AN EXPERIMENTAL INVESTIGATION OF FLY ASH AND QUARRY DUST WITH GEOPOLYMER

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ABSTRACT

This study investigates the feasibility of using fly ash and quarry dust as sustainable alternatives in the production of geopolymer concrete (GPC)**.** Geopolymer concrete is a green construction material that utilizes industrial by-products activated with alkaline solutions instead of traditional Portland cement. In this experimental work, fly ash is used as the primary binder, while quarry dust serves as a partial or full replacement for fine aggregates. Various mix proportions were prepared and tested to evaluate mechanical properties such as compressive strength**,** split tensile strength, and flexural strength. The influence of different curing methods and alkaline activator concentrations was also examined. The results demonstrate that geopolymer concrete incorporating fly ash and quarry dust exhibits good mechanical performance, making it a viable and environmentally friendly alternative to conventional concrete.The major problem the world is facing today is the environmental pollution. In the construction industry mainly the production of Portland cement will causes the emission of pollutants results in environmental pollution. We can reduce the pollution effect on environment, by increasing the usage of industrial by-products in our construction industry.Geopolymer concrete is such a one and in the present study, to produce the geo-polymer concrete the Portland cement is fully replaced with fly ash and the fine aggregate is replaced with quarry dust and alkaline liquids are used for the binding of materials.The alkaline liquids used in this study for the polymerization are the solutions of Sodium hydroxide (NaOH) and sodium silicate (Na2Sio3). Different molarities of sodium hydroxide solution i.e. 8M, 10M and 12M are taken to prepare different mixes. And the compressive strength is calculated for each of the mix. The cube specimens are taken of size 150mm x 150mm x 150mm.The Geopolymer concrete specimens are tested for their compressive strength at the age of 7days,mixes of varying sodium hydroxide molarities i.e.8M,10M and 12M are prepared and they are cured by direct sun-light and strengths are calculated for 7 days,14 days and 28 days .

1.INTRODUCTION

1.1 GENERAL

Concrete has been proved to be a leading construction material for more than a century. Concrete is the most widely used man-made construction material in the world. It is obtained by mixing cementitious materials, water, aggregate and sometimes admixtures in required proportions. Fresh concrete or plastic concrete is freshly mixed material which can be moulded into any shape hardens into a rocklike mass known as concrete. The hardening is because of chemical reaction between water and cement, which continues for long period leading to stronger with age.

1.2 NEED OF GEOPOLYMER CONCRETE

To produce environmental friendly concrete, we have to replace the cement with some other binders which should not create any bad effect on environment. The use of industrial by products as binders can reduce the problem. In this respect, the new technology geo-polymer concrete is a promising technique. In terms of reducing the global warming, the geo-polymer technology could reduce the CO2 emission to the atmosphere caused by cement and aggregates industries by about 80% (Davidovits, 1994c). And also the proper usage of industrial wastes can reduce the problem of disposing the waste products into the atmosphere.

1.3 ALTERNATIVE MATERIALS IN CONCRETE

This project is attempted to reduce of waste materials in concrete instead of using natural materials. Due to the usage of alternative materials, it is used to avoid the natural depletion resources. The recycling of construction materials is primarily an attempt to reduce the cost of production of new materials and also reduces the consumption of natural resource.

1.4 Ground Granulated Blast furnace Slag (GGBS)

Ground Granulated Blast furnace Slag (GGBS)is a byproduct from the blast furnace used to make iron. According to the report of the working Group on cement industry forthe 12thfive year plan, around 10 million tones blast furnace slag is currently being generated in the country from iron and steel industry. Iron ore, coke and limestone are fed into the furnace and the resulting molten slag floats above the molten iron at a temperature of about 1500°C to 1600°C. After the molten iron is tapped off, the remaining moltenslag, which consists of mainly siliceous and aluminous residue is then waterquenched rapidly, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size, which is known as GGBS.

Fig.1.1. Ground Granulated Blast furnace Slag (GGBS)

1.5 Manufacturing Sand (M-SAND)

About 20 to 25 per cent of total production in each crusher unit is left out as the waste material-quarry dust. Many studies have examined the influence of the partial replacement of fine aggregate in concrete using crusher dusts or small crushed sand samples on concrete properties. However, little work has been performed on the complete replacement of natural fine aggregate in concrete with crusher dusts.

