Strength behaviour of geopolymer concrete replacing fine aggregates by M- sand and E-waste

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Abstract — *Geo binder is a sustainable binding material that produces no emissions of carbon dioxide during curing and after curing. Aggregates contribute more than 65% for producing geopolymer concrete. The Eco-friendly sand material and Cost effective material called Manufacture sand was used as a partial replacement material for fine aggregates by various percentages. Manufacture sand is generally produced by crushing, screening and washing a rock in desired shapes and sizes. Electronic waste is one of the hazardous waste materials; it is a non-degradable waste material creates harmful effects on environment. Such materials are cost effective for processing, other than using this process to make it degradable; these electronic materials were replaced here partially in place of fine aggregates which are a very cost effective technique for degrading from earth. Polypropylene fibers were used in concrete to avoid micro cracks and to get the closed surface of concrete which in terms give good strength. Manufacture sand and electronic waste was partially replaced by fine aggregates in 10%, 20%, 30%, 40% and 50%. Mix designs were prepared and casted separately and then tests were carried out and then the results were compared with respect to conventional geopolymer concrete and concrete made by replacement materials.*

Keywords — *Geo binder, M-sand, E-waste, Alkaline solution and polypropylene fibers.*

1.0 INTRODUCTION

Concreting is very important in construction activities all over the world. Binding material is necessary for concrete. Generally cement is used as binding material in all concrete applications. Construction is going on everywhere due to this the demand for cement is increased. To overcome this, fly ash has been introduced in place of cement. Manufacture of cement in cement industries emits large amount of pollutants which cause environmental pollution. During at the time of production of cement, carbon dioxide is released into atmosphere. One ton production of cement approximately release one ton of CO2 into the atmosphere. By taking that into consideration we are using fly ash as a binding material for concrete along with alkaline solutions, which is named as “Geo polymer Concrete”. As a result of this we can reduce demand for cement and also decrease the emissions of pollutants into the atmosphere which are releasing by cement industries. That to fly ash is a by-product of which is obtained from thermal power plant, and it is also the most abundant industrial waste in the environment. The use of geo polymer concrete significantly decreases CO 2 emission and reduces environmental pollution. Utilization of natural river sand is increasing day by day with an increasing of construction activities. It is becoming a scarce material now a day. It is the second major component in the concrete mix. Since it is a natural product; it has organic and inorganic matter. Organic matter if present in sand creates void cracks after setting of concrete which intern the strength of material get decrease and the permeability of concrete is also a matter if we use such sand. There were many issues rising on extraction of natural sand like decrease of underground water table which impacts on agriculture, effect on aquatic life, erosion of river banks and loss of water holding capacity are the problem associated with natural sand extraction. To overcome all these causes synthetic man made sand called manufacture sand can also be used in place of course aggregates and fine aggregates. Here in this investigation manufacture sand electronic waste is utilized partially in place of fine aggregates. Due to even size of all particles in M-sand, high content of reactive silica in M-sand and higher density of M-sand give better properties to the concrete mix compared to conventional concrete.

2.0 LITERATURE SURVEY

Kolli Ramujee and M.Potharaju [1] experimented geopolymer concrete and stated that it can more Resistant to attack by magnesium and higher sulphuric acids. Geopolymer concrete is more resistant to OPC concrete.

Nirav shah, et.al [2] investigated concrete with fly ash and determined the compressive and flexural strength of concrete in normal and acidic environment.

L.Krishnan, et.al [3] experimented geopolymer concrete and test results of compressive strength and stated that geopolymer concrete is an eco-friendly construction material.

Vanchai Sata, et.al [4] experimented geopolymer concrete with using recycled aggregates and made relationships of density and compressive strength, splitting tensile and compressive strength.

Lohani T.K, et.al [5] produced concrete with 100% of fly ash and results were made that increase in fly ash decreases strength.

