is in contrast to the chemical reaction of water in a Portland cement concrete mixture during the hydration process.



There are two main constituents of geopolymers, namely the source materials and the alkaline liquids. The source materials for geopolymers based on alumina-silicate 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, silica fume, slag, rice-husk ash, red mud, etc could be used as source materials. The choice of the source materials for making geopolymers depends on factors such as availability, cost, type of application, and specific demand of the end users. The alkaline liquids are from soluble alkali metals that are usually Sodium or Potassium based. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate.

This Chapter is devoted to heat-cured low-calcium fly ash-based geopolymer concrete. Low-calcium (ASTM Class F) fly ash is preferred as a source material than high-calcium (ASTM Class C) fly ash. The presence of calcium in high amounts may interfere with the polymerization process and alter the microstructure (Gourley, 2003; Gourley and Johnson,2005).

EXPERIMENTAL WORKS:

Packing density:

Packing density is new kind of mix design method used to design different types of concrete. To optimize the particle packing density of concrete, the particles should be selected to fill up the voids between large particles with smaller particles and so on, in order to obtain a dense and stiff particle structure [1,2]. Higher degree of particle packing leads to minimum voids, maximum density and requirement of cement and water will be less. In this work the co-relation curves are developed for packing density method between compression strength and water cement ratio, paste content to reduce the time involved in trial to decide water cement ratio and paste content for a particular grade of concrete. Results obtained by packing density method are compared with IS code method. The optimum bulk density was obtained at proportion of 42% coarse aggregates (20mm downsize), 18% coarse aggregates (12.5mm downsize) and 40% fine aggregates. Large number of trial casting were carried out for each grade of concrete (i.e., M20, M25, M30, M35 and M40) with different water cement ratio and three paste contents in excess of void content. To finalise mix proportions using packing density method flow table tests were carried out to decide water cement ratio and paste content in excess of void content for each grade of concrete. The finalised mix proportion for each grade of concrete was used to cast the cube specimens for 7 days and 28 days curing age. The cube compressive strength results obtained by packing density and IS code method are nearly same. The co-relation curves were plotted for packing density results alone and also combining the results of packing density and IS code methods. The co-relation curves were plotted between compressive strength vs water cement ratio at 7 and 28 days curing age and compressive strength vs paste content at 7 and 28 days curing age. Very good co-relation is obtained with a co-relation co- efficient of 0.953 (minimum) to 0.998 (maximum). These curves can be used to decide the water cement ratio and paste content for the specified grade of concrete in case of packing density method thus reducing the material and time involved in trial testing.

MATERIAL:

Fly Ash:

Fly ash is a by-product of combustion of pulverized coal in power generation plants. The sizes of fly ash particles are slightly larger than Portland cement type 1. silica has high chemical content in fly ash and other chemical materials are iron, alumina and calcium. The colour of fly ash is dark grey. The class f fly ash has more pozzolanic properties compare to class c fly ash. Class Fly ash impart significant sulphate resistance and alkali aggregate reaction (ASR) resistance to the different Concrete mixes Fly ash more economical com-pare to ordinary Portland cement.

GGBS:

GGBS is a vitrified substance which is a byproduct of iron production in a blast furnace. It consists primarily of oxides of calcium, silicon, aluminium and magnesium. Contains less than 1% crystalline silica. Contains less than 2 ppm water soluble chromium VI.

Alkaline Liquid:

The most common alkaline liquid used in geopolymerisation is a combination of sodium silicate or potassium silicate and sodium hydroxide (NOAH) or potassium hydroxide (KOH). The use of a single alkaline activator has been reported. Type of alkaline liquid is plays a crucial role in the polymerization of geopolymer concrete. The molarity of the liquid increases with increase the compressive strength of concrete and it gives more stiffness to the materials in the concrete. The father of geopolymer found that generally the KOH solution caused a lower dissolution of minerals compare to NAOH solution. so in this research we were used NAOH pellet form and sodium silicate in gel form.

Coarse aggregates:

In total concrete volume more than place is occupy by the aggregates and its increases the workability of concrete. Most of the body is covered with coarse aggregates and fine aggregates. In this experimental work the coarse aggregates which are retained 7mm, 14mm, 20mm IS sieves.

