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GEOPOLYMER CONCRETE WITH EWASTE

Bhushan V. Mhatre[1], Pradyna Y. Gharat[2], Mayur S. Dhende[3], Supriya S. Awale[4], Pallavi V. Dongare[5]

[1-4]Student, VIMEET kumbhival, khalapur
[5]Professor, Dept. of Civil Engineering, VIMEET College, khalapur, Maharashtra, India

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Abstract : *Reducing the greenhouse gas (CO2) emissions is the need of the world. Five to eight percent of total emission of CO2 of world is from the Cement industry itself. It is an established fact that the CO2 gas emissions are reduced by 80% in case of Geopolymer concrete vis-a-vis the conventional Ordinary Portland cement manufacturing. Also the State of Maharashtra tops in the list of all states of India which generates 20,270 tonnes of E-waste annually like Electronic waste and electrical equipment. Hence it is an emerging issue posing serious pollution problems to the human being and the environment. This project examines the possibility of reusing the nonmetallic portions of E-waste in concrete as coarse aggregates to increase its property compressive strength and also reduce greenhouse gas (CO2) replacing ordinary Portland cement by geopolymer. The project work is to make and to study the compressive strengths of Geopolymer concrete and Geopolymer concrete with E-waste as a partial replacement of the coarse aggregates ranging from 0 % to 30%, on the strength criteria of M30 grade concrete. The test specimens are prepared of size150x150x150 mm cubes & test shall be carried out after 7 days, 14 days and 28 days curing. This result is to be compared with conventional concrete on basis of strength, self-weight, economy & other structural parameters.*

***Key Words*: Geopolymer, greenhouse gas, fly ash, silica fume, E-waste, Compressive strength, split tensile strength.**

1.1 INTRODUCTION

For the construction of any structure, Concrete is the main material. Concrete usage around the world is second only to water. The main ingredient to produce concrete is Portland cement. On the other side global warming and environmental pollution are the biggest menace to the human race on this planet today. The production of cement means the production of pollution because of the emission of CO2 during its production. There are two different sources of CO2 emission during cement production. Combustion of fossil fuels to operate the rotary kiln is the largest source and other one is the chemical process of claiming limestone into lime in the cement kiln also produces CO2.In India about 2,069,738 thousand of metric tons of CO2 is emitted in the year of 2010. The cement industry contributes about 5% of total global carbon dioxide emissions. And also, the cement is manufactured by using the raw materials such as lime stone, clay and other minerals. Quarrying of these raw materials is also causing environmental degradation. To produce 1 ton of cement, about 1.6 tons of raw materials are required and the time taken to form the lime stone is much longer than the rate at which humans use it. But the demand of concrete is increasing day by day for its ease of preparing and fabricating in all sorts of convenient shapes. So to overcome this problem, the concrete to be used should be environmental friendly.

1.2 NEED OF GEOPOLYMER CONCRETE

To produce environmentally 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 WHAT IS GEO-POLYMER CONCRETE?

Geo-polymer concrete (GPC) is a fairly new material in the construction industry. Geo-polymers have been around since the 1950's but is wasn't until 1978 that the term geo-polymer was invented by Joseph Davidovits (1994). Geo-polymers are very similar to regular polymers in that they are transformed, they undergo polycondensation and set within minutes at low temperatures. Davidovits (1994) describes that in addition to the above, geo-polymers are inorganic, hard, and able to withstand high temperatures due to their inflammable nature. GPC is made by mixing aluminosilicate oxides with inorganic alkali polysilicates to produce polymeric Silicate-Oxygen Alkaline (Si-O-Al) bonds, the key chemical reaction required for the binding process.

Geo-polymers were initially desired for the fast setting time. Davidovits gives the example of a runway prepared with GPC. Within one hour the concrete is strong enough to be walked on, at 4 hours strong enough for vehicle loads and finally at 6 hours, the concrete runway is ready to sustain the weight of a commercial jet, as shown in Figure 2-2. It is in recent years that the desire for GPC has been more focused on the environment.

