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FLEXURAL BEHAVIOUR OF REINFORCED GEOPOLYMER CONCRETE BEAM WITH PARTIAL REPLACEMENT OF FLY ASH BY WASTE GRANITE POWDER

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Abstract : **This research work aims to study the sustainability of Geopolymer concrete beam with partial replacement of fly ash by waste Granite Powder. Reinforced Geopolymer concrete beam of M35 grade with 15% replacement of granite powder is compared with conventional reinforced geopolymer concrete beam. Beam of cross section 150 x 150mm and length 700mm were casted and cured under ambient conditions. The tension reinforcement consists of two bars of 12 mm diameter and compression reinforcement consists of two bars of 6 mm diameter. The shear reinforcement was made with 8mm stirrups at 90 cm spacing along the length. The beams thus casted is tested under two point static loading to study its flexural behaviour. The studies demonstrated that the performance of 15% replaced Geopolymer Concrete Beam is better than the conventional Geopolymer concrete beam. The addition of waste granite powder increase the Ultimate load carrying capacity and ensures superior ductile behaviour. This investigation work encourages the use of waste granite powder in the geopolymer concrete thereby enhancing its structural behaviour.**

IndexTerms **:** ***fly ash, Granite powder, ambient conditons, Geopolymer concrete beam,flexural behaviour*.**

I.INTRODUCTION

Geopolymer concrete is one of the building materials that has become more popular in recent years due to the fact that it is comparitively eco-friendly than the standard concrete. The Ordinary Portland cement (OPC) is the primary binder to produce the concrete is. The demand of concrete is increasing day by day for the need of development of infrastructure facilities. Also it consumes significant amount of natural resources and energy and releases substantial quantity of carbon dioxide to the atmosphere. Newer alternate materials are incorporated in the concrete, so that deficient properties of concrete can be enhanced to our convenience of making concrete a versatile material and eco friendly.Some of the such materials are fiber, slag, fly ash etc.. In addition, as the industries grow, their production of waste also increased many times. One of such industrial waste product is Waste granite powder that are greately accumulated from the industries and therefore usage of those wastes in efficient manner is also taken to account. The utilisation of GGBS,Fly ash and Granite powder thus find its importance in the Geopolymer concrete. The main objective of this paper is to present the Experimental investigation of geopolymer concrete with partial replacement of fly ash by waste granite powder.

II.MATERIALS AND PROPERTIES

A.Binders

Fly ash, ground granulated blast furnace slag (GGBS) and granite powder are the binders involved in geopolymer concrete

1.Fly ash

Generally ,Class F fly ash provides good pozzolanic activity and it contains less than 10% of lime (CaO). In this work, Class F fly ash is to be used which was collected from Mettur Thermal Power Station, Salem.

2.GGBS

GGBS (Ground Granulated Blast-furnace Slag) is obtained as a by-product from the blast-furnaces used to make iron. The iron ore is reduced to iron and the remaining materials forms a slag. For using the slag in the manufacture of GGBS the slag has to be rapidly quenched in large volumes of water. As a result, granules are formed like coarse sand and when it is subjected to drying and ground to fine powder it forms GGBS.

3.GRANITE POWDER

Granite belongs to igneous rock family. The stone crushing industries produce large amount of granite waste. These wastes are utilized in the concrete as a replacement material.

B.Alkaline activators

Alkaline activators include sodium hydroxide pellets and sodium silicate solution. The alkaline activators are prepared or the molarity of 12. Sodium hydroxide pellets are dissolved in distilled water which cases an exothermic reaction. Sodium silicate solution is mixed with the sodium hydroxide solution after the heat is gone.

C.Aggregates

The fine aggregate used is M-sand. The coarse aggregate used is of size 20mm and 12.5mm.

Table 1: physical properties of binders

S.NO	Description	Fly ash	GGBS	Granite powder
1.	Fineness	7%	8%	6%
2.	Consistency	43%	30%	33%
3.	Specific Gravity	2.95	2.98	2.66

Table 2: physical properties of aggregates

S.NO.	Description	M-Sand	Coarse aggregate
1.	Specific gravity	2.59	2.64
2.	Water absorption	1.5%	0.7%
3.	Bulk density	1.75 kg/m3	1480 kg/m3
4.	Crushing value	-	24.8%

III.MIX PROPORTIONS

Table 3: Mix proportions

Fly Ash	Fine Aggregate	Coarse Aggregate	Alkaline Solution
445.53	629.603	1216.89	191.58
1	1.43	2.73	0.43

IV.RESULTS AND DISCUSSION

A.GENERAL

This chapter deals with the mechanical properties and flexural behaviour of geopolymer beam.