Fine aggregates:

The size of aggregate is less than 4.75mm are called as fine aggregates. Normally sand contains silica material and it is useful to give proper bonding to the concrete. The bonding between the materials are only gives the good strength to the concrete .In this experimental work two types of fine aggregates are used that is M-sand and Dredged Marine Sand(DMS).

M-sand:

Manufactured sand (M-sand) is artificial sand produced from crushing hard stones into small and sized angular shaped particles, washed and finely graded to be used as construction aggregate. It is a superior alternative to river sand for construction purpose.

Dredged Marine sand:

Dredged Marine sand (DMS) dredging is excavation carried out underwater or partially underwater, in shallow waters or ocean waters. It keeps waterways and ports navigable, and assists coastal protection, land reclamation and coastal redevelopment, by gathering up bottom sediments and transporting it elsewhere.

Sieve Analysis:

Sieve analysis is the method of dividing a sample of aggregates into various fractions each consisting of particles of same size. The sieve analysis is carried out to determine the particle size distribution in a sample of aggregate, which we call Gradation.

Sieve Analysis Procedure:

When conducting a particle size analysis, particularly test sieve analysis, you have a set stack of test sieves, some falling on the coarse end of the spectrum and some falling on the fine. Some material will be retained on the coarser sieves, and some will be retained on the finer sieves;

however, a majority of your sample will be retained in the mid-range sieves. This is what gives you the peak that is synonyms with a proper particle size distribution curve.[3,5] That said, to calculate your distribution curve, you take the total mass of your sample material and divide it by either the weight retained or weight that passed through each sieve, plotting each sieve percentage on the graph. To make this process easy, it is recommended that a 100g sample is used to conduct a particle size analysis when possible.

Particle Distribution Curve:

Particle size distribution is the process in which a sample of material that is typically taken from a production line is examined to identify the average size of the individual particles. The particle size distribution curve is a graph that is generated to illustrate the average particle size, the smallest particle size, and the largest particle size. The curve illustrates either the amount of material that passes through or is retained on each sieve.[4] A good sample should, in general, follow the same particle size distribution curve every time you run it.

Particle Distribution Curve for Different Fine Aggregate:

Particle distribution curve for M-sand and Dredged Marine Sand using sieve analysis method in different ratios.

Table 2.6 Percentage of different fine aggregate

M-sand	Dredged Marine Sand
0	100
10	90
20	80
30	70
40	60
50	50
60	40
70	30
80	20
90	10
100	0

Design Mix:

G40 grade of concrete is designed by using Rangan and hardjito by using this design consideration we were casted different percentages of concrete by using different materials. In this paper we were used binder ratio (ie sodium hydroxide and sodium silicate ratio) is 14m solution is used for getting good results. To the total volume of concrete 75% of coarse aggregates were taken for design consideration. In this instead of cement were using GGBS and Fly ash. And also alternate for fine aggregate we were two types of sand one is M-Sand and another one is Dredged Marine Sand (DMS) are partically replaced in geopolymer concrete.

Compressive Strength Test:

Compression test is the most common test conducted on concrete. It decided the characteristic strength of the concrete. Concrete is weak in tension and strong in compression. The quality of concrete is related to its compressive strength. So the concrete should be strong in compression to attain a high compression values. In this paper we were casted 3 samples for each mix and tested on the machine. From that test results average value is takened. Totally casted 33 cubes. Size of each cube is 150mm X 150mm X 150mm and tested at 14 days and 28 days. The size of aggregate is 20mm and 14mm and 7mm for 15cms cubes. For testing the cube uniformly load is applied on the particular specimen,it forms a cracks on specimen is called the failure load of the cubes. The compressive strength of concrete is calculated by using the below expression.

$$\text{Compressive strength of concrete (N/mm2)} = \frac{\text{Applied load(N)}}{\text{Cross section area (mm2)}}$$

RESULT AND DISCUSSION:

GRAPH OF PARTICAL DISTRIBUTION CURVE

It is concluded that Dredged Marine Sand can be used in the construction works in replacement M-Sand or river sand with ratios. It can also be incorporated in geopolymer concrete gives the required strength.