1.6 Recycled Coarse Aggregate (RCA)

Construction and demolition waste (C&D waste) is increasingly seen as a valuable source of engineering materials for the construction industry. Municipal Corporation of Delhi says it is collecting 4,00 tonnes of C&D waste daily from the city which amount to almost 1.5 million tonnes of waste annually in the city of Delhi alone. Even if we discount all the waste which is illegally dump around the city 1.5 million of C&D waste if recycled can significantly substitute demand for natural sand by Delhi. However the percentage of use of these materials is not at all at a desired or sustainable level. There is also far too little knowledge of the technically realistic ways to reuse C&D waste.

1.7 GEOPOLYMER

The term geo-polymer was first coined by Davidovits in 1978 to represent a broad range of materials characterized by chains or networks of inorganic molecules. Geo- polymers are chains or networks of mineral molecules linked with co-valent bonds.

Geopolymer is produced by a polymeric reaction of alkaline liquid with source material of geological origin or by product material such as fly ash, rice husk ash, GGBS etc. Because the chemical reaction that takes place in this case is a polymerization process,

Davidovitscoined the term ‘Geopolymer’ to represent these binders.Geo-polymers have the chemical composition similar to Zeolites but they can be formed an amorphous structure.

He also suggested the use of the term ‘poly (sialate)’ for the chemical designation of Geopolymer based onsilico-aluminate. Sialate is an abbreviation for siliconoxo-aluminate.

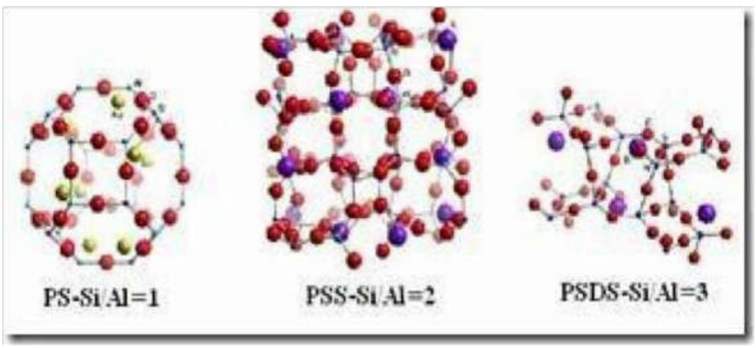


Figure-1.4. General Polymeric structures from polymerization of monomers

1.8 Fly Ash

Fly ash is manufactured by the burning of coal in an electrostatic precipitator, a byproductofindustrial coal. The cementitiousproperties of fly ash were discovered in late 19th century and it has been widely used in cement manufacture for over 100 years. InUK, fly ash is supplied as a separate component for concrete and is added at the concrete at the mixer. It generally replaces between 20 and 80 per cent of the normal Portland cement.

1.9 Production and Classification of Flyash

A thermal stationis a power plant in which the prime movers steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator.

After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated; this is known as a Rankin cycle. The greatest variation in the design of thermal power stations is due to the different fossil fuelresources generally used to heat the water. Some prefer to use the term energycenter because such facilities convert forms of heat energy into electrical energy Fly ash highly recommended for mass concrete applications. i.e. large mat foundations, dams etc. the hungry horse dam, canyon ferry dam and the Wilson dam, hart well dam and sultan dam in USA, the Lednock dam in UK and sudagin dam in Japan are few examples abroad, LUI center in Vancouver successfully used 50% fly ash for all structural elements in India, some portions of Rihand dam and some part of barrages in Bihar are some examples. Fly ash can be used for the following

- Filling of mines,
- Replacement of low lying waste land and refuse dumps, eplacement of cement mortar,
- Air pollution control,
- Production of ready mix fly ash concrete,
- Laying of roads and construction of embankments,
- Stabilizing soil for road construction using lime- fly ash mixture, Construction of rigid pavements using cement-fly ash concrete, Production of lime-fly ash cellular concrete,
- Production of precast fly ash building units,
- Making of lean-cement fly ash concrete