1.4 E-WASTE

Electronic waste (E-Waste) is one of the new waste materials that are emerging in the concrete industry. Disposal of large amounts of E-Waste material can be reused in the concrete industry where it also solves the disposal problem. Hence, the recycling and reusing of E-Waste in the concrete industry is considered as the most feasible application. E-Waste is a serious pollution problem for humans and also the environment. Therefore, some options are needed to be considered, especially on recycling material units. E- Waste is a loosely discarded surplus, broken, electrical or electronic devices. Rapid technology change and low initial cost have resulted in a fast-growing surplus of E-Waste around the globe. Several tonnes of E-Waste need to be disposed per year. E-Waste contains numerous types of substances and chemicals creating serious human health and environment problems if not handled properly. E-waste is the waste generated from the discarded electronic devices it is an emerging issue causing serious

1.5. OBJECTIVES OF STUDY

- The main objective of this paper is to study the engineering properties of geopolymer concrete so as it can be used as a green alternative to conventional cement concrete.
- To partial replace portion of coarse aggregate with e-waste.
- To use disposed E-waste.
- To study the compressive strength of using fly ash and silica fume.
- To developed and improve the technology of E-waste management

1.6. GEOPOLYMER PROPERTIES

The main characteristic of geopolymer concrete is it gains high early strength when dry-heat or steam cured, although ambient temperature curing is possible for geopolymer concrete [10]. Geopolymer concrete has been used to produce precast railway sleepers and other pre-stressed concrete building components. The early-age strength gain is a characteristic that can best be exploited in the precast industry where steam curing or heated bed curing is common practice and is used to maximize the rate of production of elements. [10] Recently geopolymer concrete has been tried in the production of precast box culverts with successful production in a commercial precast yard with steam curing. It has excellent resistance to chemical attack. Also it is resistant to alkaline attack. This is particularly applicable in aggressive marine environments, environments with high carbon dioxide or sulphate rich soils. Similarly in highly acidic conditions, geopolymer concrete has shown to have superior acid resistance and may be suitable for applications such as mining, some manufacturing industries and sewer systems. Commercial geopolymer sewer pipes are in use today. Current research at Curtin University of Technology is examining the durability of precast box culverts manufactured from geopolymer concrete which are exposed to a highly aggressive environment with wet-dry cycling in sulphate rich soils. The bond characteristics of reinforcing bar in geopolymer concrete have been researched and determined to be comparable or superior to Portland cement concrete [10]. The mechanical properties offered by geopolymer suggest its use in structural applications is beneficial.

1.7 LITERATURE REVIEW

From the research paper published by Hardjito and Rangan N A Lloyd on 25th August 2010

Curtin University of Australia, the geo-polymer gel binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geo-polymer concrete. The chemical reaction period is substantially fast. Claims that the Egyptian Pyramids were built by casting geo-polymer on site. He also reported that this material has excellent mechanical properties, does not dissolve in acidic solutions, and does not generate any deleterious alkali aggregate reaction even in the presence of high alkalinity. Some of the immediate applications of geo-polymer concrete are marine structures, precast concrete products such as railway sleepers, sewer pipes, pre-fabricated units for the housing market etc. In the experimental work, class F-fly ash obtained from Collie Power Station, Western Australia, was used as the base material. Table1 shows the chemical composition of the fly ash, as determined by X-Ray Fluorescence (XRF) analysis. Analytical grade sodium hydroxide in flake form (NaOH with 98% purity), and sodium silicate solution (Na_2O = 14.7%, SiO_2 = 29.4% and water= 55.9% by mass), were used as the alkaline activators. In order to avoid the effect of unknown contaminants in the mixing water, the sodium hydroxide flake was dissolved in distilled water and the activator liquid was prepared at least one day prior to its use. Coarse and fine aggregates used by the concrete industry are suitable to manufacture geo-polymer concrete. The aggregate grading curves currently used in concrete practice area applicable in the case of geopolymer concrete. (Hardjito and Rangan, 2005; Wallah and Rangan, 2006; Sumajouw and Rangan, 2006; Gourey, 2003; Gourley and Johnson, 2005; Siddiqui, 2007). A combination of sodium silicate solution and sodium hydroxide (NaOH) solution can be used as the alkaline liquid. It is recommended that the alkaline liquids prepared by mixing both the solutions together at least 24 hours prior to use. Sodium silicate solution is commercially available in different grades. The sodium silicate solution A53 with SiO_2-to-Na_2O ratio by mass of approximately 2, i.e., SiO_2 = 29.4%, Na_2O = 14.7%, and water = 55.9% by mass, is generally used. The sodium hydroxide with 97-98% purity, in flake or pellet form, is commercially available. The solids must be dissolved in water to make a solution with the required concentration. The concentration of sodium hydroxide solution can vary in the range between 8 Molar and 16 Molar; however, 8Molarsolution is adequate for most applications. The mass of NaOH solids in a solution varies depending on the concentration of the solution. For instance, NaOH solution with a concentration of 8 Molar consists of 8x40 = 320 grams of NaOH solids per litre of the solution, where 40 is the molecular weight of NaOH. The mass of NaOH solids was measured as 262 grams per kg of NaOH solution with a concentration of 8 Molar. Similarly, the mass of NaOH solids per kg of the solution for other concentrations was measured as 10 Molar: 314 grams, 12 Molar: 361 grams, 14 Molar: 404grams, and16 Molar: 444 grams. Note that the mass of water is the major component in both the alkaline solutions. In order to improve the workability, a high range water reducer super plasticizer and extra water may be added to the mixture. E-waste sources in the form of loosely discarded, surplus, obsolete, broken, electrical or electronic devices from commercial informal recyclers have been collected, crushed and ground to the particle size. Table 1 represents Physical properties of E-waste particle and Coarse aggregate. The E-waste contents are calculated as weight percent of coarse aggregate in the control mix. The fineness modulus of coarse aggregate with various E-waste content is between 1.86 and 2.78. The E-plastic waste particles can be considered as partial coarse aggregate substitute retaining the mix ratio as the same.