E. Badogiannis, et.al [6] experimented metakaolin as a supplementary cementitious material and stated that metakaolin exhibits higher pozzalonic reactivity.

Sanjay N. Patil, et.al [7] experimented pozzalanic material for high strength concrete and stated that optical performance is achieved by replacing 7% to 15% of Metakolin.

Discarded e-waste account for the generation of huge quantity of waste PCBs (Printed Circuit Board). Waste PCBs are generated from overstock, obsolete and end of- life computers, medical appliances, fax and copying machines, household appliances such as television, refrigerator etc., [Rashmi Kumar ET al.2014]. According to the study carried out by GTZ (German Technical Collaboration agency) and MAIT (Manufacturers' Association for Information Technology) in 2007, the total quantities of generated and recycled E-waste were 380,000 tons and 19,000 tons respectively. Above this about 50,000 tons got imported illegally into the country. About 14 million mobile handsets had been replaced in 2007[Rashmi Kumar et al.2014]. Mechanical treatment of these waste printed circuit board in crushing-sorting to separate valuable metal components, will produce a large amount of glass fibre resin powder which has become the problem of world's electronic waste disposal[Wenhong Li et al,2012]. Wenhong Li

Stated that at present, the number of waste printed circuit board (WPCBs) is increasing year by year, more than one million tons was produced. In china the valuable metal in WPCBs has huge economic value and therefore increased crushing – sorting separation technology to extract valuable metals from WPCBs, scrap circuit boards crushing –sorting valuable metals isolated ingredients will produce large amounts of resin powder which was the components of fibre glass(non-metallic powders). Non-metallic powders are composed by circuit board substrate material and resin powder [Wenhong Li et al, 2012]. Wenhong Li et al. also reported that these PCB wastes when dumped as a landfill may cause potential threat to environment and security, for the leachate would penetrate to groundwater. When subjected to incineration, non-metallic powder contains a large number of calorific value composite such as glass fibres and other inorganic constituents. The heat generated in incineration is not so high therefore results in releasing dioxins and carcinogens. Thus this project quotes to utilize this waste that threatens the environment.

Since these wastes cannot be disposed either through dumping or through incineration, efforts have been taken to use these wastes as construction material

II MATERIAL DESCRIPTION

Fly ash:-

Table I particle sizes of PCB

INGREDIENTS	***PARTICLE SIZE***
Flaky powder	0.3-0.15mm
Long rod-like powder	0.15-0.125mm
Chopped fibre and resin powder	<0.07mm

Fly ash is a by-product of combustion of pulverized coal in power generation plants. The sizes of fly ash particles are slightly larger than Portland cement type 1.silica has high chemical content in fly ash and other chemical materials are iron, alumina and calcium. The colour of fly ash is dark grey. The class f fly ash has more pozzlanic properties compare to class 'c' fly ash. Class F fly ash impart significant sulphate resistance and alkali aggregate reaction (ASR) resistance to the different Concrete mixes Fly ash more economical com-pare to ordinary Portland cement. In this research the Specific gravity of fly ash is 2.30. The chemi-cal properties of fly ash is shown in the below table1.

Fig: Fly ash

Table1. Chemical composition of fly ash.

Chemical component	***percentage***
Sio_2	56.9
Al_2o_3	17.49
Fe_2o_3	4.52
Cao	1.21
K_2o	2.755
Na_2o	0.65
Mgo	0.54
Loss of ignition	0.64

Poly Propylene Fibers:-

Polypropylene is available in two forms. They are film fibers and monofilament fibers. Monofilament fibers are produced by an extrusion process and then cut different desired length. These are similar to monofilament fibers but it is in the form of flat film. In these two forms the construction industries are more preferred monofilament fibers. This monofilament are available in different lengths like 6mm, 10mm, 12mm, and 24mm. we are normally used extraction fibers This are used in concrete to decrease the sudden failure of the structure.

