PERFORMANCE ASSESSMENT OF GEOPOLYMER CONCRETE WITH PARTIAL REPLACEMENT OF E-WASTE AS COARSE AGGREGATE

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Abstract - *The major problem now faced by the world is environmental pollution. Carbon dioxide, the leading greenhouse gas, is the main pollutant that causes global warming. It is an immediate necessity of the word to reduce the greenhouse gas emission. It is found that 80% of the CO2 emission can be reduced by using geopolymer concrete when compared to the ordinary Portland cement manufacturing. Geopolymer concrete is a concrete in which Portland cement is completely replaced by fly ash and GGBS (Ground Granulated Blast Furnace Slag). Fly ash and GGBS are industrial by products. On an average, 30- 35 tons of E-waste is generated in Kerala every month. It is also an emerging issue that causes serious pollution problems. This project examines the possibility of using E-waste in geopolymer concrete by partially replacing the coarse aggregate. The present study covers the use of E-waste as partial replacement of coarse aggregate in geopolymer concrete. Tests are conducted to study the compressive, split tensile and tensile strengths of Geopolymer concrete and Geopolymer concrete with E-waste as a partial replacement of the coarse aggregates.*

Key Words: Geopolymer, E-waste, fly ash, GGBS,Pollution.

1. INTRODUCTION

Concrete is the most widely used construction material in the world. Ordinary Portland Cement (OPC) has been traditionally used as the binding material for concrete. The manufacturing of OPC requires the burning of large quantities of fossil fuels and decomposition of limestone which results insignificant emissions of carbondioxide (CO2) to the atmosphere. This CO2 emission is the main cause for global warming, which have become a major concern. In order to reduce this, Geopolymer technology was introduced.

On the other side, each year million tons of industrial and agricultural wastes are produced in our country. The management of these wastes and other related issues is a big bottleneck for the development. Moreover, the increasing concern about the ecological significances of waste disposal has led researchers to investigate the consumption of the wastes as potential construction materials. The abundance and availability of waste materials such as fly ash (FA), ground granulated blast furnace slag (GGBS), silica fume, red mud and rice husk ash (RHA) worldwide create an opportunity to make use of these by-products of different industries as partial or complete replacement for OPC in concrete. By using these waste materials in concrete, we cannot only minimize the problems associated with the production of cement but also solve the problem of waste disposal. In view of this, there is a need to develop sustainable alternatives to the conventional binder (cement) utilizing the cementitious properties of industrial and agricultural by-products. In this study geopolymer concrete is a concrete in which Portland cement is completely replaced by fly ash and GGBS (Ground Granulated Blast Furnace Slag). Fly ash and GGBS are industrial by products.

New electrical and electronic products have become an integral part of our daily lives providing us with more comfort, security, easy and faster acquisition. Due to technological growth, there is a high rate of obsolescence in the electronic equipments which leads to one of the fastest growing waste streams in the world. This waste stream consists of end of life electrical and electronic equipment products. Electronic and electrical equipment's are made up of several components, many of which contains toxic substance, like lead, chromium, mercury, beryllium, cadmium, acids and plastics etc. Since many research works were carried out using E-Waste as a partial replacement of coarse aggregate. The major objective of this project is to reduce as far as possible the used and discarded electronic and electrical equipments and convert waste into socially and industrially beneficial and used raw material with low cost and environmental friendly technology.

1.1 Objective

The main objective of this study is as follows.

1. This project examines the possibility of using E-waste in geopolymer concrete by partially replacing the coarse aggregate.
2. Tests are conducted to study the compressive, tensile, split tensile strengths of Geopolymer concrete and Geopolymer concrete with E-waste as a partial replacement.
3. To find optimum mix which gives the maximum strength.

2. MATERIALS PROERTIES USED

2.1 Fly ash

Fly Ash is a byproduct of electricity producing plant using coal as fuelIt is a good pozzalona the colour of fly ash is either grey or blackish grey.The chemical composition is mainly composed of the oxides of silicon (SiO_2), aluminum (Al_2O_3), iron (Fe_2O_3), and calcium (CaO).

Properties	Test results IS 3812(Part 1)-2003
Fineness	7.66%
Specific Gravity	2.2

Fig -1: fly ash

2.2 Ground Granulated Blast Furnace Slag (GGBS)

Granulated Blast furnace Slag (GGBS) is obtained by quenching molten iron slag (a by-product of iron and steel making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder.

Table -2: Properties of GGBS

Properties	Test results IS 16714:2018
Fineness	6.7%
Specific Gravity	2.85

Fig -2: GGBS

2.3 *Alkaline Activators*

The combination of Sodium hydroxide and Sodium silicate is used as the alkaline activator in this study. Alkaline liquids are prepared by mixing of the Sodium hydroxide and Sodium silicate solutions at the room temperature at least 24 hours prior to use.