B.MECHANICAL PROPERTIES

The following test were conducted to study the mechanical properties of geopolymer concrete beam with varying percentage of granite powder.

1.COMPRESSIVE STRENGTH TEST

Size of the cube specimen is 100 x 100 x 100mm. The Cube is tested under compression testing machine by gradually increasing the load at the rate of 140 kg/m2 per minute. Then the compressive strength is obtained by dividing ultimate load by area exposed to load.

Table 4: compression strength test results

Proportion	Compressive strength ($N/mm^{2)}$ for Ambient curing		
	7 days	**14 days**	**28 days**
0%	25.5	33.45	42.8
5%	28.5	35.21	46.50
10%	31	37.59	49.61

15%	34	41.50	53.62
20%	30	36.45	48.86
25%	28.7	34.40	45.50

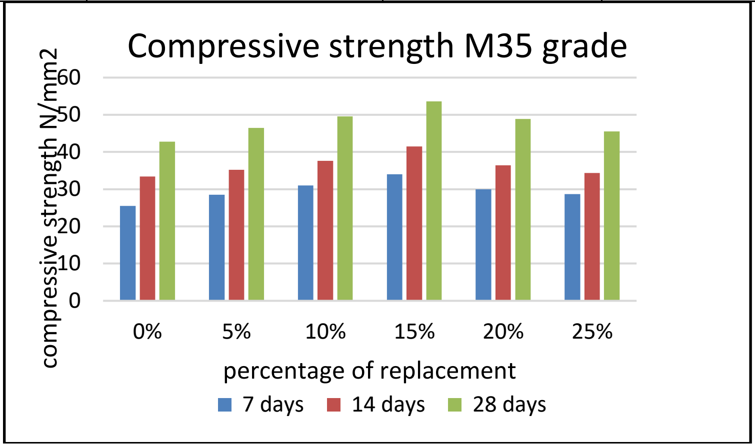

Fig.1 compressive strength test

2.SPLIT TENSILE STRENGTH TEST

Size of the cyclindrical specimen is 100mm diameter and 200mm length. This method consists of applying a diametric compressive force along the length of the cylindrical specimen.

Table 5: split tensile strength test results

Percentage of replacement	Split tensile strength ($N/mm^{2)}$
0%	3.33
5%	3.81
10%	3.96
15%	4.195
20%	2.85
25%	2.365

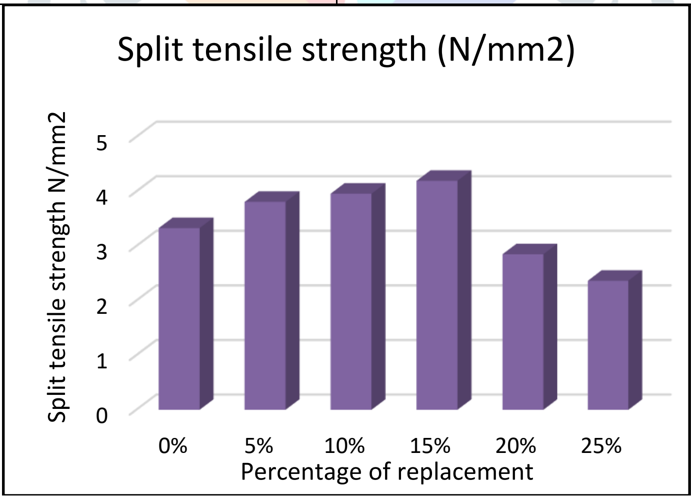

Fig.2 split tensile strength test

C.FLEXURAL BEHAVIOUR

The flexural behavior is analysed using the following results:

Size of the beam specimen is 150x150x700mm. G-I and G-II are the beam with 0% granite powder and G-III and G – IV are the beam with 15% granite powder.The tensile zone reinforcement consisted two 12 mm bars and the compression zone had two 6 mm bars. Shear reinforcement was made with 8mm stirrups at 90 mm spacing along the length of the beam. First the beams are cured for a period of 28 days.. The two-point loading arrangement is used for testing of beams. The load is transmitted through a load cell and spherical seating on to a spreader beam. The spreader beam is installed on rollers seated on steel plates bedded on the test member with cement in order to provide a smooth leveled surface. The test member is supported on roller bearings acting on similar spreader plates. The specimen is placed over the two steel rollers bearing leaving 50 mm from the ends of the beam. The remaining 600 mm is divided into three equal parts 200 mm.