➢ **D. M. J. Sumajouw D. Hardjito S. E. Wallah B. V. Rangan (2007)**

Presents the results of experimental study and analysis on the behaviour and the strength of reinforced Geo-polymer concrete slender columns. They concluded that heat-cured low-calcium fly ash-based geo-polymer concrete has excellent potential for applications in the precast industry. The products currently produced by this industry can be manufactured using geo-polymer concrete. The design provisions contained in the current standards and codes can be used in the case of geo-polymer concrete products.

Properties	**E-waste particle**	**Coarse aggregate**
Specific gravity	1.01	2.65
Absorption (%)	<0.2	0.5
Colour	White and dark	Dark
Shape	Angular	Angular
Crushing value	<2%	27.5%
Impact value	<2%	25.53%

Table -1: Physical Properties of E-Waste Particles and Coarse Aggregate

➢ **N A Lloyd and B V Rangan (2010)**

Concluded based on the tests conducted on various short-term and long-term properties of the geo-polymer concrete and the results of the tests conducted on large-scale reinforced geo-polymer concrete members show that geo-polymer concrete is well-suited to manufacture precast concrete products that can be used in infrastructure developments. In this paper a simple method to design geo-polymer concrete mixtures has also described and illustrated by an example.

1.8 MIX DESIGN

As the Geopolymer concrete are new construction materials they don't have any standard mix design. To identify the mix ratios for different grades of Geopolymer Concrete the trial and error method. To identify the best mix or optimum mix for the Geopolymer with E-Waste the various parameters and ingredients are varied. The parameters changed in the mix proportions are Density, Morality and percentage ratio between the Fly ash and Silica fume. Design of geopolymer concrete mix, coarse and fine aggregates together were taken as 75%-80% of entire mixture by mass. The density is 2400 kg/m^3.The Morality or the concentration of sodium hydroxide pellets solution is 12M. And the major parameter is the ratio between the Fly ash and Silica fume which is fully replaced for ordinary cement and the percentage is varied in range of 90% & 10%.

1.9 MIX RATIO

Mix Ratio 1: 70% Fly Ash + 30% Silica Fume of Fly Ash And 100% FA

Mix Ratio 2: 70% Fly Ash + 30 %Silica Fume of Fly Ash And 95% FA+ 5% E-Waste Mix Ratio 3: 70%Fly Ash + 30%Silica Fume of Fly Ash And 90% FA+ 10% E-Waste

Mix Ratio 4: 70%Fly Ash + 30%Silica Fume of Fly Ash And 85% FA + 15% E-Waste

Mix	FLYASH (Kg/m3)	SILICA FUME (Kg/m3)	FA (Kg/m3)	E-WASTE (Kg/m3)	CA (Kg/m3)	NaoH (13M) (Kg/m3)	Na2Sio (Kg/m3)
GP	285	120	670	-	1240	70.8	70.8
GP1	285	120	636.5	33.5	1240	70.8	70.8
GP2	285	120	603	67	1240	70.8	70.8
GP3	285	120	569.5	100.5	1240	70.8	70.8