Table -3: Properties of Alkaline activators

Properties	Test results
Specific Gravity sodium silicate	1.39
Specific Gravity sodium hydroxide	1.41

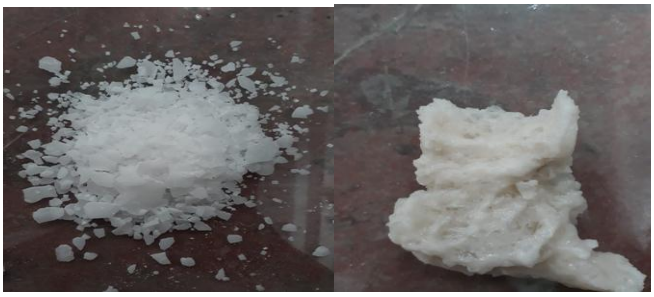

Fig -3: sodium silicate and sodium hydroxide

2.4 E-Waste

Rapid technology change, low initial costs have resulted in a fast growing surplus of electronic waste around the globe.E-waste available in the form of loosely discarded, surplus, obsolete, broken, electrical or electronic devices from commercial recyclers have been collected which were crushed to the particle size.

Table -4: Properties of E-waste

Properties	Test results
Specific gravity	1.20
Water absorption (%)	0.20
Fineness	2.50

Fig -4: E-waste

2.5 Coarse Aggregate

Coarse aggregates are produced by disintegration of rocks and by crushing rocks. Coarse aggregates are usually those particles which are not retained on an IS 4.75mm sieve.

Table -5: Properties of Coarse Aggregate

Properties	Test Results	Range	IS CODE
Fineness Modulus	2.98	2.9-3.2	IS 383-1970
Specific Gravity	2.98	2.5-3.0	IS2386 (part-III)-1963
Water Absorption	1.8%	0.1-2.0%	IS2386 (part-III)-1963
Bulk Density	1.811 g/cc	-	
Porosity	46.6%	-	
Void Ratio	0.257		

4.6 Fine Aggregate

Fine aggregate is a naturally occurring granular material composed of finely divided rock and mineral particles. In this study M sand is used as fine aggregate.

Table -6: Properties of Fine Aggregate

Properties	Test Results	Range	IS CODE
Fineness Modulus	2.602	2 .6 -3.0	IS 383-1970
Specific Gravity	2.5	2.5 -2.9	IS2386 (part-III)-1963
Bulking	14.28%		
Bulk density	1.39g/cc		
Porosity	36.5%		
Voids ratio	0.48		

3. MIX PROPORTIONING OF CONCRETE

Concrete mix design is the process of finding right proportion of GGBS, Fly ash, sand and aggregates for concrete to achieve target strength in structures. Based on the test results of materials, the mix proportion for M40 concrete is done according to ACI meathod. Mix proportion of M40 concrete geopolymer(control mix),is given below.

Table -7: mix proportioning of concrete

GGBS (kg/m3)	FLY ASH (kg/m3)	Proportion	Sodium silicate (kg/m3)	Sodium hydroxide (kg/m3)	w/c ratio
85	200	1:2.45:5.01	120	80	.43

4. CASTING AND CURING OF CONCRETE

Casting is a manufacturing process in construction in which a concrete mix paste is usually poured into a mould of desired shape. Usually cube, cylinder and prism specimens are moulded for testing the mechanical properties of concrete.

Curing is the maintenance of a satisfactory moisture content and temperature in concrete for a period immediately following placing and finishing so that the desired properties may develop. Curing has a strong influence on the properties of hardened concrete; proper curing will increase durability, strength, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing.

5. RESULT AND DISCUSSION

5.1 COMPRESSIVE STRENGTH OF CONCRETE CUBES

Compressive strength is the capacity of a material or structure to withstand load tending to reduce size, as opposed to tensile strength, which withstands load tending to elongate. The testing is done on compressive test machine. Find out the compressive strength of concrete cube at 7 days, 14 day, and 28 days of variation percentage of ggbs and fly ash on geopolymer concrete to find optimum mix and also replaced geopolymer concrete by partial replacement of coarse aggregate with e-waste.