Fig.3 flexural strength test

Two point loading arrangement is done as shown in the figure. Loading is done by hydraulic jack .Lines are marked on the beam to be tested at L/3 ,L/2 & 2L/3 locations from the left support(where L=900mm the center to center distance between the supports) Three LVDT are used for recording the deflection of the beams. One LVDT is placed just below the center of the beam at L/2 and the remaining two LVDT are placed just below the point loads i.e. at L/3 and 2L/3 to measure deflections.Load was increased gradually and the corresponding deflection in the beam was measured at the middle and two loading points by high accuracy dial gauges. Loading was continued and data were recorded until the beam suffered flexural failure by crushing in the compression zone.

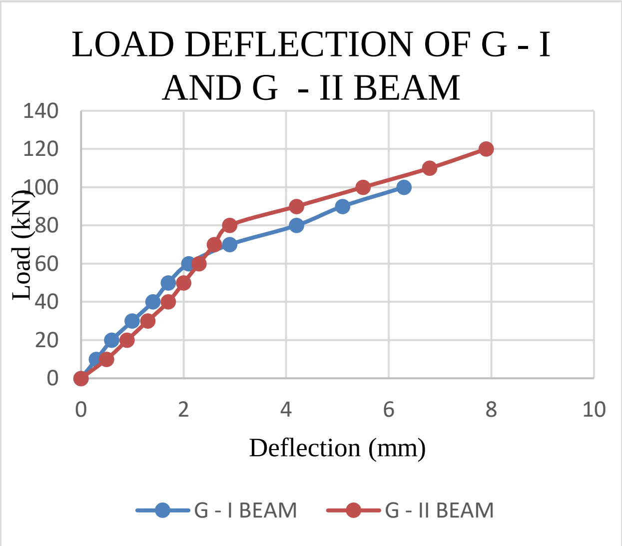

Fig.4 Load vs. Deflection Curve for 0% granite powder

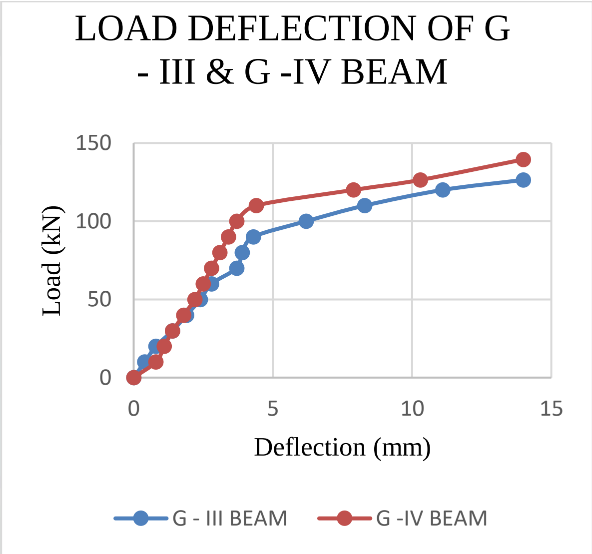

Fig.5 Load vs. Deflection Curve for 15% granite powder

Table 6: Ultimate load and deflection

Parameter	0% GRANITE POWDER		15% GRANITE POWDER	
	G - I	G - II	G - III	G – IV
First crack load	30 kN	50 kN	40 kN	60 kN
Ultimate load	100 kN	120 kN	126.4 kN	139.1 kN
Max. Deflection (mm)	6.3	7.9	14.0	14.0

D.MOMENT CURVATURE RELATIONSHIP

Moment-curvature relations can be calculated from three criteria by computing the curvature (rotation per unit length) using deflection at midspan, combination of deflection at midspan and load points and linear strain distribution across a section by plotting a graph between radius of curvature along X-axis and moment along Y-axis.