1.10 QUARRY DUST

Now-a-days the natural river sand has become scarce and very costly. Hence we are forced to think of alternative materials. The Quarry dust may be used in the place of river sand fully. The world wide consumption of fine aggregate inconcrete production is very high, and several developing countries have encountered difficulties in meeting the supply of natural fine aggregate in order to satisfy the increasingneeds of infrastructural development in recent years. The physical and chemical properties ofquarry dust satisfy the requirements of fine aggregate. It isfound that quarry dust improves its mechanical property ofconcrete if used along with super plasticizer. Usage of quarrydust it will also reduce the cost of concrete.

2. LITERATURE REVIEW

Rangan, B.V. (2018) stated that Geopolymer concrete is more resistant to heat, sulphate attack, water ingress & alkali-aggregate reaction. The role of calcium in Geopolymer concrete made up of fly ash is very prominent since it may cause flash setting.

Wallahet. al, (2016) Explained that, heat-cured fly ash-based Geopolymer concrete undergoes low creep and very little drying shrinkage in the order of about 100 micro strains after one year. And it has an excellent resistance to sulphate attack. IN

RaffaeleCasciaro. et.al. (2017) They have proposed a multilevel strategy and methods, which should be considered as level to develop a multi task code suitable for analyzing masonry structures. According to national joint research project supported by the Italian Ministry MIUR and make a proposal for that one. The multilevel tricks have been designed only for the detailed description of the masonry structures and their assembly. These are only focused on the plane analysis of brick masonry walls and proposed scheme using local and global levels of description.

D. Hardjito..et.al.(2016) This author researched in silicon and aluminum materials in concrete. This silicon and aluminum materials from geological origin or by product materials like fly ash. The chemical composition of geopolymer is similar characteristics of zeolite Fly ash are based in geopolymer binders shows excellent short and long-term mechanical characteristics of concrete.

G.Saravanan.et.al..(2014) Has investigated the amount of carbon dioxide released during the manufacture of ordinay Portland cement due to the calcinations of lime stone. The production of OPC needed the Combustion of fossil fuel is in the order of 600 kg. In addition, the energy required to produce OPC is only next to steel and aluminum.

DjwantoroHardjito, Steenie E Wallah, Dody M.J. Sumajouw, and B.V.Rangan (2022)describe the effects of several factors on the properties of fly ash based Geopolymer concrete, especially the compressive strength. The test variables included were the age of concrete, curing time, curing temperature, quantity geopolymer of super-plasticizer, the rest period prior to curing, and the water content of the mix.

Shuguang Hu, Hongxi Wang, GaozhanZhang ,Qingjun Ding(2007) they prepared three repair materials by using cement-based, geo-polymeric, or geopolymeric containing steel slag binders.

N.P.Rajamane,.et.al.(2016) This study presents mechanical properties and durability of structures of different grade of geopolymer concretes (GPCs). In this project the Portland cement has completely replaced by the geopolymer as the binder. The data's are utilized to discuss about various aspects of new types of concretes, which have been high potential to become environmental friendly alternate materials to control Portland cement based concretes

Vidya Jose1..et.al. (2012) hollow core slab is made by precast pre-stressed concrete member and continuous voids provided to reduce the self weight concrete it's and cost. The core slabs are primarily used as a floor deck system in residential and commercial buildings like parking structures. These are in small depths and panning for long distances. A hollow core slab provides the prestressed member for load capacity, span range, and deflection control of Structural member.

These slabs can make use of pre-stressing strands; it allows slabs with depth of 150 and 260 mm and spans over 9 meters.

Zhu Pan, Jay G. Sanjayan, B. V. Rangan (2009) they concluded that the ductility of the mortars has a major correlation to this strength gain/loss behaviour. They prepared the specimens with two different fly ashes, with strengths ranging from 5 to 60 MPa, were investigated. They concluded that the strength losses decrease with increasing ductility, with even strength gains at high levels of ductility. This correlation is attributed to the fact that mortars with high ductility have high capacity to accommodate thermal incompatibilities.