Fig: polypropylene fibres

Alkaline liquid:-

The most common alkaline liquid used in geopolymerisation is a combination of sodium silicate or potassium silicate and sodium hydroxide (NOAH) or potassium hydroxide (KOH). The use of a single alkaline activator has been reported. Type of alkaline liquid is plays a crucial role in the polymerization of geopolymer concrete. The molarity of the liquid increases with increase the compressive strength of concrete and it gives more stiffness to the materials in the concrete. The father of geopolymer found that generally the KOH solution caused a lower dissolution of minerals compare to NAOH solution.so in this research we were used NAOH pellet form.

Coarse and fine aggregates:-

In total concrete volume more than 70% place is occupy by the Aggregates and it increases the workability of concrete. Most of the body is covered with coarse aggregates and fine aggregates. In this experimental work the coarse aggregates which are retained in 10mm I.S Sieve and passed in 20mm I.S Sieve are consider as per I.S 383-1970. The size of aggregate is less than 4.75mm are called as fine aggregates. Normally Sand contains silica material and it is useful to give proper bonding to the concrete. The bonding between the materials are only gives the good strength to the concrete. The physical properties of fine aggregates are shown in below table 2.

Table 2: Properties of Fine Aggregates

Characteristic	***Value***
Type	Uncrushed(shape)
Specific gravity	2.68
Fineness modulus	2.50
Water adsorption	1.02
Grading zone	II

Electronic waste:-

This electronic waste and printed circuit boards are generated from circuit boards, over-stock, obsolete and computers end of life, medical appliances, fax , household appliances such as television, refrigerator etc. This waste material is used in concrete to decrease the environmental pollution. Some efforts have been taken by the construction industry to use this waste materials.by using pulverizing machine to crush the printed circuit boards and use in concrete. The sizes of the particles are 0.3mm to 0.15mm and it is dark in colour.

Fig: electronic waste

The Physical Properties of E-Waste Are Shown Below Table 3.

Table 3 Properties of E-Waste

Characteristic	***Value***
Specific gravity	1.01
Water absorption	0.19%
colour	Dark

According to zone 2 particles the fineness modulus for manufacture sand is 10% and the specific gravity of the particles are 2.5 to2.9. Silt and organic impurities are absent in manufacture sand. Setting time of manufacture sand is faster compare to river sand.it is more economical compare to river sand.

III Design mix:-

G25 grade of concrete is designed by using various design codes and considerations are like geopolymer concrete -1 and geopolymer concrete -2.by using this design considerations we are casted different percentages of concrete by using different materials.in this paper we were used binder ratio (i.e. sodium silicate and sodium hydroxide ratio) is 2.5 and 16M solution is used for getting the good results. To the total volume of concrete 79% of aggregates were taken for design considerations. Electronic waste and manufacture sand are partially replaced in geopolymer concrete instead of fine aggregates. The various replacing percentages are like 10%, 20%, 30%, 40% and 50%.the design mix propositions are shown in table 4.

Table 4 Design mix propositions (kg/m3) and Ratios of G25 grade of concrete

Fly ash	Coarse aggregate	Fine aggregate	Sodium silicate	Sodium hydroxide
352	1344	528	121.71	50.28
1	3.8	1.5	2.5	2.5

Table 5 Mix propositions of E-waste and M-sand

Mixes	Partial replacement of E-waste as fine aggregates		Partial replacement of M-sand as fine aggregates	
	F.A	E.W	F.A	M.S
Nominal mix	100%	0%	100%	0%
Mix -1	90%	10%	90%	10%
Mix -2	80%	20%	80%	20%
Mix -3	70%	30%	70%	30%
Mix -4	60%	40%	60%	40%
Mix -5	50%	50%	50%	50%

