Feasibility of Geopolymer Concrete Incorporating plastic Aggregates

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Abstract: ***In this experimental work, the HDPE(high density polyethylene) plastic as coarse aggregate is used in fly ash based geopolymer concrete. The geopolymer concrete was prepared with low calcium fly ash and the coarse aggregates of size 10-20mm was replaced with plastic aggregates at different percentages I.e. 0%, 10%, 20% and 30% to study the strength properties such as compressive strength and split tensile strength. Geopolymer concrete was prepared with the use of alkaline solutions NaOH and Na_2SiO_3. Geopolymer concrete samples at all percentages were cured in oven at 60^oc for 24 hours and then kept under room temperature for curing for 3, 7 and 28 days. It has been experimented that, due to the increase of the plastic aggregate percentage in concrete decreases the compressive strength. Geopolymer concrete is a raw material based concrete that leads to the usage of materials which are produced as a raw material from industries and when these raw materials were induced in the geopolymer preparation it leads to the reduction of carbon emissions and acts as a greater concrete towards environment. The usage of plastic in geopolymer concrete is another benefit for the environment. It has been observed that the concrete shows the better strength at 0% replacement of plastic in geopolymer concrete.***

Index Terms: Aqueous solution, fly ash, Geopolymer concrete, Plastic aggregates(HDPE), strength properties.

I. INTRODUCTION

GENERAL:

Cement is a binding material used in construction sector for sticking different materials together like bricks, stones and is used in formation of concrete. It is a strong adhesive substance used for sticking different materials together. It is a fine material(powder) made of alumina(Al_2O_3), silica(SiO_2), lime(CaO), iron oxide(Fe_2O_3) and magnesium oxide(MgO), burned together in a high sensation of heat and relevance as an element of mortar and concrete. During formation, mixing and curing of cement emits different kinds of gases like carbon dioxide, nitrogen oxide, SO_3 , etc which creates harmful activities in the environment like ozone depletion, global warming, health problems in humans and in animals .To diminish these kinds of problems, we use geo-polymer instead of cement to make the concrete, environment friendly. The cement industry individually causes 6 to 7.5% of global CO_2 emission.

Geopolymer :

Geopolymer is related to the class of compounds not constituting the carbon basis (inorganic).

Geopolymer is a substance acquired by chemical mixture of two or more elements in a definite proportion (weight). Geopolymer is fire resistant and can be used in low energy ceramic tiles, paints, binders and grouts, biotechnologies etc. In this research, we replace cement with geo-polymer. Sodium hydroxide (NaOH) and sodium silicate(Na2SIO3) are used to form a geo-polymer by adding fly ash. NaOH is a white solid ionic compound consisting of sodium cations(Na^+)and hydroxide anions(OH^-)

Formula = NaOH
Molar mass = 40 g/Mol
Density = 2.13 g/cm^2
PH = 13
Odor = odourless

Reaction with acids:-

Sodium hydroxide reacts with protic acids to produce water and the corresponding salts for example

$$NaOH[aq] + HCL[aq] \rightarrow Nacl[aq] + H_2O[L].$$

In general such neutralization reactions are represented by on simple net ionic reaction.

$$OH^-[aq] + H^+[aq] \rightarrow H_2O(water).$$

This type of reaction with strong acid releases heat and hence is exothermic.

SODIUM SILICATE:

Concrete treatment with a sodium silicate solution helps to reduce porosity.

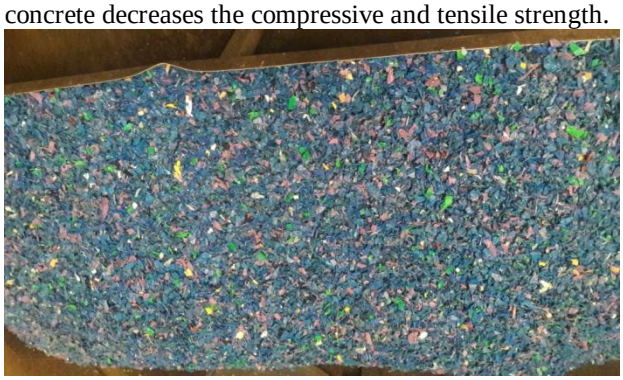
FLY ASH:

Fly ash is known as one of the biggest waste materials produced by burning of coal in various industries. Nowadays fly ash is almost used in all type of construction like soil compaction, concrete etc, by giving better results than the normal concrete. In concrete the compressive strength increases by adding fly ash and is the best way to dispose the waste. Low calcium fly ash- based geo-polymer is used as a binder, instead of cement, to produce concrete. The ingredients present in low calcium (class F) fly ash is almost the same in sodium silicate and sodium hydroxide that's the reason why we use the ingredients mentioned above for obtaining geo-polymer which acts as a binding material in concrete, currently 90 million tonnes of fly ash is being generated annually in India.