XiaoluGuo, HushingShi, Warren A. Dick (2009) they studied the compressive strength and micro structural characteristics of a class C fly ash Geopolymer (CFAG) were studied. They concluded that a high compressive strength was obtained when the class C fly ash (CFA) was activated by the mixed alkali activator (sodium hydroxide and sodium silicate solution) with the optimum modulus viz., molar ratio of SiO_2/Na_2O of 1.5. When CFA is alkali activated the sphere seems to be attacked and broken due to the dissolution of alumino-silicate in the high pH alkali solution environmental protection.

3.EXPERIMENTAL WORK

This Chapter describes the experimental work. First, Mix design of geopolymer concrete, manufacturing and curing of the test specimens are explained. This is then followed by description of types of specimens used, test parameters, and test procedures.

The mix design in the case of geo-polymer concrete is based on conventional concrete with some modification. In the case of conventional concrete the material proportion can be found out for the required strength using the code, but in the case of geo-polymer concrete there is no design method or codal provisions. Here by means of trial and error method optimized mixes is being produced.

The mass of fine aggregates + coarse aggregates = 1750kg/m .Coarse Aggregate

= 60% of 1750

= 1050 kg/m

3.1 PREPERATION OF ALKALINE LIQUIDS

NOTE: Molarity = moles of solute/litre of solution

In this project the compressive strength of geo-polymer concrete is examined for the mixes of varying molarities of Sodium hydroxide (8M, 10M, and 12M). The molecular weight of sodium hydroxide is 40. To prepare 8M i.e. 8 molar sodium hydroxide solutions, 320g of sodium hydroxide flakes are weighed and they can be dissolved in distilled water to form 1 liter solution. For this, volumetric flask of 1 liter capacity is taken, sodium hydroxide flakes are added slowly to distilled water to prepare 1liter solution.

Fig 3.1 sodium hydroxide in pellets form **Fig 3.2 sodium hydroxide in flakes form**

3.2 MANUFACTURING AND CASTING OF GEO-POLYMER CONCRETE

The conventional method used in the making of normal concrete is adopted to prepare geo-polymer concrete. First, the quarry dust, coarse aggregate and Flyashare mixed in dry condition for 3-4 minutes and then the alkaline solution which is a combination of Sodium hydroxide solution and Sodium silicate solution with super- plasticizer is added to the dry mix. The mixing is done about 6-8 minutes for proper bonding of all the materials. After the mixing, the cubes are casted with the mixes GP1 toGP3 by giving proper compaction. The sizes of the cubes used are of size 150mmX150mmX150mm.

Fig 3.3 Fresh geo-polymer concrete & Casting of geo-polymer concrete cubes

For the curing of geo-polymer concrete cubes, the cubes are placed in direct sun- light. For the sun light curing, the cubes are remolded after 1 day of casting and they are placed in the direct sun light for 7 days.

Compressive strength is the capacity of a material or structure to withstand axially directed pushing forces. Cubes of 150mm×150mm×150mm were casted and compressive strength test was conducted on specimens at 7 days. To conduct the test the specimens are placed in a compression testing machine and the load is applied to the cube and the load at failure is noted as failure load. The compressive strength is calculated by using the formula given in 4.1. The results in tables 5.1.1.

$F_{ck}=P_c/A$

Where,

P_c=load at failure in N A=loaded area of cube in mm^2

Fig 4.5 Polymer Concrete Cubes after Compression Test

4. RESULTS AND DISCUSSIONS

The results of the tests which are specified in chapter 4 are given in the following tables with their corresponding graphs.

TABLE 4.1 Compressive strength

Name of The mix	Compressive strength in N/mm^2 of specimens Cured By		
	7days	14days	28days
CC	18.6	23.4	27.0
GP1	30.0	27.5	21.5
GP2	31.5	28.7	22.5
GP3	38.0	30.0	24.0