Table 2: Mix Proportion

Ingredients Of geo-polymer concrete	Fly ash	NaOH	Na2SiO3	Sand	Coarse aggregate	Total water (W/GPB)	Extra water
Quantity (kg/m3)	405	70.88	70.88	683.13	1268.66	108.35	29.46
Proportion	1	0.35		1.82	3.37	0.211	0.07

Table 3: Quantity of materials required per cubic meter for M30 grade of geo-polymer concrete

1.10 Collection of raw materials

Collecting materials such as Ordinary Portland Cement of grade 53, fine aggregates, coarse aggregates, fly ash, E waste and geopolymer ingredients. Physical properties of Portland cement are calculated. Similarly, physical properties of fine aggregates and coarse aggregates are calculated. Sieve Analysis is carried out for fine aggregates as well as for coarse aggregates and the results are obtained. Also, physical properties of E waste are calculated.

2.0 Mixing

The fly ash is collected and weighed; the fine aggregates and the coarse aggregates are batched separately. The sodium hydroxide flakes are prepared for 8 molar and 12 molar solutions in one litre of water. Sodium silicate solution is added in sodium hydroxide and it is kept for 24 hours prior mixing the concrete. Dry mixing is to be done for 3 minutes and wet mixing is to be done for 4 minutes. The mixture is to be mixed thoroughly and properly.

2.1 Casting

After mixing the concrete is placed in standard cubes of size 15x15x15cm and are properly filled with tamping rod, so that it becomes a homogenous mixture.

2.2 Curing

As soon as the cubes are casted they are wrapped by foil paper and kept in oven to prevent excessive evaporation. The temperature for 12 hours is 100°C and for the next 24 hours it is kept for 60°C. The curing is done with the moulds itself wrapped by foil in the oven. Later the block is unmoulded and then it is carried out for testing

2.3 Quantity of Cubes to be casted

Conventional concrete			
Day	7days	14days	28days
Grade			
M30	3	3	3
	12 no's		

Table4: Conventional concrete

Grade	E-waste %	Name of mix	7 days	14 days	28days
13M	5%	GP	21.8	24.6	35.5
	10%	GP1	21.2	24.2	35.5
	15%	GP2	21.1	24	35
	20%	GP3	20.4	23.5	33.5

Table5: Compressive strength in N/mm2 of Geopolymer concrete with E waste (13Mole)

