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Utilization of e-waste in geopolymer concrete by partial replacement of coarse aggregate.

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Abstract: **-** Portland cement concrete industry has grown astronomically in recent years. It will continue to grow as the result of continuous urban development. However, Portland cement concrete posses problems such as durability and carbon dioxide emission. Many concrete structures have shown serious deterioration, way before their intended service life, especially those constructed in a corrosive environment (Mehta 1997). Geopolymer is a class of aluminosilicate binding materials synthesized by thermal activation of solid aluminosilicate base materials such as fly ash, metakaolin, GGBS etc., with an alkali metal hydroxide and silicate solution. These binders are currently attracting widespread attention due to their potential utilization as a high performance, environmental friendly and sustainable alternative to Portland cement India being the largest coal fly-ash producer in the world produces abundant by- product from thermal power plant known as coal fuel ash.

E-waste is the problem with which every country is dealing right now. Because there is no method for the disposal of e-waste and with the growth in the consumption of electronic goods this problem is getting bigger and bigger. The most effective way of the disposal of e-waste is through landfill and this method require large land mass which is very difficult to find in these days. So this is a very good concept of using e-waste as an ingredient in concrete by partial replacement of aggregate. We cannot replace it completely as aggregate provides some key properties to concrete like strength, durability and workability. Using e-waste as building material seems right when we look at the amount of aggregate required for making concrete and if we are able to reduce that amount it will be very beneficiary as it reduces the load from the natural resources. In our research work we have partially replaced the aggregate with e-waste. We have casted concrete cubes with 4%, 8%, and 12% and 16% e-waste and compare the compressive strength of concrete with conventional concrete cubes of G30 grade. In our results we have found out that compressive strength of cubes starts increasing when we add e-waste, but after a point it starts decreasing. At the inclusion of 8% e-waste the compressive strength of concrete is 47.25N/mm_2 and thereafter it starts decreasing. At the replacement of 12.5% aggregate with e-waste the compressive strength of concrete is 38.50N/mm_2.

Keywords: *- Geopolymer concrete, E-waste,* Workability and Compressive strength.

I. INTRODUCTION

1.1 GENERAL

Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calcination of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminum. On the other hand, the abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for OPC to manufacture concrete. When used as a partial replacement of OPC, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate (C-S-H) gel. In 1978, Davidovits (1999) proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminium in source materials of geological origin or by-product materials such as fly ash and rice husk ash. He termed these binders as geopolymers. Palomo et al (1999) suggested that pozzolans such as blast furnace slag might be activated using alkaline liquids to form a binder and hence totally replace the use of OPC in concrete. In this work, low-calcium fly ash-based geopolymer is used as the binder, instead of Portland or other hydraulic cement paste, to produce concrete. The fly ash-based geopolymer paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geopolymer concrete, with or without the presence of admixtures. The manufacture of geopolymer concrete is carried out using the usual concrete technology methods.

1.2 FLY ASH INDUCED CONCRETE

Out of various cementing materials, Fly ash is the most widely used material worldwide. Fly ash is by product from the combustion of pulverized coal in thermal power plants. Fly ash, if not utilized has to be disposed of in landfills, ponds or rejected in river systems, which may present serious environmental concerns since it is produced in large volumes. This is particularly an important issue for India, which currently produces over 100 million ton of fly ash annually. A concerted effort is required for the concrete producers & end users to take a pro-active approach to find optimum utilization areas for supplementary cementing materials, which will enhance the concrete product and efficiently utilize its properties. The use of fly ash in concrete in optimum proportion has many technical benefits and improves concrete performance in both fresh and hardened state. Fly ash use in concrete improves the workability of plastic concrete, and the strength and durability of hardened concrete. Generally, fly ash benefits concrete by reducing the mixing water requirement and improving the paste flow behavior.

- The decrease in water content combined with the production of additional cementitious compounds reduces the pore interconnectivity of concrete, thus increasing durability and resistance to various forms of deterioration.
- The decrease in free lime and resulting increase in cementitious compounds, combined with the reduction in permeability enhance concrete durability. This brings several associated technical benefits, such as resistance to alkali-silica reaction and resistance to sulphate reaction.
- Improved resistance to alkali silica reaction is achieved as fly ash reacts with available alkali in the concrete which makes them less available to react with certain silica minerals contained in the aggregates.
- Fly ash concrete is more durable than asphalted concrete and needs almost no maintenance.
- The design of a highway pavement is based on flexural strength and fly ash concrete continues gaining strength with age.
- More paste volume and lesser bleeding and segregation of concrete mix during placing and compaction leads to better finishing and texturing.
- Higher compressive strength results over period of time as fly ash continues to combine with free lime.
- Fly ash enhances the density of matrix thus increases the points of contact, causing increase in tensile strength, consequently the flexural strength, which is the design criterion for pavement quality concrete.
- The lubricating action of fly ash reduces water content and hence drying shrinkage.
- The pozzolanic activity between fly ash and lime generate less heat resulting in reduced thermal cracking when fly ash is used to replace Portland cement.