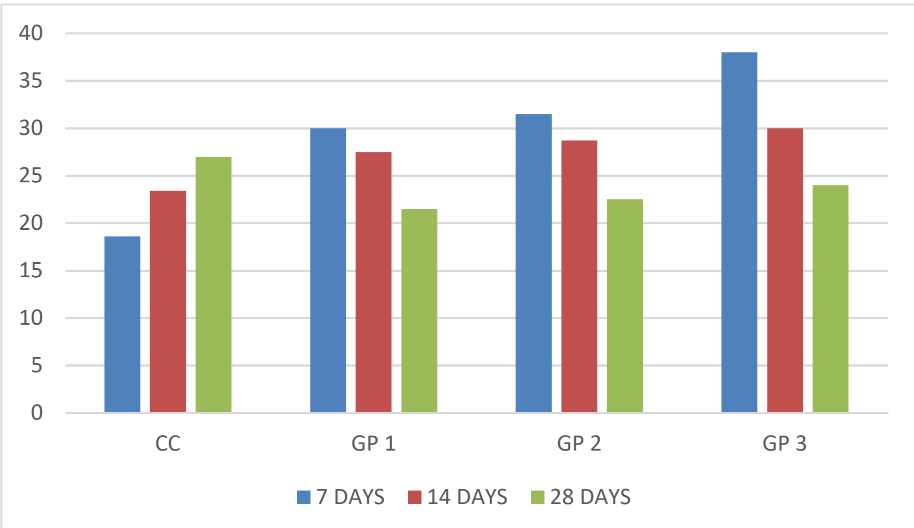


Figure 4.1 Compressive strength of specimens at the age of 7 , 14 & 28 days

By showing the above graph the compressive strength increase the strength by 40% in 7days.The other one shows the increase of the strength by 60% it reflects that by increase the days limit the strength of the mixture can be increased .The last one shows the increase of the strength by 75%.In case of considering the split tensile test the strength can be varies as it compare with the compressive strength. The only difference can we observe is mixing ratio of the quantity .The graphs shows that increase of composition by 40% to 80 %

Flexural Strength Test

TABLE 4.2 Flexural Strength of Values at 7 Days

Sl. No.	Mix % of Quary dust	Fly ash	bd^2 1 x 10^6 (mm^3))	Load KN	Flexural Strength (N/mm^2)
1	0 %	100%	15cm x 15cm x 70cm (3.375)	21.25	3.78
2	10 %			23.75	4.22
3	15 %			26.25	4.67
4	20%			25.00	4.44

TABLE 4.3 Flexural Strength of Values at 14 Days

Sl. No.	Mix % of Quarry dust	Fly ash	bd^2 1 x 10^6 (mm^3)	Load KN	Flexural Strength (N/mm^2)
1	0 %	100%	15cm x 15cm x 70cm (3.375)	33.00	5.87
2	10 %			35.00	6.22
3	15 %			36.875	6.55
4	20%			39.375	7.00

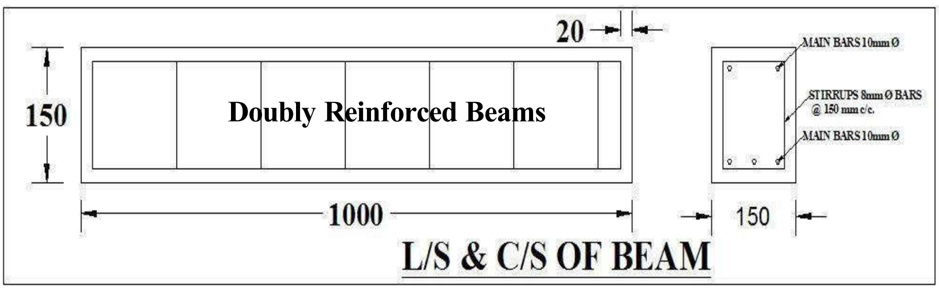
5.5 Static Loading of Beams

Beams were cast in steel mould as shown in Fig. and after curing they were removed and arranged in UTM under three-point bending. Strain gauges were used to measure the strain and to calculate the forces, moments, and deformation of structures and materials. In this experiment it is used to measure the strain in a beam through the use of eight resistance

C = Distance from the center of the beam to the point where the strain is being measured h/2 in mm

E = Modulus of Elasticity, M = Moment in N/m b = Width in mm, h = Thickness in mm, e = Strain in µm/m

The load vs. strain and load vs. deflection readings for different beams are shown with different designations of beams.



