An Experimental Study to Investigate the Feasibility of Marble Dust in Geopolymer Concrete as Fine Aggregate

Krishan Mohan[1] Pradeep K.T.V.[2]
[1]M.Tech Scholar [2]Professor
[1,2]IES Institute of Technology and Management, Bhopal, India

Abstract— Geo-polymer concrete is a non-conventional material in the field of construction material, it has already solved the problem of inclusion of cement in concrete with a newer material of fly ash or GGBF slag. But taking a step further in this field the constituents of geo-polymer concrete apart from binder material like fine and coarse aggregate can be replaced by supplementary materials which can reduce environmental degradation in a low economic scale. To study the behaviour of geo-polymer concrete, having partial replacement (5%, 10%, 15%, and 20%) of fine aggregate with waste marble dust, an experimental study is carried out and the effect on flexure and compressive strength characteristics is studied. Various properties of fresh concrete like its workability, flow index etc. are also considered. For the present study all other parameters like curing temperature, and alkaline solution to solid mass ratio etc. are kept constant. The result of this present investigation indicates that the replacement of certain percentage of fine aggregate with waste marble powder attains maximum compressive and flexural strength. The optimal percentage for replacement of marble powder with fine aggregate is found out by testing of specimen for compressive strength and flexural strength .This also reduces the costs for construction of structures by using marble powder which is freely or cheaply available and more importantly use of geo-polymer concrete minimizes the consumption of cement. More over the use of marble dust reduces the excessive excavation of sand from the river bed thus reducing the environmental impact.

Keywords: Geo-Polymer Concrete, Fine Aggregate

I. Introduction

In the modern world, the ever-increasing demand of concrete for infrastructure development has pushed the cement industry to its peak capacity. It is a well-known fact that the production of ordinary Portland cement have an adverse impact on environment, not only it consumes a substantial amount of natural resources but also releases a significant amount of carbon di oxide and other greenhouse gases in the environment. The world-wide cement industry contributes about 7% of greenhouse gas release to the earth’s atmosphere. In order to address environmental effects associated with the production of Portland cement, there is a need to develop substitute binders to make concrete without hindering its mechanical properties

The development of inorganic alumino-silicate polymer, called geo-polymer is one of many efforts to produce more environmentally friendly concrete, it is synthesized from materials having geological origin or are by-product materials such as fly ash that are rich in aluminium and silicon.

In this study, low calcium fly ash (class F type) is used in production of geo-polymer concrete specimens. For activation of fly ash as binder a combination of sodium hydroxide and sodium silicate is used. Alkaline solution to fly ash ratio is fixed at 0.40. The concentration of sodium hydroxide solution was maintained as 8 M (Molars). Furthermore, effects of addition of marble dust in geo-polymer concrete as a replacement of fine aggregates in different proportion is studied.

A. Need of the Present Study

Ordinary Portland cement contains a huge amount of silica and alumina which acts as a binder when reacts with water, the usage of cement is increasing drastically worldwide. Many researchers, have carried out the change in mechanical parameters in geo-polymer concrete but none has considered to replace other constituents of the concrete with supplementary material. Hence, there is a need of innovative supplementary materials like fly ash, recycled marble dust etc. which can replace multiple constituents in concrete.

In geo-polymer concrete, cement is replaced by fly ash in which the concrete gives more compressive strength comparing to normal concrete and also it is less expensive than normal cement concrete. On the other hand marble dust replaces fine aggregate and provides better workability.

The advantage of geo-polymer concrete having fine aggregates replaced by marble dust is twofold since it reduces the environmental impact of production of cement and also it is economical.

B. Objective of Study

The main objective is to study the effects on workability, compressive strength and flexure strength on addition of marble dust or marble powder to a geo-polymer concrete having constant water to alkaline solids ratio by mass at various ages.

II. Literature review

Carbon dioxide (CO2) emissions trading is a critical factor for the cement industries, as the greenhouse effect created by the emissions is measured to produce an increase in the global temperature which may result in climate change. The ‘tradeable emissions’ is an economic mechanisms that is expected to help the countries worldwide to meet the emission reduction targets established by the 1997 Kyoto Protocol. There is a speculation that one tonne of emissions have a trading value about US$10 (Malhotra, Making Concrete "Greener" With Fly Ash." 1999) and (Malhotra, Role of Supplementary Cementing Materials and 2004). Binders can be produced by any polymeric reaction of alkaline liquids with silicon and aluminium as source materials of geological origin or by-product materials like fly ash or GGBF slag. (Davidovits 1978) .These binders are called geo-polymers because the chemical reaction which is taking place in this case is polymerization reaction.