There is no doubt that the reduced use of natural resources and recycling of used and waste materials are the key elements in sustainable development but this is not just sufficient.

1.3 GEOPOLYMER MATERIAL

Geopolymers are inorganic polymeric binding materials. Joseph Davidovits, coined the term geopolymer in 1978 to classify the newly discovered geosynthesis that produces inorganic polymeric materials. The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous. Geopolymer material with sodium hydroxide and cured at elevated temperature will attributed more stable cross- linked alumino silicate polymer structure. The properties and uses of geopolymers are being explored in many scientific and industrial disciplines.

1.4 E-WASTE MATERIAL

E-waste is the waste generated form the discarded electronic devices it is an emerging issue causing serious environmental problems as it is very difficult to efficiently dispose the e-waste without causing any harm to the environment. The conventional method for the disposal of e- waste is dumping the waste into land fill but this method has so many serious problems as it needs a lot of landmass which is in scarcity in our country and it also contains so many different harmful materials like lead, cadmium, beryllium etc. these materials when mixes with soil they contaminate the soil and when mixes with ground water they contaminated it also makes it very harmful to consume by any anyone and if someone consume this water it with cause serious health issues and in some cases it even cause cancer. In India we generate about 15 million metric tons of e-waste and this number is going to 30 million metric tons by the year 2018 and still 3% of the e-waste generated in is decomposed properly and the rest of it is decomposed by the small peddlers who will not concern the harmful effects of the e-waste.

Prasanna et al (June 2014) conducted the research on replacing the coarse aggregate with e-waste by 5%, 10%, 15% and 20% in one batch and they also made another batch with using same percentage of e-waste and also adding 10% of fly ash. The concrete strength is found out to be optimum when 15% of coarse aggregate is replaced with e-waste. Amiya Akram et al (July 2015) use shredded e-plastic and fly ash and partially replace the coarse aggregate with it they make two batches one with e-plastic alone and one with e-plastic and fly ash. In one batch they replace coarse aggregate with e-plastic by 5%,10% and 15%. They check the compressive strength and the flexure strength of the concrete. They found out that the compressive strength will increase at 10% but decrease after that and same for flexure strength the concrete became more ductile when e-plastic is added to it as in flexure strength test the specimen fails without any sound as it became less brittle. Balasubramanian et al (july 2016) Carried out investigation to evaluate the compressive strength, flexure strength and split tensile strength when coarse aggregate is partially replaced with e-waste. Concrete mixtures were made by replacing the coarse aggregate with e-waste by 5%, 10%, 15%, 20%, 25% and 30% and then comparing the results with standard concrete mixture in their research they have found out that the compressive strength, flexure strength and split tensile strength have increased when coarse aggregate is replaced with e-waste by 15% and after that the strength starts reducing. They have found out that the concrete became more light weight and it can bear the seismic loads more effectively as compared to conventional concrete.

This research work is conducted in the G30 grade geopolymer concrete at 8 molarity and the percentage of replacement of aggregate varies from 0%, 4%, 8%, 12% and 16%. We have casted geopolymer concrete cubes and check the compressive strength of concrete. We also compared the results with the strength of geopolymer concrete cubes at 8M at 80^0C(chandan.et.al 2004). In our research we have found increment in the compressive strength and workability, both the characteristics of concrete after adding e-waste till the 8%, thereafter it starts decreasing. This research shows that if we replace the coarse aggregate with 8% of e- waste, the compressive strength is increased by 24.34%. So by using e-waste as raw material it will solve the problem of e-waste disposal, less amount of conventional aggregate is required and it will also increase the strength of concrete.