Table 3.1.1 100% M-Sand

Is sieve	Weight of fine aggregate retained	Percent retained	Cumulative percent retained	Percent passing
4.75mm	0	0	0	100

2.36mm	92.5	9.25	9.25	90.75
1.18mm	298.5	29.85	39.1	60.9
600micron	157.5	15.75	54.85	45.15
300micron	175.5	17.55	72.4	27.6
150micron	201.5	20.15	92.55	7.45
75micron	72.5	7.25	99.8	0.2
Pan	1	0.1	99.9	0.1

Fineness modulus = (0+9.25+39.1+54.85+72.4+92.55+99.8) / 100

= 367.9 /100

= 3.67

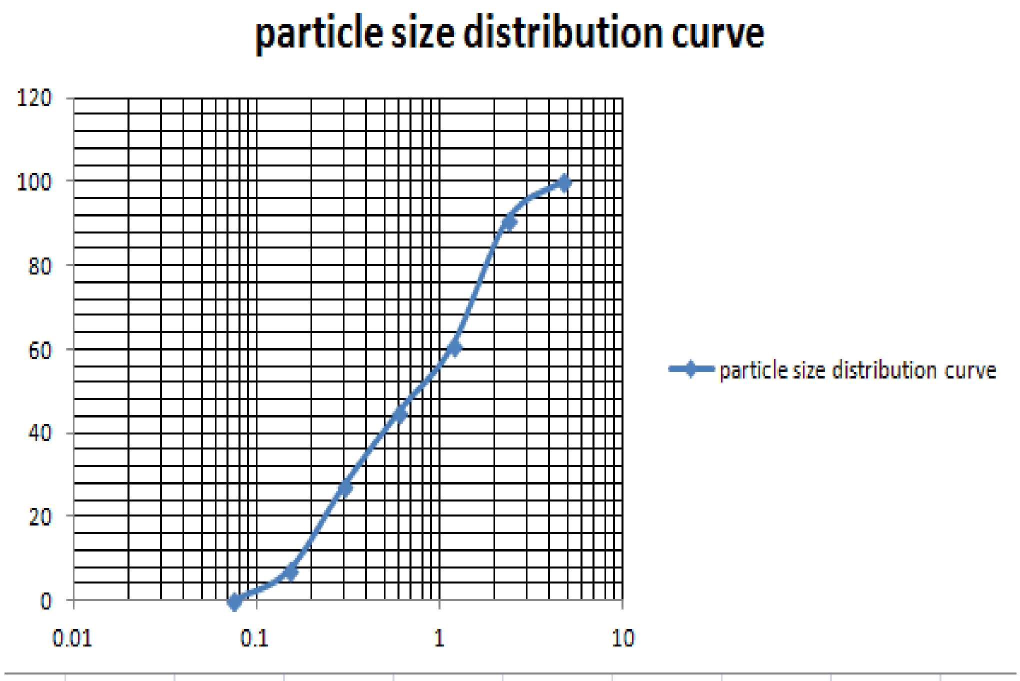


Fig. 3.1.1 100% M-Sand.

Table 3.1.280% DMS & 20% M-Sand.

	Weight of fine aggregate		**Cumulative percent retained**	

Is sieve	retained	Percent retained		Percent passing
4.75mm	60	6	6	94
2.36mm	100.5	10.05	16.05	83.95
1.18mm	193	19.3	35.35	50.25
600micron	144	14.4	49.75	36.35
300micron	139	13.9	63.65	27.7
150micron	106.5	10.65	74.3	23.25
75micron	24.5	2.45	76.75	20.8
Pan	20	2	78.25	18.8