Although the chemical composition is same as the zeolithic material, the cellular structure is amorphous in nature instead of crystalline in geo-polymer. Materials that contains high percentage of Silicon (Si) and Aluminum (Al) in amorphous form act as a possible source material for the manufacture of geo-polymer. It could be of natural origin like kaolinite, clays, or can be a byproduct material such as fly ash, silica fume, slag, rice husk ash, red mud, etc. Choice of source material used in making of geo-polymers can depend on various factors like availability, cost, type of application and other specific criteria based on customer demands (Hardjito. D and Rangan 2005). In the research report (Hardjito. D and Rangan 2005) Extensive studies on concrete based on fly ash were conducted. The fly ash with low calcium content was used to replace Portland cement wholly. The mechanical properties of concrete were found to be similar to those of concrete made with Portland cement. The concrete also had excellent compressive strength making it suitable civil engineering applications. The stress strain model for concrete obtained from experimental studies was found to be similar to that of ordinary Portland cement concrete, hence stress strain models used for ordinary Portland cement can also be used for geo- polymer concrete using suitable correction and modification factors (Sarker 2008). The study conducted by Lloyd & Rangan 2010 specified that concrete prepared by about 75% part aggregate to total mass, 0.35 alkaline liquid to fly ash ratio and curing at high temperature above 60 C was found to have strength in range of 40-60 MPa. It was observed that, in concrete cured at high temperature, the compressive strength gained in one day was about 80% of that of 28 days' compressive strength. Anuradha et al 2011 conducted studies using river sand and crushed granite stone aggregates which are locally available in India. The mix design procedure for concrete based on the geo- polymer concrete mix design was proposed. The concrete obtained from this procedure was found to have good compressive strength. The price of concrete was also estimated to be about 10% to 30% cheaper than ordinary Portland cement concrete. Kushwah, et al., 2015 observed that marble powder can be used in concrete mix as replacement of fine aggregates. The mechanical properties of marble slurry are determined like specific gravity, fineness modulus was founded and it also showed that utilization of marble slurry by replacing it with sand up to 30% which shows equal strength as of conventional concrete i.e. 1:2:4 cement concrete ratio with 0% marble slurry. It concludes that marble slurry can easily be utilized in cement concrete mix.

III. Methodology and Experimentation

In the present study fine aggregate is replaced in proportion of 5 %, 10 %, 15 %, and 20% in a geo-polymer concrete. 5 types of design mix are prepared with different proportion of marble dust. Three cubes and three beams were cast for each case, therefore total of 45 cubes and 45 beams were cast. In this experimental study testing of normal geo-polymer concrete and geo-polymer concrete with marble dust has been carried out and then the properties are compared.

A general overview of materials used in the making of geo-polymeric concrete is given in Figure 3.1 and 3.2.