1.5 METHODOLOGY

The methodology for the present work will consists of following steps

- To develop geopolymer concrete using fly ash as a source material
- To develop the process of mixing with optimized use of alkaline activators like sodium hydroxide and sodium silicate.
- Setting up of curing regimens applied to the geopolymers concrete to study the effect on the rest period before heat curing.
- To observe the fresh and hardened properties of fly ash-based geopolymer concrete, mainly its workability and compressive strength.
- To study the effect of super plasticizer on low calcium fly ash based geopolymer concrete.
- To study the effect of E-Waste on workability and compressive strength of G 30 grade concrete and the percentage of replacement of aggregate varies from 0%, 4%, 8% , 12% and 16%.

II. EXPERIMENTAL PROGRAM

2.1 Materials

The material used in present investigation were locally available in Bihta, Dist- Patna(Bihar) and physical properties were found through various laboratory tests conducted in Concrete and Road material lab, NSIT Bihta.

2.1.1 Fine aggregate

Ordinary sand available in Bihta, Patna (Sone river sand) having the following characteristics has been used.

- Specific gravity : 2.67
- Fineness modulus : 2.60
- Unit weight : 1.674 gm/cc
- Water absorption : 0.44%
- Bulking : 25%

Sand after sieve analysis (Table 2.1) confirm to zone – II as per IS 383-1970.

Table 2.1 Sieve analysis of fine aggregate

IS Sieve (mm)	Wt.Retained (Kg)	Cum. Wt. (Kg)	% Retained	% Passing
4.75	0.034	0.034	3.4	96.6
2.36	0.026	0.060	6	94
1.18	0.140	0.200	20	80
600	0.162	0.362	36.2	63.3
300	0.425	0.787	78.7	21.3
150	0.185	0.972	97.2	2.30

2.1.2 Coarse aggregate

Locally available black crushed stone (Pakur stone) in Bihta with maximum nominal size of 20 mm and 10 mm have been used as coarse aggregate.

The physical properties for the coarse aggregate as found through laboratory test according to IS 2386-1963 is resulted as:

- Aggregate crushing value = 24%
- Aggregate impact value = 29%
- Specific gravity = 2.74
- Water absorption = 0.94%
- Unit weight = 1.60gm/cc
- Fineness Modulus = 6.15

Sieve analysis of the locally available coarse aggregate is given in Table 2.2 and 2.3.

Table 2.2 Sieve analysis of coarse aggregate 20 mm

Sieve size (mm)	Weight retained(Kg)	Cum.wt (Kg)	Percent retained	Percentage passing	Remarks
40	0.000	0.000	0	100	60%
20	0.470	0.470	9.4	90.6	
12.5	3.461	3.931	78.62	21.38	
10	0.463	4.393	87.88	12.12	
4.75	0.562	4.956	99.12	0.88	

Table 2.3 Sieve analysis of coarse aggregate 10 mm

Sieve size (mm)	Weight retained(Kg)	Cum.wt (Kg)	Percent retained	Percentage passing	Remarks
40	0.000	0.000	0	100	40%
20	0.000	0.000	0	100	
12.5	0.000	0.000	0	100	
10	1.400	1.40	28.00	72	
4.75	3.304	4.704	94.08	5.92	

2.1.3 Flyash

Fine low calcium fly ash samples taken from Bokaro Thermal Power Station, Bokaro (Jharkhand) were used in this study. This fly ash was of average quality formed with the combustion of lignite and bituminous coal. The colour of the fly ash was light grey. The sample satisfied the requirements of IS 3812(Part I).

2.1.4 E-Waste

We use Printed Circuits Boards (PCB) as e-waste. We collect the e-waste from local electronic shops. The size of the aggregate is between 1.18mm to 2.36mm. All the metals attached on the PCB were removed by hand.

Table-2.4 Properties of E-waste

S.N	Properties	Experimental Values of E-waste
1	Water Absorption	0.05%
2	Specific gravity	1.30
3	Crushing Value	2.45%
4	Impact Value	1.95%
5	Fineness Modulus	2.50

2.1.5 Water

Potable water mentioned in IS:456-2000 for mixing and curing of concrete specimens was used throughout the research.