Fineness modulus = (6+16.05+35.35+49.75+63.65+74.5+76.75) / 100

= 321.85 / 100 = 3.21

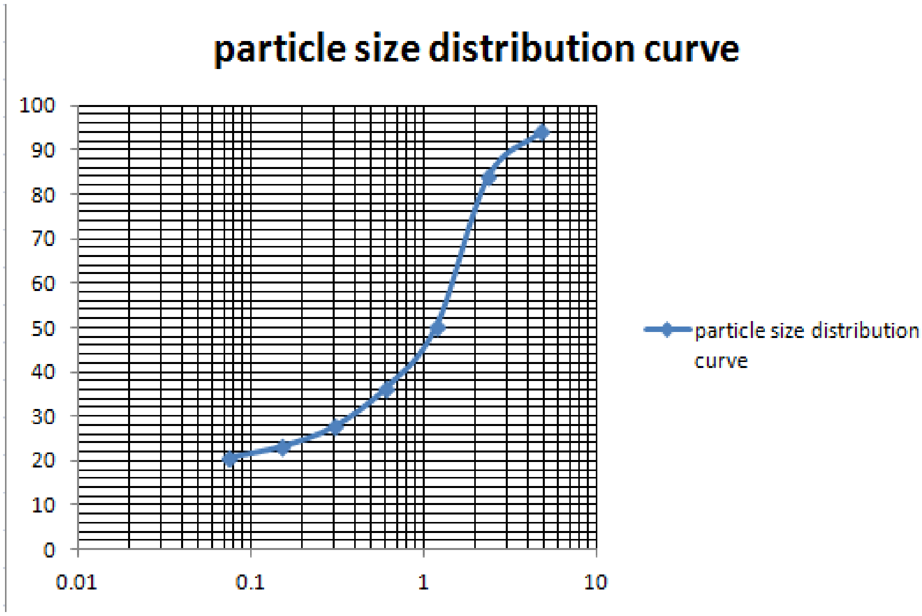


Fig. 3.1.280% DMS & 20% M-Sand.

We took two different types of fine aggregate that is M -Sand and Dredged marine sand .we found that packing density of different ratios by using sieve analysis method . In that we determined 100% M-Sand and 80% DMS & 20% M-Sand gives more efficient result compare to other ratios.

A higher packing density of aggregates results in smaller ratio of voids and thus a lower paste content required.

COMPERSIVE STRENGTH ON SPICEMEN:

The evaluation of concrete with M-Sand and DMS as a partial replacement of fine aggregates. Fly ash and GGBS replacement of cement has done through testing the specimens. Concrete contains fly ash ,GGBS , coarse aggregate , fine aggregate , alkaline solution , water &admixteres for geopolymer concrete are before one day of the casting prepare the alkaline solution. For the preparation of solution using plastic bucket, glass rod the solution are sodium hydroxide , sodium silicate and water ,the DMS , M-Sand are replacement of fine aggregate with various percentages like 10%, 20%, 30% ,40% ,50% ,60% ,60% ,70% ,80% ,90% ,100%. In this research we were used GGBS, and fly ash are added to the concrete by volume of the cement.

For testing the compressive strength for cubes of mix percentages are totally 33 cubes and size of the specimen is 150mm X 150mm X 150mm were casted for strength of geopolymer concrete. From the date of casting specimens are kept in as its in the mould for 24hrs. Next day demould the concrete specimen and kept in room temperature. The specimen are tested on compressive testing machine for 14th day and 28th day.

Fig. 3.2.1 Concrete Mixing.

Fig. 3.2.2 Vibrating.

Fig 3.2.3 Geopolymer Cube

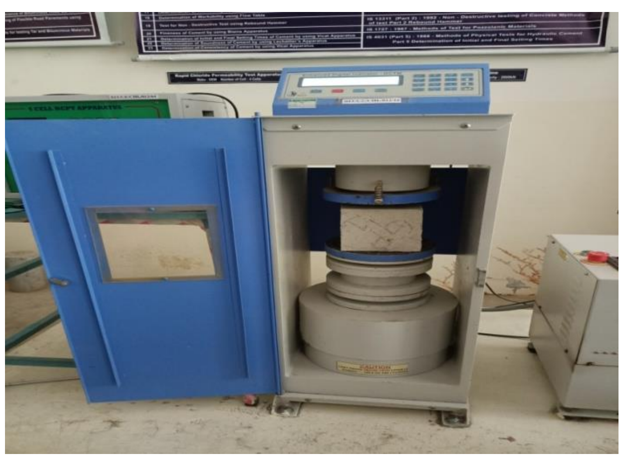


Fig. 3.2.4 Compression Test on Cube.

RESULTS OF COMPRESSIVE TESTS ON CONCRETE:

Table 3.3 Results of Compressive Tests on Concrete.