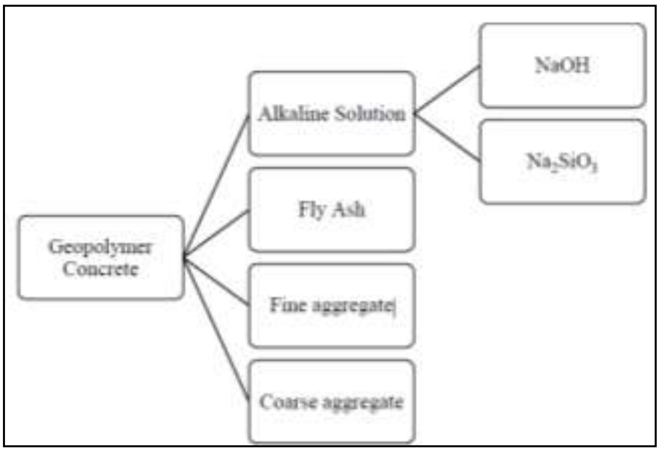

Fig. 3.1: Materials used in making geo-polymer concrete

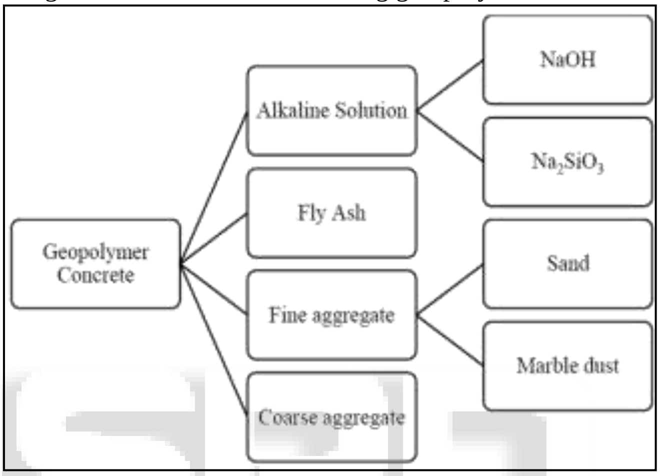

Fig. 3.2 Materials used in geo-polymer concrete with marble dust

A. *Aggregate*

Locally available coarse and fine aggregate are used in study. The fine aggregate conforms to grading zone III of IS 383:1970. The aggregates are washed and graded with consistency before use. The coarse aggregate are available in the laboratory.

The coarse aggregate used are of maximum size 20 mm. Aggregate passing through 20 mm and retaining 4.75 mm is used for experimental work. Both coarse aggregate and fine aggregates were used in surface dry condition. The sieve analysis results carried out in the lab are presented in a Table 1.

The gradation curve for coarse aggregate was shown in Figure 3.3.

Fine aggregate for the normal concrete constitutes of locally available river sand, passing through 4.75 mm used in the experimental work. The sieve analyses are presented in Table 2. The gradation curve for coarse aggregate was shown in Figure 3.4.

IS Sieve Size	Weight retained (%)	Cumulative Weight retained (%)	Cumulative Weight Passing (%)
20 mm	45.0	45.0	55
16 mm	38.0	83.0	17
12.5 mm	15.0	98.0	2
10 mm	1.35	99.35	0.65
84.7 mm	0.05	99.40	0.60

Table 1: Sieve analysis of coarse aggregate

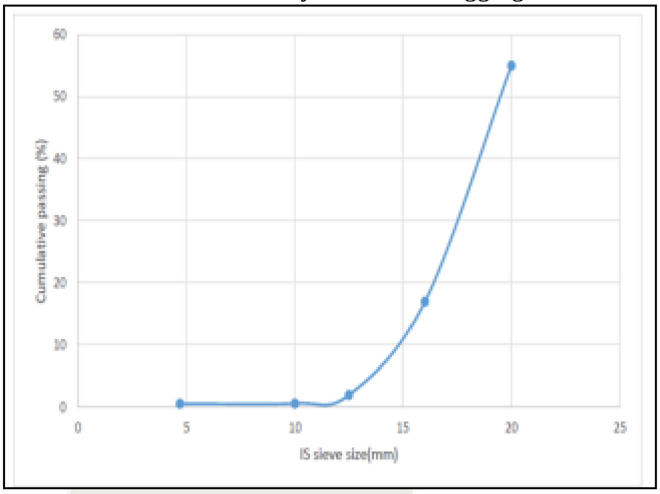

Fig. 3.3: Gradation curve for coarse aggregate

IS Sieve Size	Weight retained (%)	Cumulative Weight retained (%)	Cumulative Weight Passing (%)
4.75mm	1.15	1.15	98.85
2.36mm	0.6	1.75	98.25
1.18mm	20.85	22.6	77.4
600µm	25.55	48.15	51.85
300µm	29.75	77.9	22.1
150µm	20.5	98.4	1.6