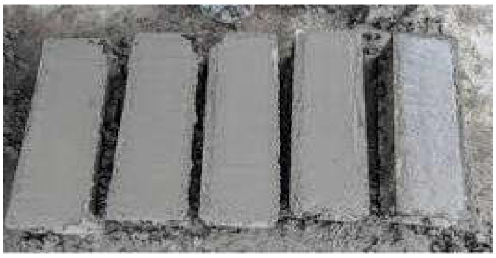


Fig 4.2 Flexural Strength of Beam by using conventional concrete (28 Days)

TABLE 4.4 Strength of Beam by using Fly Ash 100%

LOAD KN	Deflection in mm		Strain in 10^-6		Stress N/mm²
	Experimental Deflection mm	Numerical Deflection mm	Experimental Strain 10^-6 N/mm²	Numerical Strain 10^-6 N/mm²	
0	0.00	0	0	0	0
10	0.59	0.94	504.042	570.85	16.345
20	0.77	1.19	672,056	712.35	16.459
30	0.94	1.35	840.070	896.4	16.945
40	1.42	1.69	1260.106	1325.85	17.503
50	1.62	1.81	1680.141	1754.265	17.750
75	1.62	1.98	2100.177	1980.25	18.035
100	1.82	2.04	2520.212	2685.1	18.385

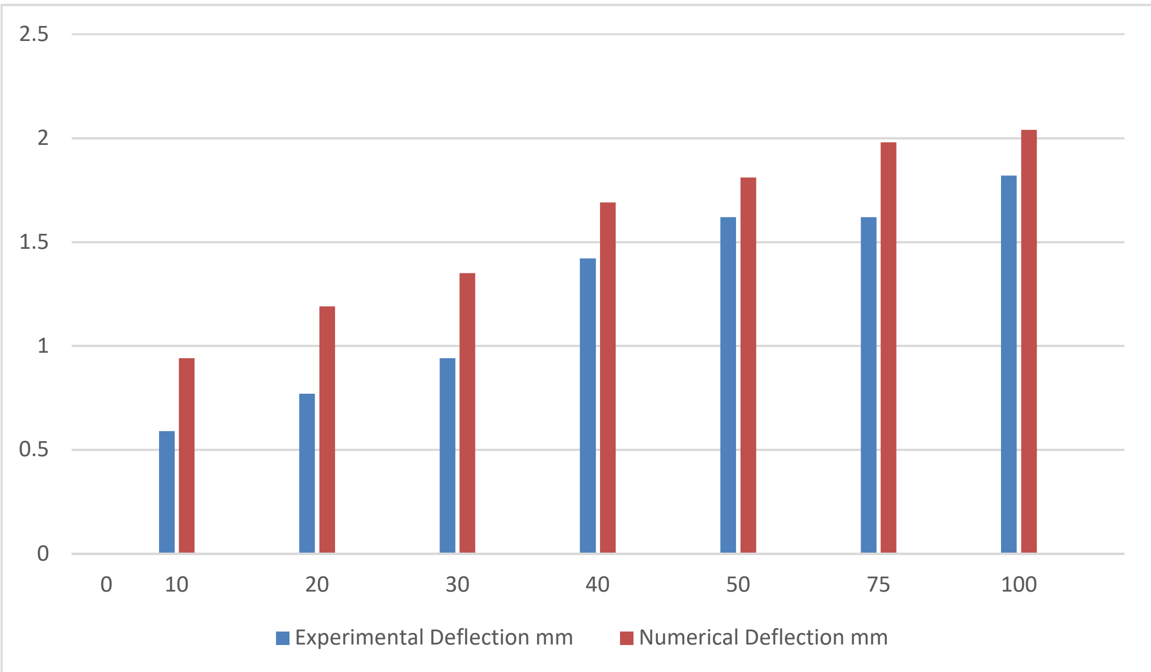


Fig.4.3 Strength of Beam by using Fly Ash 100%

TABLE 4.5 **Strength of Beam by using Fly Ash 80% & Quary dust 20% Concrete (28 Days)**

