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Geo-Polymer Concrete Mixture with Plastic Granules as Fine Aggregate Replacement

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***Abstract*—The purpose of this study is to overcome the plastic material which are being wasted are used as fine aggregates in geo-polymer concrete mixture. Plastic granules were used as the replacement for fine aggregates. The compressive strength and the tensile strength of different specimen were conducted to check the property of plastic granules and how effective is the specimen compared to normal concrete. Six mixes were made to compare with the increments of 0%, 20%, 40%, 60%, 80%, and 100%. All the stages of replacement showed a notable decrease in compressive strength. After being known that compressive strength was less, tensile strength showed significant strength. The alkaline liquids used in this study for the geo-polymerization are sodium hydroxide (NaoH) and sodium silicate (Na2SiO3). The test specimens were (150 x 150 x 150) mm cubes. The geo-polymer concrete specimens are tested for their compressive strength at the age of 7 and 28 days. The test results indicate that the combination of GGBS and alkaline solution can be used for development of geo-polymer concrete. This study insures that reusing waste plastic as a sand-substitution aggregate in concrete gives a good approach to reduce the cost of materials and solve some of the solid waste problems posed by plastics.**

Keywords—plastic granules, alkaline activator solution, concrete, compressive strength, split tensile strength

I. INTRODUCTION

1.1 General

The most common construction material is the concrete which requires large amount of natural resources and energy. Natural resources used in concrete mixtures include lime stone, clay, sand, natural gravel, crushed stone, and water. These natural resourses get depleted as the urban areas grow rapidly, these resourses get depleted more in the recent years in the increasing rate. Therefore, it is necessary to develop a new material that consumes less natural resources and energy in order to make our construction methods more sustainable.

The research in to new and innovative waste materials being under taken world-wide and innovative ideas that are expressed are worthy of this important subject. Much organization had started a large number of research project concerning the feasibility, environmental suitability and performance of using waste plastic in concrete. These studies try to match societal need for safe and economic disposal of waste materials with the help of environmentally friendly highway industries, which needs better and cost effective construction materials.

The productive use of waste material represents a means of alleviating some of the problems of solid waste management. The reuse of wastes is important from different points of view. It helps to save and sustain natural resources that are not replenished, it decreases the pollution of the environment and it also helps to save and recycle energy production processes. Plastic wastes are among the wastes; their disposal has harmful effects on the environment due to their long biodegradation period, and therefore one of the logical methods for reduction of their negative effects is the application of these materials. Although some of these materials can be beneficially incorporated in concrete, both as part of the cementitious binder phase or as aggregates, it is important to realize that not all waste materials are suitable. Many efforts have been made to study the use of waste/by product materials, such as fly ash, GGBS, silica fume, and natural pozzolana, to replace Portland cement in a concrete mixture.

Others studied effects of plastic in concrete mixtures as aggregate replacement on material properties. While the previous studies showed potential advantages of using plastics in concrete (e.g., light weight and low energy consumption), they also reported some disadvantages, such as decreases in compressive strength and flexural strength of plastic concrete mixtures with the increase of the plastic ratio in the mixtures. Furthermore, material properties of plastic concrete mixtures may vary depending on the type of plastics that is used in the mixtures. For this reason, it was of interest of this research to study effects of one type of plastics, high-density polyethylene

(HDPE), on concrete properties. This paper investigated the application of HDPE plastic on partial/full fine aggregate replacement for concrete mixtures.

PLASTIC

The word "plastic" means substances which have plasticity, and accordingly, anything that is formed in a soft state and used in a solid state can be called a plastic. Therefore the origin of plastic forming can be traced back to the processing methods of natural high polymers such as lacquer, shellacamber, horns, tusks, tortoiseshell. As well as inorganic substances such as clay, glass, and metals. Because the natural high polymer materials are not uniform in quality and lack mass productivity in many cases, from early times it has been demanded in particular to process them easily and into better quality and to substitute artificial materials for natural high polymers. Celluloid, synthetic rubber, ebonite, and rayon are these artificial materials. Presently, it is defined that the plastic are synthesized high polymers which have plasticity, and consequently substances made of these natural materials are precluded.