Table 2: Sieve analysis of fine aggregate

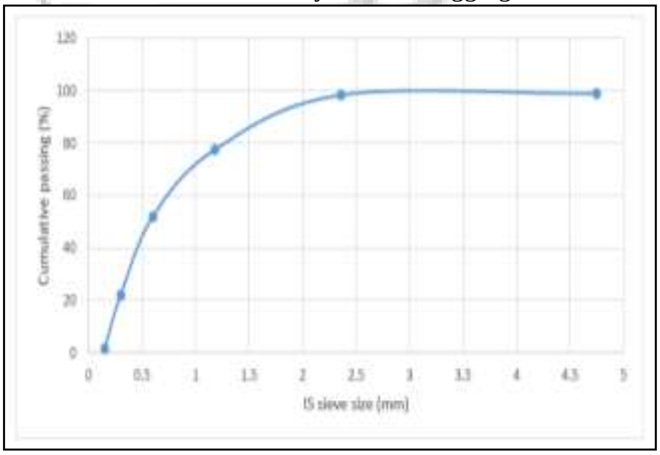

Fig. 3.4: Gradation curve for fine aggregate

In the laboratory, the fly ash and the aggregates are first mixed together thoroughly. The aggregates are prepared in surface dry condition. The alkaline solution is then added to the dry materials and the mixing is continued further. The fresh concrete could be handled up to 2 hours without any sign of setting and without any deprivation in the compressive strength. This fresh concrete is cast into the moulds immediately after mixing, in three layers for cubical specimens of size 150 mm × 150 mm × 150 mm and beam specimen of size 750 mm × 150 mm X 150 mm. Three cubes and three beams were cast for each case, therefore total of 45 cubes and 45 beams were cast. To improve workability of concrete, super plasticizer Sika is used in all mixes. The dosage of super plasticizer is kept to 1% of fly ash by weight. In this experimental work, the water to geo-polymer solids ratio was fixed as 0.26 a constant value, to find out the influence of marble dust and other parameters on the compressive strength of Geo-polymer concrete. Alkaline solutions of sodium silicate and sodium hydroxide are then used to react with the fly ash to produce the binder. In the present study outdoor curing in dry condition at an ambient temperature of about 40 ˚C.

Fig. 3.5: Fresh Geo-Polymer Concrete

Fig. 3.6: Geo-polymer beam specimen with 5% marble dust

IV. EXPERIMENT CONDUCTED

A. Workability Test

– In the present study the workability of the fresh concrete is measured by conventional slump cone test as per IS: 1199(1989).

B. Compressive Strength Test

– The test is performed on standard compression testing machine of 3000 kilo Newton Capacity, as per IS: 516-1959.
– Totally 45 cube specimen three for each case of size 150 mm × 150 mm × 150 mm is casted and tested for the compressive strength at the age of 7 days, 14 days and 28 days.

C. Flexural strength test

- For determining the flexural strength of the beam specimen the conventional two point load test confirming to IS: 516 -1959 is carried out on the hardened beam specimen.
- Total 45 number of beam specimens of size 750 mm × 150 mm × 150 mm is casted and tested for the flexural strength at the age of 7 days, 14 days and 28 days.

V. RESULTS

A. Results of Workability Test:

- The workability of all the mixes is maintained in the range of 20 mm to 60 mm slump but it is observed that with the addition of marble dust the workability of fresh concrete increased consistently.

Concrete mix	Marble dust content (% replacement of sand)	Slump (mm)
Mix 1	0	26
Mix 2	5	32
Mix 3	10	39
Mix 4	15	44
Mix 5	20	51

Table 5.1: Slump of various mixes

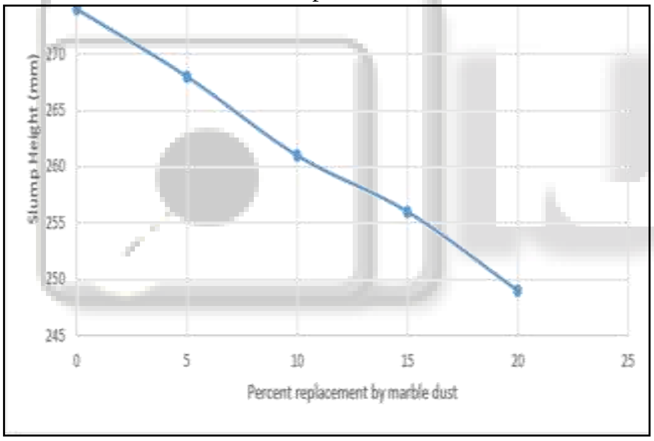

Fig. 5.1: Height of slump with respect to quantity of marble dust in percent

B. Compressive Strength

- The test result reveals that the compressive strength of geo- polymer concrete varies from minimum of 4.4 MPa to 21.1 MPa.
- It is observed that maximum compressive strength is recorded at 10 % replacement, this means that the optimum percentage of proportioning of marble dust with fine aggregate lies within the range of 10% to 15%.

Concrete mix	Marble dust content (% replacement of sand)	Compressive Strength at various ages (N/mm^2)		
		7 days	14 days	28 days
Mix 1	0	5.8	11.5	16.3
Mix 2	5	6.3	11.9	18.1
Mix 3	10	6.1	12.6	21.1
Mix 4	15	4.3	12.2	20.6
Mix 5	20	4.4	10.7	14.9

Table 5.2: Compressive Strength of various Geopolymer concrete mixes

C. Flexural Strength

- The minimum failure load recorded is 1.7 kN and the maximum failure load recorded is 3.6 kN.
- It can be deduced from this that the flexure strength is developed at a higher rate in geo-polymer concrete mixed with marble dust.