IV Experimental Work

The evaluation of concrete with electronic waste material and manufacture sand as a partial replacement of fine aggregates has done through testing the specimens. Concrete contains fly ash, coarse aggregates, fine aggregates, alkaline solution, water & admixtures for geopolymer concrete are in the ratio of 1:1.5:3.8.before one day of the casting prepare the alkaline solution. For the preparation of solution using plastic bucket and steel rod .the solutions are sodium hydroxide and water .the electronic waste and manufacture sand are used as a partial replacement of fine aggregate with various percentages like 10%, 20%, 30%, 40%, and 50%. In this research we were used Polyprolyne fibers to decrease the sudden failure of the structure. These fibers are added to the concrete by volume of the cement. For testing the compressive strength for cubes ,cylinders and beams of conventional and other mix percentages are totally 30 –cubes and size of specimen is (150X150X150) mm were casted for strength of geopolymer concrete. As per mix prepositions 15-cyclinders were casted for split tensile test of geopolymer concrete and size of specimen is 150mmX300mm.from the date of casting specimens are kept in oven curing for 24 hrs. In 60^0C with conceal curing purpose method only. Next day de-mould the concrete specimens and kept in room temperature. The specimens are tested on compressive testing machine for 7th day and 28^{th} day of that alkaline solution added to concrete. For split tensile test 28 days curing is required to test the concrete specimens. For beam flexural test 28-days ambient curing is required to test the concrete specimens.

1. COMPRESSIVE STRENGTH TEST

Compression test is the most common test conducted on concrete. It decided the characteristic strength of the concrete. Concrete is weak in tension and strong in compression. The quality of concrete is related to its compressive strength. So the concrete should be strong in compression to attain a high compression values. In this paper we were casted 3-samples for each mix and tested on the machine. From that test results average value is taken and compare to normal geopolymer 25 grade of concrete. Totally casted 50 cubes. Size of each cube is 150mm X 150mm X 150mm and tested at 7days and 28 days. The size of aggregate is 20mm and 10mm for 15cms cubes. Size of aggregates are varies for 10cms cubes. For testing the cube and cylinders uniformly load is applied on the particular specimen, it forms a crack on the surface (or) inside the specimen that cracks on specimen is called the failure load of the cubes and cylinders. The compressive strength of concrete is calculated by using the below expression

Compressive strength of concrete (N/mm2)

= Applied load (N)/cross section area (mm2)

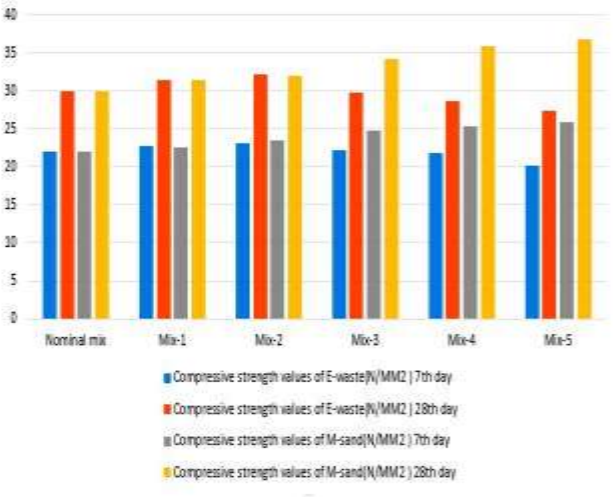
The above figure shows the uniformly load applied on the specimen at the top surface and plate is fixed at the bottom of the specimen. The failure of the specimen is shown in above fig.

Table 6 Compressive Strength values for geopolymer Concrete with E- waste & M- sand

Mix	*Compressive strength values of E-waste(N/MM^2)*		*Compressive strength values of M-sand(N/MM^2)*	
	7th day	*28th day*	*7th day*	*28th day*
Nominal mix	22	30	22	30
Mix-1	22.7	31.5	22.5	31.5
Mix-2	23.2	32.2	23.5	32
Mix-3	22.2	29.8	24.7	34.2
Mix-4	21.8	28.6	25.3	35.8
Mix-5	20.2	27.3	25.9	36.8

The above test results are shown 7th day and 28th day of different mix propositions by replacing M-sand and E-waste as a fine aggregates. The compressive strength of concrete is slightly increasing while adding M-sand as a fine aggregate and for E-waste 32.2 N/MM^2 is the maximum compressive strength of concrete while E-waste is added as a fine aggregate up to 20% replacement.