LOAD KN	Deflection in mm		Strain in 10^-6		Stress N/mm²
	Experimental Deflection mm	Numerical Deflection mm	Experimental Strain 10^-6 N/mm²	Numerical Strain 10^-6 N/mm²	
0	0.00	0	0	0	0
10	0.55	0.90	502.042	550.85	14.345
20	0.70	1.10	670,056	702.35	15.459
30	0.90	1.31	830.070	866.4	15.945
40	1.41	1.62	1250.106	1315.85	16.503
50	1.60	1.80	1660.141	1744.265	16.750
75	1.59	1.93	2000.177	1880.25	17.035
100	1.78	2.00	2420.212	2585.1	17.385

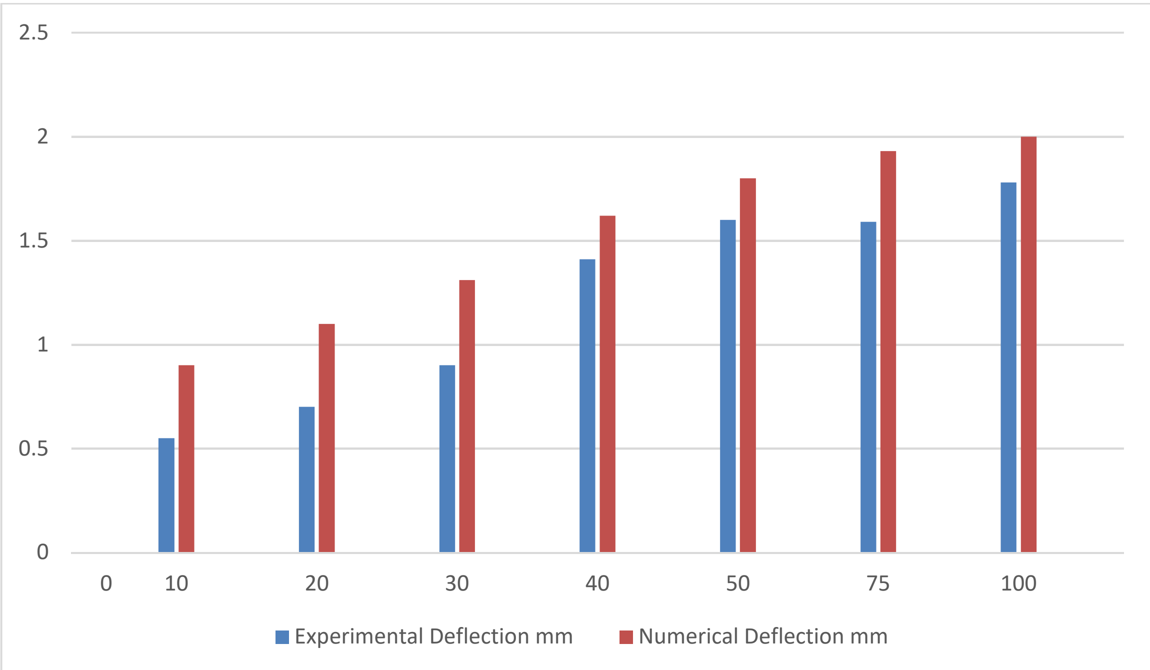


Fig 4.4 Strength of Beam by using Fly Ash 80% & Quary dust 20% Concrete(28 Days)

5. CONCLUSIONS

Based on the experimental work reported in this study, the following conclusions.

- Higher concentration (in terms of molar) of sodium hydroxide solution results in higher compressive strength of fly ash & quarry dust based geopolymer concrete.
- Longer curing time, in the range of 4 to 96 hours (4 days), produces higher compressive strength of fly ash &quarry dust based geo-polymer concrete.

However, the increase in strength beyond 24 hours is not significant.

- The fresh flyash-based geo-polymer concrete is easily handled up to 120 minutes without any sign of setting and without any degradation in the compressive strength.
- In addition to that fly ash shall be effectively used and hence no landfills are

required to dump the fly ash

To Provide a most Economical Concrete It should be easily adopted in field.

- To reduce the cost of construction.
- To promote low cost housing for the people.
- To find the optimum strength of the partial replacement of concrete.
- To make the maximum usage of locally available materials.

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