Concrete mix	Marble dust content (% replacement of sand)	Two point load test result at various ages (kN)		
		7 days	14 days	28 days
Mix 1	0	1.7	2.1	2.6
Mix 2	5	2.2	2.6	2.8
Mix 3	10	2.2	3.0	3.6
Mix 4	15	1.7	3.0	3.1
Mix 5	20	1.7	1.8	2.2

Table 5.3: Failure load in flexure of various geopolymer concrete mixes

VI. CONCLUSIONS

The following conclusions can be drawn from the present experimental study:

- The workability increases as the percentage of marble dust increases, since it is finer than sand therefore provides more surface area to cling to the coarse aggregate more effectively.
- The compressive strength of geo-polymer concrete increases with the increase in marble dust percentage up to 10% replacement at a maximum value of 21.1 MPa which is about 1.3 times that of geo-polymer concrete without replacement, but gradually decline as the percent replacement is increased. However it is observed that at 15% replacement the value of compressive strength is still higher than normal geo-polymer concrete. This means that the maximum compressive strength can be achieved by keeping the proportion of Fine aggregate and marble dust within the range of 10% to 15%.
- In the case where 20% fine aggregate is replaced by marble dust the compressive strength falls below the compressive strength of geo-polymer concrete without replacement. It may be due to presence of calcium (Ca) in marble dust which starts taking part in the geo-polymer reaction and hinder the properties of alkaline activator solution and binder characteristics

– Flexure test shows very interesting results, the gain in tensile strength in various mixtures are not consistent and are showing very abrupt results. The maximum failure load in two point load test is recorded at 3.6 kN at 28 days in the case of 10% replacement of fine aggregate, which is about 1.4 times that of geo-polymer concrete without replacement. The result shows that the gain in max flexural strength is not rapid or consistent.

REFERENCES

[1] Hardjito. D, Wallah, S.E., Sumajouw, D.M.J., and Rangan, B.V. 2004. ""Properties of geopolymer concrete with fly ash as source material: Effect of mixture composition." *Seventh CANMET/ACI International Conference on Recent Advances in Concrete Technology. Las Vegas, USA. 109-118.*

[2] ACI Committee 363. 1993. " State of the Art of High Strength Concrete." *American Concrete Institute.*

[3] Anuradha, R. et al. 2011. "Modified guidelines for geo polymer concrete mix design using Indian standards."

[4] Bakharev, T,. 2005. ""Durability of geopolymer materials in sodium and magnesium sulfate solutions." *Cement and Concrete Research 1233-1246.*

[5] Bakharev, T,. 2006. "Thermal behaviour of geopolymers prepared using class F fly ash and elevated temperature curing." *Cement and Concrete Research 1134-1147.*

[6] Bakharev.T. 2005. ""Resistance of geopolymer materials to acid attack." *Cement and Concrete Research 35: 658-670.*

[7] Davidovits, J. 1994. " High-Alkali Cements for 21st Century Concretes. Concrete Technology Past, Present and Future." *ACI Special Publication 383-398.*

[8] Davidovits, Joseph. 1978. "GEOPOLYMERS: Inorganic polymeric new materials." *Journal of Materials Education 16 (2,3): 91–138.*

[9] Deepak Ravikumar, Sulapha Peethamparan and Narayanan Neithalath. 2010. "Structure and strength of NaOH activated concretes containing fly ash or GGBFS as the sole binder." *Cement and Concrete Composites 32: 399-410.*

[10] Demirel B, Yazıcıolu S. 2007. "The effect of silica fume on the mechanical properties of carbon fiber reinforced lightweight concrete." *Süleyman Demirel University J. Nat. App. Sciences 103-109.*

[11] Demirel, Bahar. 2010. "The effect of the using waste marble dust as fine sand." *International Journal of the Physical Sciences 5 (9): 1372-1380.*

[12] Djwantoro Hardjito, Steenie Wallah, E, Sumajouw, D.M.J., Vijaya Rangan, B,. n.d. "On the Development of Fl

[13] Hardjito. D and Rangan, B.V. 2005. "Development and properties of low calcium fly ash based geopolymer." *Research Report GC1, Faculty of Engineering 1-90.*

[14] IS 1727, 1967. n.d. *"Methods of test for Pozzolanic materials", Bureau of Indian Standards. New Delhi: Bureau of Indian Standards.*

[15] IS: 2386, 1963. n.d. *"Methods of test for aggregates for concrete. New Delhi: Bureau of Indian Standards.*

[16] IS: 516, 1959. n.d. *Method of test for strength of concrete. New Delhi: Bureau of Indian Standards*