In 1978, professor Joseph Davidovits introduced the development of mineral binders with an amorphous structure, named geopolymers. Davidovits (1988, 1994) proposed that an alkaline liquid could be used to react with silicon (Si) and the aluminium (Al) in a source material in by-product materials such as GGBS and rice husk ash to produce binders. The chemical reaction that takes place in this case is a polymerization process, he coined a term "Geopolymer" to represent these binders. This was a class solid material, produced by the reaction of an alumino silicate powder and an alkaline liquid. Geopolymer concrete is starting to revolutionize concrete. It is being used more in highway construction projects and offshore applications.

1.2 Aims and Objectives of the study

The aim of the research is to determine the compressive & spilt tensile strength of the concrete block by replacing the plastic granules as fine aggregate

- The primary objectives To determine the compressive strength and Density of Plastics granules used as fine Aggregate for Constructional Concrete with the Conventional concrete.
- To reduce the pressure on naturally availability materials by replacing it with plastic aggregate.
- To compare the physical characteristics of natural aggregate with Plastic aggregate.
- Determining the strength properties of concrete for 3,7,14 days.
- To study the behaviour of hardened concrete with plastic fine aggregate and compare its properties to those of conventional concrete.
- It represents an environmental friendly and economical viable solution, for utilization of waste plastic.

II. METHODOLOGY

The purpose of this project is to utilize recycled materials for the production of concrete. As disposal of plastic waste is not possible easily, they create adverse impact on environment. Reuse of plastic waste in concrete industry is considered as the most feasible application. It decreases the pollution of the environment and reduces the cost of materials.

A. MATERIALS USED

1. AGGREGATES(coarse and fine aggreagtes)

Various properties of aggregates can influence the performance of concrete, therefore various considerations have to be kept in mind while selecting the material. Natural crushed stones were used for coarse aggregates and for fine aggregates manufactured sand and plastic granules were used. Natural stone Aggregates passing through 20mm IS sieve and Manufactured M-sand passing through the sieve 4.75 & Plastic Granules passing through the sieve 4.75 is used.

1.1 Coarse aggregates

Natural crushed stones are taken for coarse aggregates. It is the important constituent in concrete. The aggregates with size 4.75mm to 50mm are taken for coarse aggregates. The aggregates occupy 70 to 80 % of volume of concrete.

Table 1: Properties of Coarse aggregates

Sl. No.	Properties	Values
1	Specific gravity	2.65
2	Fineness modulus	6.2
3	Water absorption	0.185
4	Impact value	13.93%

1.2 M-sand(Manufactured Sand)

Manufactured sand is a substitute of river sand for concrete construction. Manufactured sand is produced from hard granite stone by crushing. The crushed sand is of cubical shape with grounded edges, washed and graded to a construction material. The size of manufactured sand is less than 4.5mm. The specific gravity of this m-sand is 2.66.

1.3.Plastic

Plastics that cannot be degraded further been powdered into fine particles. These plastics consist mainly of high density polyethylene (HDPE).

Table 2: Properties of plastic granules

Sl. No.	Properties	Values
1	Specific gravity	2.77

2. GGBS(ground granular blast furnance)

Ground granulated blast furnace slag confirming to IS 12089 were used. GGBS is obtained by rapid cooling of molten iron slag (a by-product of iron and steel industry) from a blast furnace in water or steam.

Table 3: Properties of GGBS

SL. NO.	descriptions	GGBS
1	Fineness(sq.m/kg)	400
2	Appearance	Very fine powder
3	Particle size	35 microns-mean
4	Colour	Grey to black
5	Odour	odourless
6	Specific gravity	2.90

Table 4: chemical analysis of GGBS

Parameters	% by mass of GGBS
SiO_2	43.4
Al_2O_3	12.5
Fe_2O_3	1.3
CaO	40.3
MgO	1.5
Na_2O	0.9
K_2O	0.6

3.ALKALINE ACTIVATOR SOLUTION

Sodium Silicate**:** The Sodium Silicate (Na_2Sio_3) which is available in semi solid form is used.