2.4 TEST RESULTS

The following are the results of conventional concrete tested

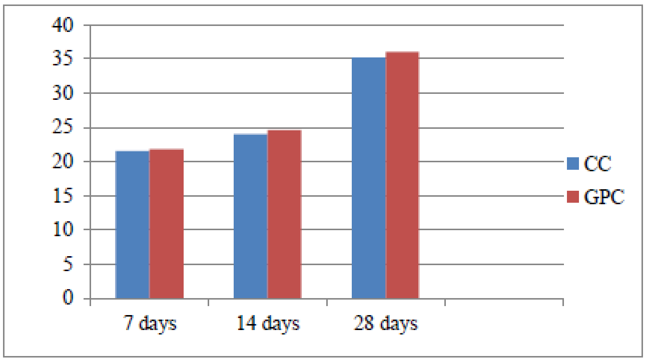

Fig1: Compressive strength of specimens CC and GPC

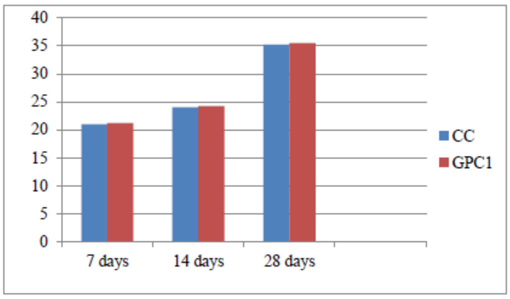

Fig2: Compressive strength of specimens' CC and GPC1

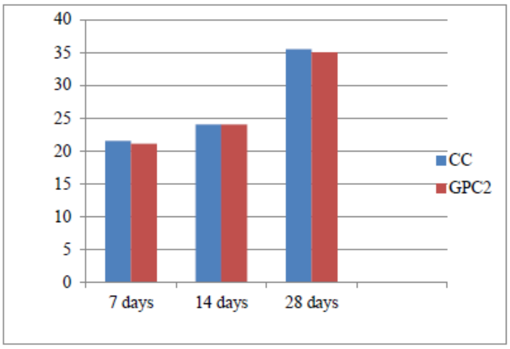

Fig3: Compressive strength of specimens CC and GPC2

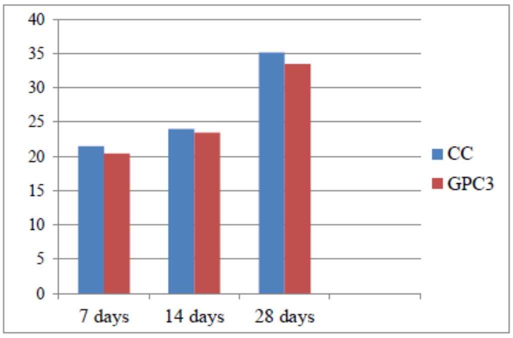

Fig4: Compressive strength of specimens CC and GPC3

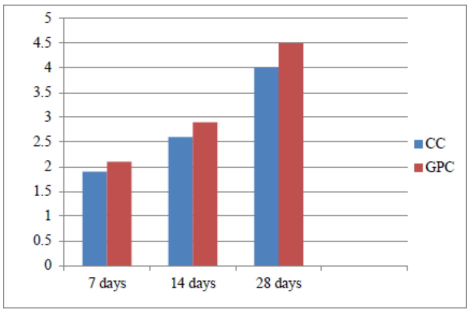

Fig5: Split tensile test of specimen CC and GPC

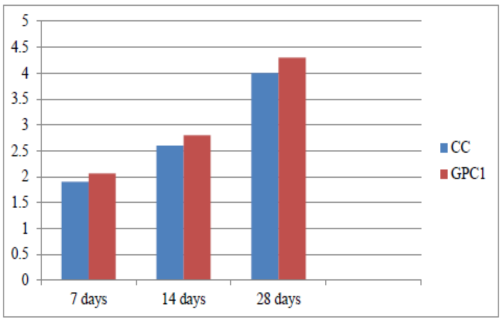

Fig6: Split tensile test of specimen CC and GPC1

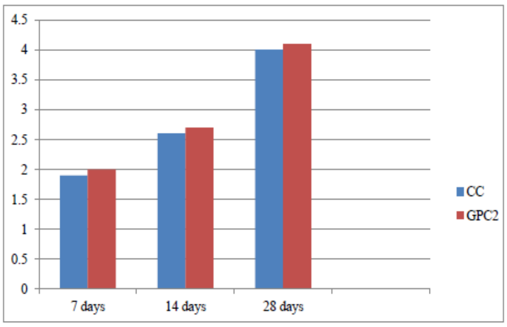

Fig7: Split tensile test of specimen CC and GPC2

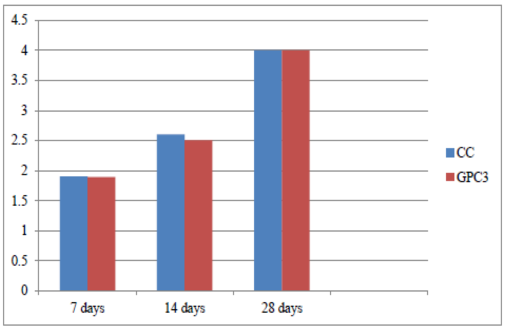

Fig8: Split tensile test of specimen CC and GPC3

2.5 Testing

Testing for the conventional concrete cubes is to be done after 7, 14 and 28 days respectively. The testing for geopolymer E waste cubes is to be done after 24 hours and 48 hours of oven curing and it is tested for compression. Testing is done compression testing machine having capacity of 10000 KN.

2.6 CONCLUSIONS

This paper proposed the guidelines for the design of fly ash based geo-polymer Concrete of ordinary and standard grade on the basis of quantity and fineness of fly-ash, quantity of water and grading of fine aggregate by maintaining water to-geo-polymer binder ratio of 0.35, solution-to-fly ash ratio of 0.35, and sodium Silicate-to-sodium hydroxide ratio of 1 with concentration of sodium hydroxide as 13 M. Heat curing was done at 60 °C for duration of 24 h and tested after 7 days after oven heating. Experimental results of M20, M25, M30, M35 and M40 grades of geo-polymer concrete mixes using proposed method of mix design shows Promising results of workability and compressive strength.

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