Plastic waste :

Plastic waste is known as more than average waste material produced around the world and is not a degradable material. Plastic waste is one of the risky, wild, hazardous material causing harm on actions on the environment. In this study the coarse aggregate will be partially replaced by plastic aggregate in different percentages like 0% , 10% , 20% and 30% . By adding plastic in concrete the properties raises than normal concrete like fire resistant, takes less curing time, workability. It has been observed that degradation of plastic takes thousands of years.

This results in the heap of plastic wastes which leads to serious environmental problems caused due to illegal landfilling and incineration. (Saikia and Brito, 2012) reported that plastic wastes leads to reduction of water permeability in soils and affecting the fertility of soil, which often results in the hampering of wastewater drainage. It has also been observed that the increase of plastic content in concrete decreases the compressive and tensile strength.



FINE AGGREGATES:
From zone II ,the fine aggregates are used. The zone is defined due to the gradation test by sieve analysis and with specific gravity 2.64g/cc. Fine aggregates are used according to IS-383 code

S.NO.	*IS SIEVE SIZE*	*WEIGHT RETAINED IN GRAMS*	*% OF WEIGHT RETAINED*	*% OF PASSING*
1.	*4.75mm*	*100*	*5*	*95*
2.	*2.36mm*	*150*	*7.5*	*92.5*
3.	*1.18mm*	*205*	*10.25*	*89.75*
4.	*600µ*	*985*	*49.25*	*50.75*
5.	*300 µ*	*381*	*19.05*	*80.95*
6.	*150 µ*	*154*	*7.7*	*92.3*
7.	*pan*	*11*	*0.55*	*99.45*

II. MATERIALS AND METHODS

MATERIALS USED:
The geopolymer concrete was produced by using low calcium fly ash(class F) which is obtained from the thermal power plant Ropar and Bathandi Punjab, The specific gravity was calculated as 2.35g/cc. The combination of sodium hydroxide and sodium silicate forms the alkaline solution 1:2.5 ratio before one day of casting the solution was prepared, the sodium hydroxide was used of 12 molarity and the solid content present in the sodium silicate was 38%. The HDPE plastic was obtained from Baddi technoplastic LTD of 10- 20mm size the specific gravity was calculated as 2.77g/cc. The coarse aggregates of size 10-20mm size with specific gravity 2.74g/cc was used. The sand of zone II passes from the sieve 4.75mm size with specific gravity 2.64g/cc was used.

MIXING PROCEDURE AND CURING:
The alkaline solutions which is made before one day of casting used for the mixing of geopolymer concrete. The raw material are mixed homogeneously and alkaline solutions are mixed with the ingredients and the amount of solid content present in the solution is fulfilled by adding water to it. The powder to alkaline ratio was 0.35 and when the cubes and cylinders are casted they are kept in oven for 24 hours at 60^{o}C temperature and then specimens are kept at normal room temperature for curing.

***TEST PROCEDURE*:**

The tests were conducted to examine the strength properties of geopolymer concrete containing plastic as coarse aggregates at different percentages.

COMPRESSIVE STRENGTH:
The compressive strength forms the fundamental property for analysis and calculation and is one of the most essential property of concrete. For compression test, the cubes of dimensions 150 ×150 × 150mm were casted and cured. Three cubes was taken for each testing of concrete for 3days, 7days and 28 days at 0%,10%, 20% and 30% replacement with plastic aggregates. These cubes were tested on compressive testing machine and rate of loading should be applied approximately 140kg/ sq-cm /min as per IS-516. Three cubes were tested for each test period and their average was taken.

SPLIT TENSILE STRENGTH:
The specimen of cylinder of diameter 150mm and length 300mm was used to find out the split tensile strength of geopolymer concrete by casting three cylinders for each test at each percentage. 36 cylinders were casted to check the split tensile strength when tested after 3 days, 7days and 28 days.

III. RESULTS AND DISCUSSIONS:

COMPRESSIVE STRENGTH:

Compressive strength is done to determine the strength of concrete by casting cubes at different percentages of aggregates replaced by plastic i.e. 0%, 10%, 20% and 30% by casting cubes of size 150 × 150 × 150 mm. The testing is done for compression in compressive testing machine. The cubes are tested for compression according to code IS 516 – 1959. In this compression test the specimens placing in the middle of the testing machine the bearing or loading surfaces of testing machine shall be cleaned by the wiper and the surface of the specimens shall be cleaned to remove the loose material from the surface of the specimen which are to be in contact with the compression platens. The specimens shall be placed in the compressive testing machine in such a manner that the load will applied perfectly on the specimen. The axis of the specimen shall be carefully placed at the centre of the loading plates, the load shall be applied on the specimens without shocks and increased continuously at the rate approximately 140 kg/sqcm/min, the load shall be applied untill the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall then be recorded.