Sodium Hydroxide**:** NaOH 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 alkaline activator solution consists of sodium hydroxide and sodium silicate in the study. A 6M sodium hydroxide and 6M sodium silicate is prepared. For 1M sodium solution 40g of sodium hydroxide pellets are dissolved in one liter of water. So, for 5M sodium hydroxide solution 240g is dissolved in one liter of water. For 1M sodium silicate solution 122g of sodium silicate is dissolved in one liter of water so for 5M solution 732g of sodium silicate is dissolved in one liter of water. This sodium silicate solution is prepared before 24hours of the casting of specimen. The chemical composition of this sodium silicate solution was Na_2O=8%, SiO_2=28% and water 64 % by mass. This mixture of solution forms the alkaline activator solution. Both these solutions are mixed together at the time of mixing.

B. MATERIAL PREPARATION

Concrete materials used in this study included ground granular blast furnace slag (GGBS), manufactured sand, plastic granules, natural crushed stones, and water. Both manufactured sand and crushed stones used in this study conformed to ASTM C33 (American society for testing and materials) for concrete aggregates as fine and coarse aggregates.

HDPE was selected as the plastic for fine aggregate replacement in this study. The purpose for the experiment was to determine how best to incorporate construction waste materials back into concrete saving both energy and reducing the need to discard plastic waste into landfills. The experiment began by finding the gradation of the fine aggregate owing to that the gradation of sand could provide a baseline for the desired incorporation of recycled HDPE plastic as a fine aggregate replacement option.Sieve analysis was performed on a manufactured sand sample to determine its gradation. The gradation test was conducted in accordance with ASTM C136, and the results can be found below in Table 1.

To accurately replace the gradation of the sand with the plastic, all of the plastic would have had to been sieved, weighted, and then remixed at the correct ratios. This process would have resulted in a lot of wasted plastic, which would have been counterproductive to the green initiative this project intended to propose. In order to compensate for the removal of the sieve size and above, and to model better the initial gradation of the sand, HDPE plastic pellets of uniform size were added. The quantity of pellets added was based on the original gradation of the manufactured sand.

Table 5: Sieve Ananlysis of Sand

Sieve Number (mm)	Empty weight Of sieves (gm)	Weight Retained (gm)	Percent Weight Retaine d (%)	Cumula-tive Percent Retained (%)	Cumula -tive Percent Passing (%)
4.75	413	5.4	.54	0.54	99.46
2.36	390	101.5	10.15	10.6	89.4
1.18	351	292.5	29.25	39.85	60.15
0.6	346	187	18.7	58.55	41.45
0.3	355.5	149.9	14.9	73.45	26.55
0.15	340.5	114.5	11.45	84.9	15.1
.075	300	83	8.3	93.2	6.8
Pan	467	67.1	6.71	100	0

III. MIX DESIGN

Geo-Polymer doesn't have a particular standard mix design yet. While the strength of cement concrete is known to be well related to its water cement ratio, such as simplistic formulation may not holds good for geo-polymer. For geo-polymer formulation is done by trail and error method basis. Djwantoro Hardjito, et al (2004), showed that geopolymer paste binds the coarse aggregates, fine aggregates and other unreacted materials together to form the GPC (Geo Polymer Concrete), and as usual concrete technology methods to produce GPC mixes can be often employed. Using the aforementioned materials, mix proportions for one control mix and five experimental mixes were created. The control mix was designed with a 0.5 water to cement ratio. The mix design was determined so that a reasonably concrete strength would be achieved to adequately determine the strength degradation induced by the increasing quantity of plastic. The experimental sample mixes utilized the same mix design with the exception of the fine aggregate. The water content of the actual batch weight was adjusted to account for the absorption of the aggregates. For the HDPE plastic, due to the susceptibility of plastic to heat, an absorption testrequiring heating samples in

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an oven was difficult to perform. Based on the manufacturer specifications, the HDPE plastic had an absorption between 0% and 0.1%. Therefore, for the purpose of this experiment, it was assumed that the HDPE had no absorption. The HDPE plastic replaced the sand by volume. As mentioned previously, both the HDPE plastic and the sand were in a state of 0% absorption. Therefore, as the volume of sand was reduced and plastic added, the water content in the sample mixes did not need to be adjusted.