Table -8: Table for varying GGBS-FLY ASH binder ratio

Mix	GGBS (%)	FLY ASH (%)
M1	90	10
M2	80	20
M3	70	30
M4	60	40
M5	50	50
M6	40	60

Table -9: Compressive strength of specimen

sample	7days strength (N/mm^2)	14days strength (N/mm^2)	28days strength (N/mm2)
M1	33.2	36.5	40.1
M2	32.4	38.6	42.3
M3	36.9	39.5	43.5
M4	38.5	42.8	48.5
M5	36.4	41.6	44.2
M6	32.6	35.4	40.1

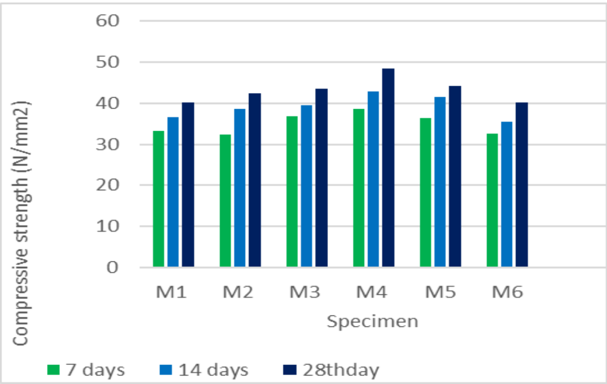

Chart -1: Variation of compressive strength

Table -10: Compressive strength of e-waste admixed concrete

Sample (percentage variation)	7 days strength (N/mm^2)	14 days strength (N/mm^2)
5%	38	40
10%	38.5	41.5
15%	37.25	39
20%	37	38.5

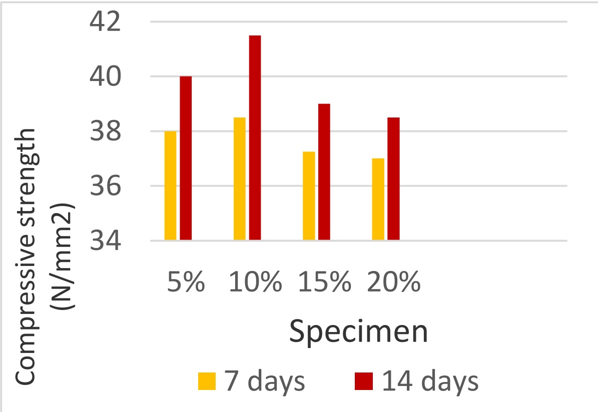

Chart -2: Variation of compressive strength.

5.2 Flexural strength of concrete beam

Flexural strength, also known as modulus of rupture, or bend strength, or transverse rupture strength is a material property, defined as the stress in a material just before it yields in a flexure test. The testing is done on universal testing machine. Find out the flexural strength of concrete beam at 7 days, 14 day, and 28 days of variation percentage of ggbs and fly ash on geopolymer concrete to find optimum mix and also replaced geopolymer concrete by partial replacement of coarse aggregate with e-waste

Table -11: flexural strength of specimen.

sample	7 days strength (N/mm^2)	14 days strength (N/mm^2)	28 days strength (N/mm2)
M1	4.5	4.75	4.8
M2	4.6	4.85	5

M3	4.8	4.9	5.10
M4	4.95	5.1	5.2
M5	4.8	4.95	5.1
M6	4.7	4.85	4.9

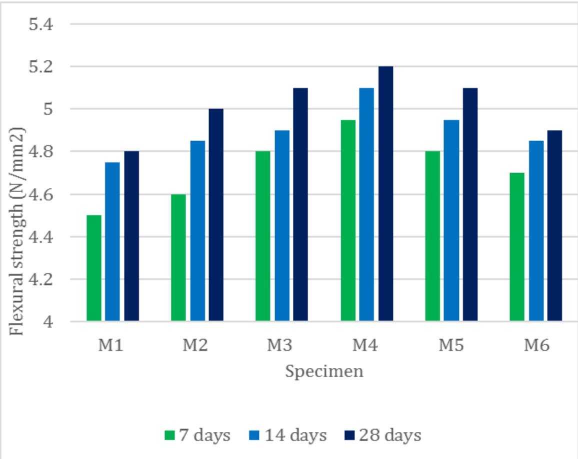

Chart -3: Variation of flexural strength.

Table -12: flexural strength of e-waste admixed concrete.

sample(percentage variation)	7 days strength (N/mm^2)	14 days strength (N/mm^2)
5%	4.8	4.85
10%	4.9	5
15%	4.80	4.85
20%	4.78	4.8

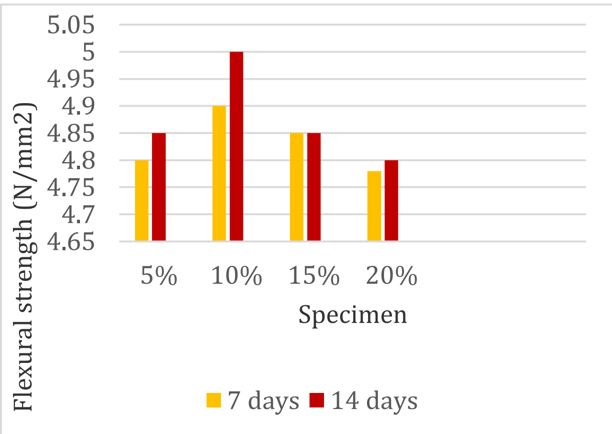

Chart -4: Variation of flexural strength.