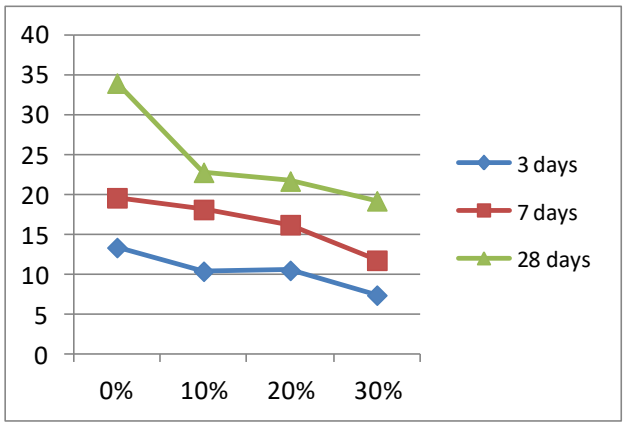
In this experiment the results shows that the compressive strength decreases as we increase the percentage of plastic in geopolymer concrete. The geopolymer concrete shows the highest results at 0% replacement of plastic with aggregates and then starts decreasing the compressive strength.

Fig shows the compressive testing in compressive testing machine

Average compressive strength in MPa.

s.no.	%replacement of aggregates by plastic	3 days	7 days	28 days
1.	0%	13.35	19.6	34
2.	10%	10.37	18.13	22.8
3.	20%	10.48	16.22	21.7
4.	30%	7.37	11.75	19.22

Compressive strength of 3, 7 and 28 days at 0%, 10%, 20% and 30% percent.



Percentage used

fig- 1; shows the compressive strength at 3, 7 and 28 days at different percentages

SPLIT TENSILE STRENGTH:

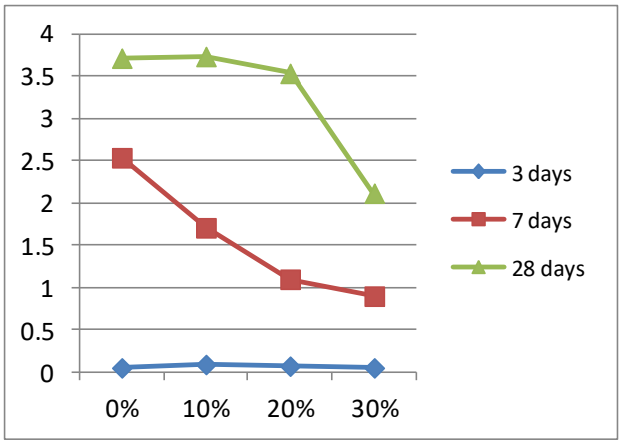
The cylinders were prepared of 150×300mm size to check the split tensile strength of geopolymer concrete, it is a mechanical test, at least three cylender specimens shall be tested for each age and percentage of tests. Compressive testing machine is used to check the split tensile strength, the test specimen shall be placed in the middle of loading pieces carefully positioning along the top and bottom of the plane of loading of the specimen. It shall be ensured and clear that the top platen is parallel with the bottom platen. The load shall be applied smoothly without shock and increased continuously at a nominal rate, The maximum load applied shall then be recorded. In split tensile strength at 10% replacement shows the peak value and then starts decreasing the tensile strength.

Fig. shows the split tensile testing on cylenders.

Average tensile strength in MPa.

s. no.	% replacement of aggregates by plastic	3days	7days	28days
1.	0%	0.05	2.54	3.72
2.	10%	0.09	1.71	3.74
3.	20%	0.07	1.1	3.54
4.	30%	0.05	0.9	2.12

Split tensile strength of 3days, 7days and 28days ay 0%, 10%, 20%, 30%.



Percentage used

Fig-2; shows split tensile strength at 3, 7 and 28 days at different percentages

IV. CONCLUSION:

1. Geopolymer concrete with plastic aggregates is eco-friendly (reduces carbon dioxide emissions and adopt various waste materials.
2. Compressive strength reduces in fly ash based geopolymer concrete due to the replacement of coarse aggregates by plastic aggregates.

3. Split tensile strength shows slight increment at 10% replacement of coarse aggregates by plastic aggregates after 28 days, so the results shows that the plastic can be used in geopolymer concrete upto 10% replacement with coarse aggregates.
4. Geopolymer concrete is an environment friendly concrete consumes very less amount of water and reduces environment pollution created by normal concrete.
5. It was concluded that the plastic based geopolymer concrete can be beneficial/used in low density structures.

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