SI.NO	MIX ID	COMPRESSIVE STRENGTH (Mpa)			AVERAGE
		14 DAYS			
		Trial 1	Trial 2	Trial 3	
1	GP1	45.93	40.53	42.61	43.02
2	GP2	53.03	40.07	47.52	46.87
3	GP3	37.80	42.88	32.67	37.78
4	GP4	53.5	48.21	42.35	48.02
5	GP5	37.51	33.04	41.91	37.48
6	GP6	35.57	42.16	38.74	38.82
7	GP7	22.40	40.07	33.01	31.82
8	GP8	44.62	39.12	43.25	42.33
9	GP9	45.44	42.20	39.04	42.22
10	GP10	23.78	35.83	27.94	30.18
11	GP11	34.93	37.11	41.25	37.76

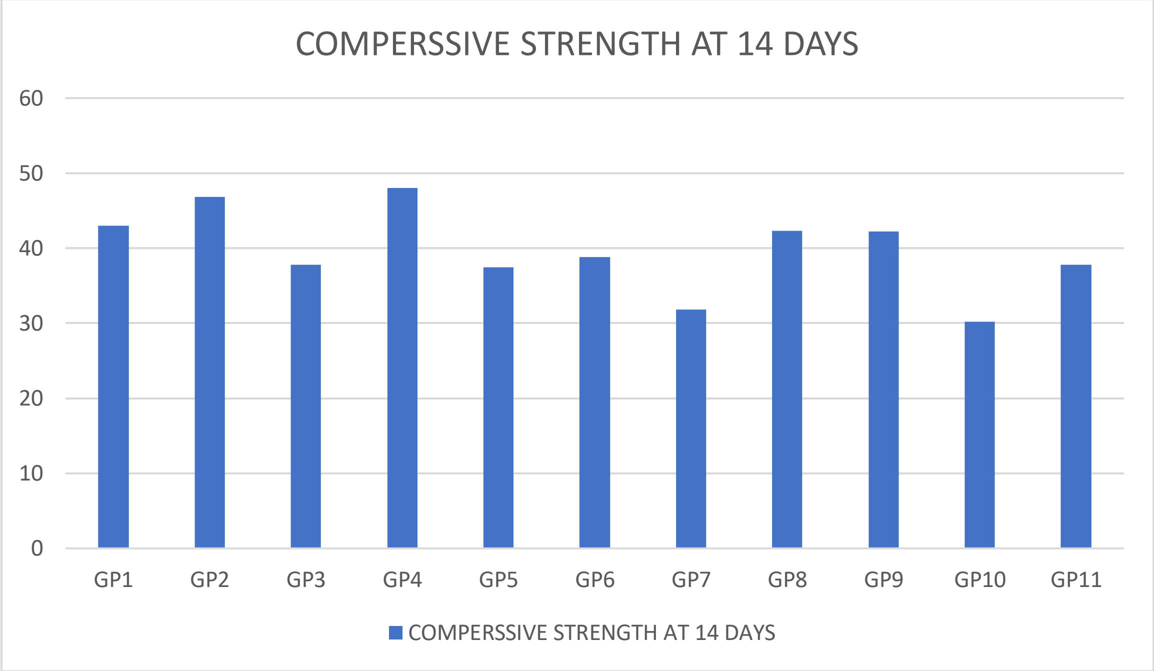


Fig. 3.3 Results of Compressive Tests.

Experimental work on concrete cube on that we cast a cube in different types of fine aggregates with different ratios we found that 100% M-Sand and 80% DMS & 20% M-Sand attains maximum strength .finally we conclude that above ratio mixtures used for construction purposes.

Conculsion:

The following conclusions were arrived based on the detailed investigation made:

- Designing the concrete mixes by packing density method , the required quantity of cement content was reduced. If packing density is high in concrete means gives strength to the structure.
- With regard to substituting DMS in concrete, the strength characteristics strongly match with Geopolymer concrete with M-Sand . Hence, DMS shall be recommended as fine aggregate in Geopolymer concrete.
- With the use of GGBS, the new fine aggregate becomes suitable for cast-in-situ applications too as ambient curing conditions are sufficient to get desired strength.

In general, the workability gets decreased with increased percentage of DMS which shall be overcome by proper admixtures as used in this work.

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