Bar chart No.1 Compressive Strength of Concrete



2. SPLIT TENSILE TEST

In this test we were tested cylindrical specimens. The size of each cylinder is 150mm X 300mm tested at 28th days. The specimen is placed in the machine in a proper manner that the load is applied top surface of the section with 2 line spaced a part. The load is applied at the top surface of the cylindrical specimen and increased continuously until the specimens fails, the maximum load of the specimen is recorded. Totally 30 cylinders we were casted for different mix propositions of normal geopolymer 25. For each mix 3- samples were casted and tested. From that testing samples average value is taken as a split tensile strength of concrete. The different mix ratio values of split tensile test and normal mix as shown in below table and those values are clearly shown in the bar graph. There is the formula to calculate the split tensile test as shown below.

Split tensile test = 2P/ (3.14dl)

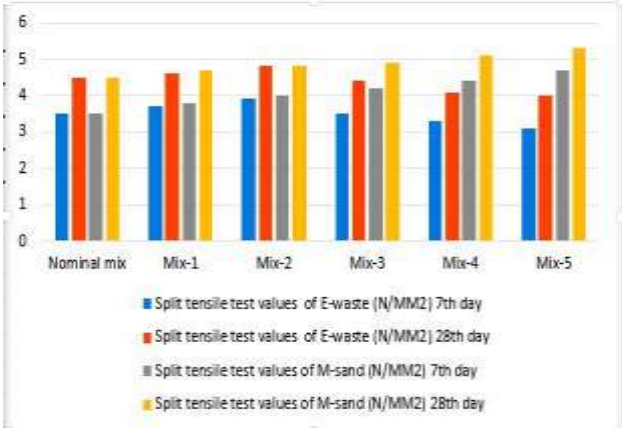
Where p – Applied load (KN)
d – Diameter of the cylinder in mm
L–Length of the cylinder in mm

Table 7 split tensile test values of geopolymer Concrete

mix	*Split tensile test values of E-waste (N/MM^2)*		*Split tensile test values of M-sand (N/MM^2)*	
	7th day	*28th day*	*7th day*	*28th day*
Nominal mix	3.5	4.5	3.5	4.5
Mix-1	3.7	4.6	3.8	4.7
Mix-2	3.9	4.8	4.0	4.8
Mix-3	3.5	4.4	4.2	4.9
Mix-4	3.3	4.1	4.4	5.1
Mix-5	3.1	4	4.7	5.3

From the above test results maximum value getting at mix-2 i.e. 4.8 at 20% replacement of E-waste and by replacing fine aggregates as a M-sand it increases the split tensile strength of concrete. All values are compared to nominal concrete as shown in below bar chart.