The investigation was done on the proportion 1:1.5:2.2 (GGBS, fine aggregate, coarse aggregates) by replacing the fine aggregate that is M-Sand by plastic granules. The percentages of replacement are 0, 20, 40, 60, 80,100 %. For all the proportions the alkaline solution to binder taken is 0.5 kept as constant.

IV. CASTING, CURING AND TESTING OF THE SPECIMENS

4.1 Casting of specimens

GGBS, Fine aggregates and coarse aggregates were taken in mix proportion 1:1.5:2.2 which corresponds to M25 grade of concrete. Fine aggregates is replaced by Iron ore tailings. All the ingredients were mixed in dry condition till we get homogeneous mixture. To this dry mix required amount of alkali activated solution of 6M was added and solution to binder ratio is 0.5 and the entire mix is again mixed till we get homogenous mixture. This mixed concrete is poured into the moulds at this time the compaction is done in 3 layers by hand compaction and then it kept on the vibrator for compaction. After the compaction the surface is well levelled and given smooth finishes. After 24 hours the specimens were demoulded.

4.2 Curing of specimens

The demoulded specimens were placed for curing the curing is done by placing the demoulded specimens in atmospheric temperature that is sunlight so this type of curing is called as ambient curing. This type of curing eliminates the heat curing of geo polymer. These specimens are cured for 3,7, 14 days.

4.3 Testing of specimens

The specimens are tested for compressive strength for cubes of size 150mm x 150mm x 150mm cast iron steel moulds. For each proportion 3 cubed were tested at the age of 3 days, 7 days, 14 days. The specimens are also tested for split tensile strength for cylindrical moulds of size 150mm diameter and 300mm high cast iron moulds. For each proportion 3 cubes were tested at the age of 3 days, 7 days, 14 days.

4.3.1 Compressive strength test

The specimens of dimensions 150mm x 150mm x 150mm which was prepared are tested in 2000KN capacity compression testing machine. The compressive strength is calculated by using the equation,

F=P/A

Where, F= Compressive stress in N/mm^2.
P= Maximum Load in N
A=Cross sectional area in mm^2.

The average compressive strength of various proportions is given in table 6.

Table 6: Average compressive strength of various proportions

Mix proportions	Compressive strength in N/mm^2		
	3rd Day	7th Day	14th Day
0%	37.77	38.22	39.7
20%	22.66	24.4	30.0
40%	19.55	23.3	24.4
60%	18.66	21.11	23.33
80%	13.77	15.33	17.77
100%	13.33	14.44	15.11

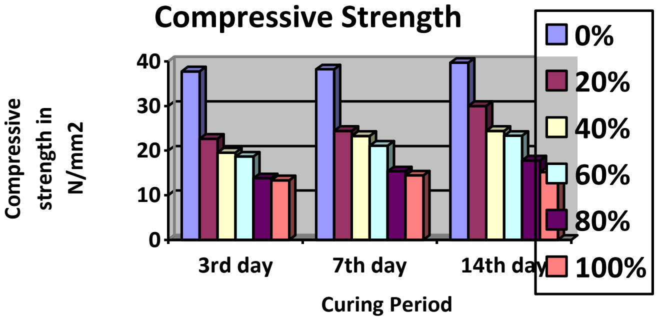

Fig 1. Compressive strength of geopolymer concrete with replacement of fine aggregates by plastic granules

4.3.2 Split tensile strength

The cylindrical specimens of dimensions 150mm diameter and 300mm high which was prepared are tested in 2000KN capacity tensile strength testing machine. The split tensile strength is calculated by using the equation,

F=2P/(πxDxL)

Where, F= Split tensile strength in N/mm2
P= Load at failure in N.
D= Diameter of the cylindrical specimen in mm.
L= Length of the cylindrical specimen in mm.