2.1.6 Geopolymer Concrete

Concrete of grade G30 is to be used in the research. In this research 8M geopolymer concrete which was cured at 80°C is to be used for calculating compressive strength. The proportions for different molarity is given below(Chandan, 2004)

Table-2.5 Mix Proportion of Geopolymer Concrete

Mixture NO.	Molarity	Fly Ash (Kg)	Coarse Aggregate		Fine Aggregate	NaOH Mass (Kg)	Na_2SiO_3 (Kg)	Water	Super plasticizer (%of Fly Ash by mass)
			Fr-I (Kg)	Fr-II (Kg)					
1	8M	427	766.08	510.72	547.20	11.07	46.93	91	0
2	10M	427	766.08	510.72	547.20	13.37	46.93	88.7	0
3	12M	427	766.08	510.72	547.20	15.37	46.93	86.7	0
4	14M	427	766.08	510.72	547.20	17.20	46.93	84.8	0
5	16M	427	766.08	510.72	547.20	18.90	46.93	83.2	0
6	14M	427	766.08	510.72	547.20	17.20	46.93	84.8	1.5 polycarboxylic base
7	14M	427	766.08	510.72	547.20	17.20	46.93	84.8	1.0 Naphthalene Sulphonate base
8	14M	427	766.08	510.72	547.20	17.20	46.93	84.8	1.5 Naphthalene Sulphonate base
9	14M	427	766.08	510.72	547.20	17.20	46.93	84.8	2.0 Naphthalene Sulphonate base

III. EXPERIMENTAL RESULTS AND DISCUSSION

The experimental results are presented and discussed. Each of the compressive strength test data plotted in Figures or given Tables corresponds to the mean value of the compressive strengths. The effects of salient parameters on the compressive strength of low-calcium fly ash-based geopolymer concrete are discussed. The effect of use of different dose of E Waste on workability and strength of fly ash-based geopolymer concrete

3.1 Workability and Compressive strength test

3.1.1 WORKABILITY

Workability is the ease with which concrete flow and it is calculated by slump test conducted on fresh concrete. The workability of the fresh concrete was measured by means of the conventional slump test. It was seen that the workability increase with increase percentage of E-waste the results are shown in table 2.5

Table-2.5 Workability of concrete with varying dose of e-waste.

S.No	Cube Designation	Slump in mm	%age of E-waste
1	A1	29	0
2	A2	33	4
3	A3	39	8
4	A4	48	12
5	A5	57	16

3.1.2 COMPRESSIVE STRENGTH TEST

The compressive strength of geopolymer concrete as well as concrete with e-waste at 7days and 28days are given in table-2.6. It can be clearly seen that the strength of the concrete will increase up to 24.34 % when 8% aggregate is replaced by e-waste after 28 days. But when we further increase the percentage of e-waste the strength of concrete starts decreasing

Table-2.6 Result of compressive strength with varying dose of e-waste.

S.No	Cube Designation	Compressive Strength (N/mm^2)		%age of E-waste
		7 days	28 days	
1	A1	25.00	38.00	0
2	A2	30.22	44.75	4
3	A3	31.71	47.25	8
4	A4	25.25	38.50	12
5	A5	22.40	34.45	16

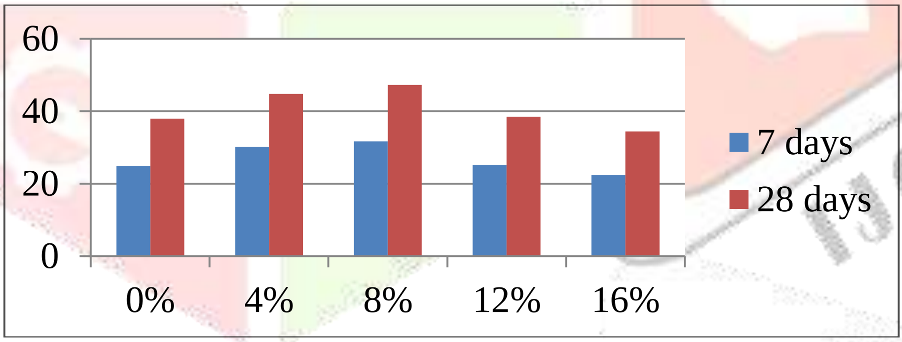

Fig. 1 Compressive strength of concrete with varying dose of e-waste (bar chart).

CONCLUSION:

1. The strength of concrete is increased by 24.34% at the inclusion of 8% of e-waste.

2. The study concludes that the electronic waste can replace coarse aggregate up to 12% because there is almost same value of strength at 0%.

3. . It increase the workability of concrete.

4. Makes the concrete light weight and thus the weight of structure is reduced.

5. Makes the concrete more flexible hence can easily bear the seismic loads.

6. It reduces the stress on the natural resources.

7 . It provides an effective way to disposal the e-waste.

8. Saves the land which is used to dispose the e-waste.

9. It reduces the risk due to the harmful materials of e-waste.

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