5.3 SPLIT TENSILE STRENGTH OF CONCRETE

Split tensile strength is one of the basic and important properties of concrete. The ability of concrete withstand in pulling force (tensile stress) without broke is called tensile strength of concrete. The testing is done on compressive test machine. Find out the split tensile strength of concrete cylinder at 7 days, 14 day, and 28 days of variation percentage of ggbs and fly ash on geopolymer concrete to find optimum mix and also replaced geopolymer concrete by partial replacement of coarse aggregate with e-waste.

Table -13: split tensile strength of control mix

sample	7 days strength (N/mm^2)	14 days strength (N/mm^2)	28 days strength (N/mm2)
M1	2.7	2.95	3.15
M2	2.75	3.25	3.1
M3	2.8	3.1	3.2
M4	2.9	3.2	3.5
M5	2.9	3.1	3.3
M6	2.8	3	3.2

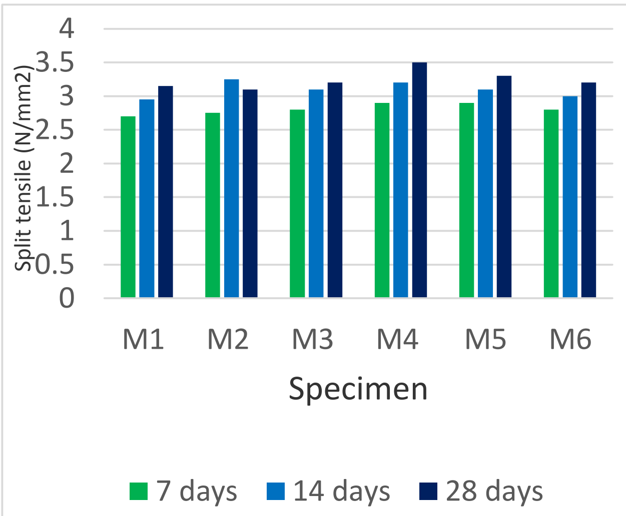

Chart -5: Split tensile strength variations.

Table -14: split tensile strength of e-waste admixed concrete.

Sample (percentage variation)	7 days strength (N/mm^2)	14 days strength (N/mm^2)
5%	2.75	2.8
10%	2.8	2.9
15%	2.7	2.6
20%	2.7	2.55

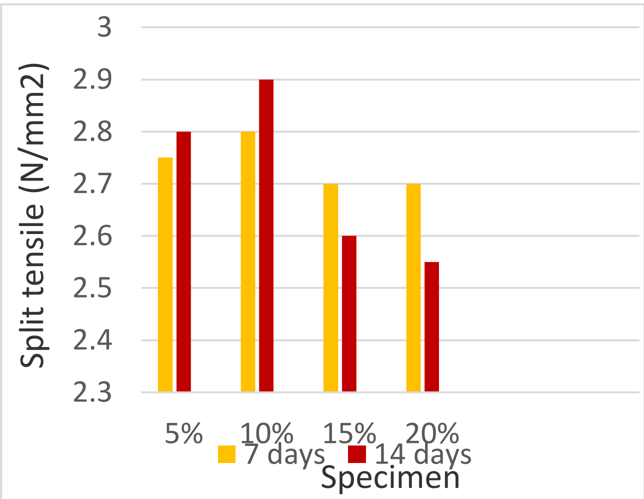

Chart -6: Split tensile strength variations.

6. CONCLUSIONS

From the compressive strength test results, it is evident that the compressive strength increases with Ggbs of 60% and 40% fly ash replacement and then it decreases, although the results is still higher. When the content is increased above it decreased the compressive strength. The replacement of e-waste in the optimum mix at varying percentage at a replacement of 10 percentage gives the maximum strength. it is due to decrease in density of concrete due to the replacement of coarse aggregate. From this study we can use Electronic waste in to the concrete by partial replacing the coarse aggregate. It is identified that the E- waste particles can be used as the construction material.

The use of E-waste in concrete is possible to improve its mechanical properties and can be one of the economical ways for their disposal in environment friendly manner.

Split tensile strength also increases with 60% and 40% fly ash replacement and then it decreases, although the results of this replacement is still higher than those of the control mix. Also the flexural strength of the specimens increases with 60% and 40% fly ash replacement and then it decreases The replacement of e-waste in the optimum mix at varying percentage at a replacement of 10 percentage gives the maximum split tensile strength and flexural strength.

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