The average split tensile strength of various proportions is given in table 6.1

Table 6.1 The Average Tensile Strength

Mix proportions	Split tensile strength in N/mm^2		
	3rd Day	7th Day	14th Day
0%	2.97	3.11	3.6
20%	2.68	2.97	3.39
40%	2.54	2.75	3.11
60%	2.26	2.47	2.97
80%	1.76	2.12	2.54
100%	1.41	1.76	1.83

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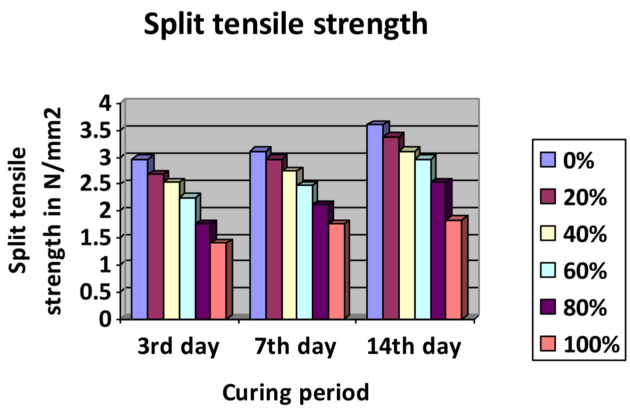

Fig 1.2 Split tensile strength of geopolymer concrete with replacement of fine aggregates by plastic granules.

V.RESULTS AND DISCUSSIONS

On geo-polymer concrete, a trial and error method was adopted to develop the process of manufacturing GGBS and plastic granules based geo-polymer concrete following technology currently used to manufacture opc concrete. After some failure in the beginning the trial and error method yielded successful results with regard to manufacture of GGBS and plastic granules based geo-polymer concrete. The optimum mix is GGBS: fine aggregate: coarse aggregate are 1:1.5:2.2.

The compressive strength of concrete shows for different percentage of M-sand and plastic granules. For higher strength of specimens with plastic granules, 60% of M-sand and 40% of plastic granules which gives more strength compare to the others specimens. The maximum strength achieve within 14 days curing.

General properties of the fresh GPC are dependent on the type and the contents of the materials used in the mixture. As compared with the conventional Portland cement concrete mixes, GPC mixtures exhibit a different rheological behavior. The geo-polymer concrete gains about 60-70% of the total compressive strength within 7 days.

Geo-polymer concrete is an excellent alternative solution to the CO_2 producing port land cement concrete. M-sand and Silica plastic granules based geo-polymer concrete has excellent compressive strength and is suitable for structural applications. The price of M-sand and plastic granules based geo-polymer concrete is estimated to be about 10 to 30 percent cheaper than that of Portland cement concrete.

IV. CONCLUSION

1) To prepare GGBS and plastic granules based geo polymer concrete, trial and error methods were adopted. During the trial and error methods, no proper bonding was obtained between materials for some trials of solution/binder ratio. Later the optimum mix of GGBS: fine aggregate: coarse aggregate is obtained to be 1:1.5:2.2 with a solution/binder ratio of 0.45 as it gives a good bonding.
2) 100% replacement of cement by GGBS with an alkaline solution of 6 molarity gives high early strength than any others in this study.
3) Based on the experimental study, higher the concentration of NaOH (molarity), higher compressive strength of geo-polymer concrete.
4) Geo-polymer concrete give good results at optimum replacement of plastic granules (60%-40%) of M-sand and plastic granules.
5) Compressive strength of geo-polymer concrete decreases with the increase in plastic content in concrete.
6) Geo-polymer concrete with plastic granules is ecofriendly, (reduce Co_2 emission) and conserve natural resources.

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