$$M = \frac{PL}{6}$$

P – Load in KN
L – Span of beam in m
M – moment in kNm

$$\Phi = \frac{36\delta^2 + L^2}{72\,\delta}$$

δ- Deflection at midspan
Φ- radius of curvature

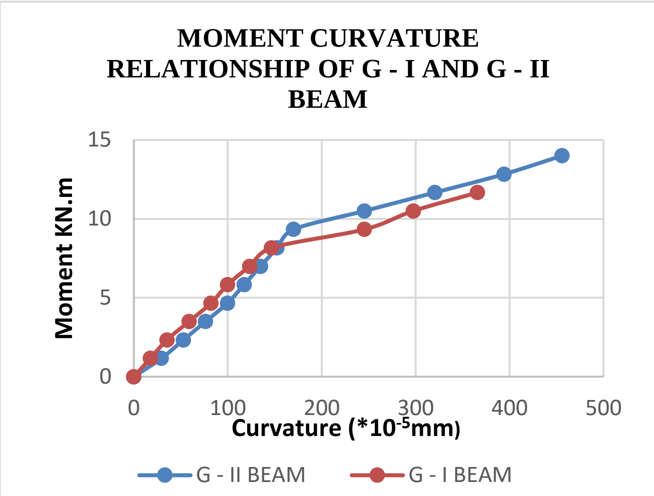

Fig.6 Moment curvature relationship for 0% granite powder

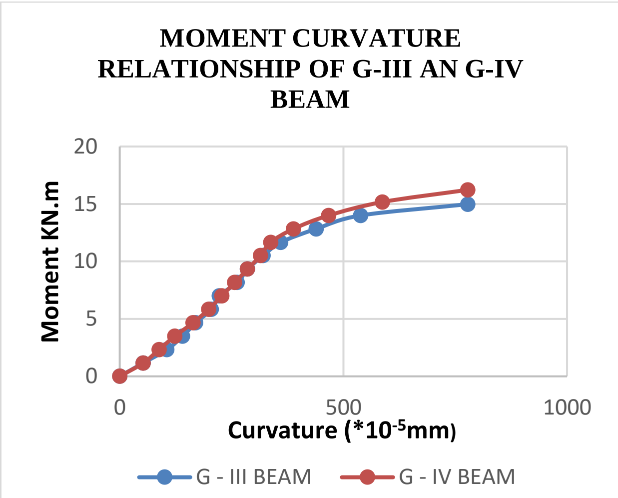

Fig.7 Moment curvature relationship for 15% granite Powder

E.DUCTILITY INDEX RESULTS ON REINFORCED GEOPOLYMER CONCERTE BEAM

Table 7: Ductility index value of beams

BEAM	MID SPAN DEFLECTION AT ULTIMATE LOAD	MID SPAN DEFLECTION AT YIELDING LOAD	DUCTILITY INDEX	AVERAGE
G - I	6.3	1.2	5.25	4.6
G - II	7.9	2.0	3.95	
G - III	14	2.4	6.09	4.715
G - IV	14	3.9	3.60	

F.ENERGY ABSORPTION CAPACITY RESULTS ON REINFORCED GEOPOLYMER CONCERTE BEAM

Table 8: Energy absorption capacity value of beams

BEAM	ENERGY ABSORPTION CAPACITY (kN mm)	AVERAGE
G - I	409.5	503.875
G - II	598.15	
G - III	1212.32	1342.95
G - IV	1473.575	

V.CONCLUSIONS

- Geopolymer concrete properties can be enhanced by considering the replacement of fly ash and GGBS with waste granite powder.
- On adding 15% granite powder to fly ash in geopolymer concrete, the strength gets increases about 25.28% in compressive, 25.97% in tensile, 42.13% in flexural at the age of 28 days compare to the geo polymer concrete without using granite powder.
- The ultimate load at failure and ultimate deflection were higher for geopolymer reinforced beam with 15% added granite powder than the conventional geopolymer reinforced beam.
- The ductility index of 15% reinforced geopolymer concrete beam was 2.5% higher than the 0% reinforced geopolymer concrete beam.

- It is concluded that energy absorption capacity of 15% replaced geopolymer concrete beam are relatively better than the 0% reinforced geopolmer concrete beam. The increased load carrying capacity and large deflections that is undergone by 15% reinforced geopolymer concrete beam increased the energy absorption capacity of the beam.
- This gives the scope that the Geopolymer concrete with fly ash and GGBS in proportion with Waste Granite Powder be employed in construction for better achievement of strength and flexural characteristics.

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