Bar chart No.2 Split tensile Strength of Concrete



3 FLEXURAL STRENGTH OF CONCRETE

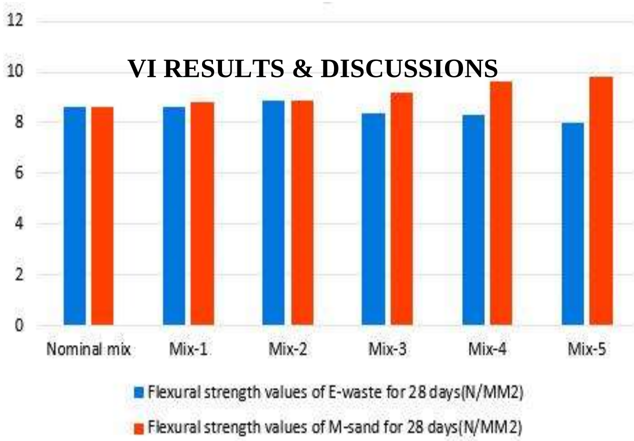
Concrete as relatively weak in tension and strong in compression. in steel reinforced concrete member's dependence is placed on the tensile strength of concrete.rebars and steel reinforcement is provided to resist the tensile forces in the concrete specimens. Tensile stress is develop in concrete due to rusting of steel reinforcement bars, drying shrinkage, and other reasons. The concrete beam is placed on two adequate subgrade supports. Point load is applied at the center of the beam maximum fiber stress are developed while bending.in case of two point loading crack will be appear at any section of the beam ,not strong to resist the stress in the middle. The bending moment of the section is maximum. While applying the two point load the modulus of rupture is lower compare to point loading .the size of the specimens are 100mmX100mmX500mm.totally 10 cylinders were casted and tested.

Table 8 flexural test values of geopolymer Concrete

Mix	Flexural strength values of E-waste for 28 days(N/MM^2)	Flexural strength values of M-sand for 28 days(N/MM^2)
Nominal mix	8.63	8.63
Mix-1	8.6	8.8
Mix-2	8.9	8.9
Mix-3	8.4	9.2
Mix-4	8.3	9.6
Mix-5	8	9.8

From the above test results increase flexural strength values by replacing fine aggregate as an M-sand in different mix propositions and other replacing material is E-waste.by replacing E-waste as a fine aggregates up to 20% strength values are increases more than that percentage decrease the flexural strength values. This test results are compared to nominal mix and that values are shown in bar chart.

Bar chart No.3 Flexural Strength of Concrete



VI RESULTS & DISCUSSIONS

The compressive strength, split tensile and flexural tests of concrete has done. The strength behaviour of geopolymer concrete is calculated by replacing E-waste and M-sand as fine aggregates. We were replacing different percentages like 10% ,20%,30%,40% and 50% .that test result values are shown in table 6,table 7 and table 8.

In this research the compressive strength of concrete is increases while adding M-sand as a fine aggregates and strength of concrete is decreases while adding E-waste as a fine aggregates.by re-placing 20%as a E-waste in concrete increases the strength value and it slightly decreases by adding more than 20% of E-waste. Bar chart 1,bar chart 2 and bar chart 3 shows the Different mix prepositions of various percentage replacing in concrete and compressive strength ,split tensile test and flexural test values are shown in table6,table7 and table8 for 7 days, and 28 days.

VII CONCLUSION

The main aim of this research is to improve the characteristic strength of geopolymer concrete, replaced with10%, 20%, 30%, 40% and 50 % of E-waste and M-sand as a fine aggregates and find out the optimum percentage replacement.

Based on the experimental investigation presented, the following results are drawn:

- The strength of geopolymer concrete was increased with increase in percentage of M-sand in various percentages.
- The strength of geopolymer concrete was increased with increase in percentage of E-waste up to20%.
- More than 20% replacement the strength of concrete is slightly decreases compare to nominal mix and its effects on the structure.

- The maximum strength obtained for M-sand at 28 days is 36.8Mpa and the maximum strength is obtained for E-waste at 28 days is 32.2Mpa.
- From the test results as mentioned above we observe that the compressive strength of concrete using PCB as a partial replacement for sand shows decrease in compressive strength when compared with control mix.
- In split tensile test the maximum strength is obtained for 20% replacement of E-waste in concrete at 28 days. For M-sand the split tensile strength is increased up to 50% replaced in concrete.
- By adding the polypropylene fibres to concrete it reduces the water permeability and shrinkage.
- To overcome the low tensile strength of concrete by adding polypropylene fibres to concrete.
- Increase in the amount of E-waste proportion in geopolymer concrete requires higher dosage of super plasticizer to get good work ability.
- By the addition of polypropylene fibers to concrete it improves the durability of concrete and resist the structure due to sudden failure.

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