FEASIBILITY STUDY ON THE USE OF PRINTED CIRCUIT BOARD IN GEOPOLYMER CONCRETE

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Abstract - **The integrated waste management approach is to be considered involving efficient use of plastic materials, recycling and disposal mechanisms. Printed circuit boards is the base of electronic industry and is an indispensible part of nearly all the electronic products available in the market.The thermo metal portions of PCBs consists of thermo set resins and reinforcing materials. They also can be reused as fillers in composite materials. PCBs are considered to be having large amount of silica. Therefore,on the basis of the current scenario, all materials in waste PCBs are a kind of resources are needed to be recycled by a proper technology. The engineering properties of geopolymer concrete so as it can be used as a green alternative to conventional cement concrete. The partial replacement of fine aggregates with printed circuit boards, so that E waste can be used in construction as it cannot be disposed off. The experimental work involves conducting the test on fly ash and ground granulated blast furnace slag based geopolymer concrete by partial replacement of fine aggregate with printed circuit boards.**

Keywords: Fine Aggregate, Fly Ash, Printed circuit board, aggregate, sand.

1. INTRODUCTION

1.1. GENERAL

As we are moving towards globalization the demand for concrete is increasing day by day due to construction activities, so the demand for Portland cement is increasingly rapidly. It is estimated that the production of cement will increase from about from 1.5 billion tons in 1995 to 2.2 billion tons in 2010 (Malhotra, 2002). The global warming is caused by the emission of greenhouse gases, such as carbon dioxide (CO2), to the atmosphere by human activities. CO2 contributes about 65% of global warming (McCaffery, 2002).Due to cement industry the percentage of carbon emission in atmosphere is increasing day by day. The harmful carbon dioxide emissions estimated to be responsible for 5 to 7% of the total global production of carbon dioxide.

There is a growth in infrastructures due to globalization in India, China. So there is a need to control this emission of CO2 by substituting a greener alternative, which may reduce the greenhouse gas effect. Whereas on the other hand in recent decades, the use of electronic and electrical devices has increased significantly, this leads to increasing amounts of waste electrical and electronic equipment (WEEE), often also called e-waste. E- waste describes loosely discarded, surplus, obsolete, broken, electrical or electronic devices. Rapid technology change, low initial costs have resulted in a fast growing surplus of electronic waste around the globe. Several tones of E-waste need to be disposed per year.

2. MATREIALS AND METHODOLOGY

2.1 GENERAL

The materials used in the manufacture of Geopolymer concrete with printed circuit boards are described in this chapter. The physical properties of flyash, GGBS, fine aggregate (river sand),coarse aggregate (20mm) and printed circuit boards are reported. The chemical composition of alkaline activators is also presented.

2.2 SELECTION OF MATERIALS

The materials are chosen based on the specifications of Indian standards. The materials used in the Geopolymer concrete are listed below

- Flyash
- Ground Granulated Blast furnace Slag (GGBS)
- Fine aggregates
- Coarse aggregates
- Printed circuit boards
- Alkaline activators (NaOH flakes, Na_2SiO_3)

2.2.1 FLYASH

Flyash is a by-product of the combination of pulverized coal in thermal power plants, it is a fine grained, powdery and glassy particulate material that is collected from the exhaust gases by electrostatic precipitators or bag filters.

When pulverised coal is burnt to generate heat,the residue contain 80 % flyash and 20% bottom ash.the size of particles is largely dependent on the type of dust collection equipment. diameter of flyash particles ranges from less than 1microns to 150 microns. It is generally finer than Portland cement.their surface area is typically 300 to 500 although some flyashes can have surface areas as low as 200 and as high as 700. However the effect of increase in specific surface area beyond 600 is reported to be insignificant.

FIGURE 2.1 FLYASH

TABLE 2.1 CHEMICAL PROPERTIES OF FLYASH

CHEMICAL COMPOSITIONS	PERCENTAGE BY WEIGHT
SiO_2	50.98
Al_2O_3	7.54
SO_3	12.88
Mg	4.02
CaO	22.82
Fe	0.69
Fe_2S	0.51
K_2O	0.56

2.2.2 GGBS

GGBS (Ground Granulated Blast furnace slag) is a by-product of iron and steel-manufacturing. It obtained by quenching molten iron from a blast furnace in water or steam, to produce a glassy , granular product that is then dried and ground into a fine powder. GGBS is used to make durable concrete structures in combination with ordinary Portland cement or other pozzolanic materials. The addition of GGBS increases durability of concrete.

FIGURE 2.2 GGBS

2.2.2 FINE AGGREGATE

Natural river sand is used as fine aggregate. The gradation of sand is determined and presented in the fig.

FIGURE 2.2 RIVER SAND

2.2.4 COARSE AGGREGATE

Coarse aggregates shall comply with the requirements of IS 383. It is better to use crushed / semi-crushed aggregates. Crushed stones of size 20mm can be used as coarse aggregate.

FIGURE 2.4 COARSE AGGREGATE

2.2.5 ALKALINE ACTIVATOR

The combination of sodium hydroxide and sodium silicate or potassium hydroxide and potassium silicate solution is used as the alkaline activator. In this project the combination of sodium hydroxide and sodium silicate is preferred due to economical purpose. Generally alkaline liquids are prepared by mixing of the sodium hydroxide solution and sodium silicate at the room temperature.

3.3.5.1 SODIUM HYDROXIDE

Generally the sodium hydroxides are available in solid state by means of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. Since the Geopolymer concrete is homogenous material, the commercial grade of the sodium hydroxide of purity 98% is used.

The sodium hydroxide pellets are dissolved in distilled water based on the corresponding morality. The heat is generated when the pellets are dissolved with water. In order to prepare the sodium hydroxide solution the molarity should be multiplied with molecular ratio.For instance, NaOH solution with a concentration of 6 Molar consists of 6 x 40 = 240 grams of NaOH solids per liter of the water.

FIGURE 2.5 NAOH FLAKES

2.2.6 PRINTED CIRCUIT BOARD

Printed circuit board sources in the form of roughly discarded, spare, outdated, broken, electrical or electronic devices have been collected which were crushed and ground to the particle size.

FIGURE 2.7 PRINTED CIRCUIT BOARD

4. MIX DESIGN

4.1 MIX PROPORTION

This chapter defines the mix design for Geopolymer concrete with printed circuit board. Hardjito and Rangan have noted that unlike conventional cement concretes GPCs are a new class of construction materials and therefore no standard mix design approaches are yet available for GPC. To identify the best mix or optimum mix for Geopolymer concrete with printed circuit board ,the trial and error method is followed by varying the percentage ratio between the fine aggregate and printed circuit boards. The fine aggregate is replaced by printed circuit boards in the percentage of 0,15,30,40,50.

4.2 DESIGN PROCEDURE

Design procedure was formulated for Geopolymer Concrete which was relevant to Indian standard (IS 10262-2009). The illustrative example of mix design for a Geopolymer concrete of M30 grade is given below,

Step 1: STANDARD PARAMETERS

Size of cube = 150 mm*150 mm*150 mm Size of cylinder :
diameter = 150 mm length = 300 mm
size of prism = 500 mm * 100mm* 100mm Density of geopolymer concrete = 2400 kg/ Alkaline liquid to binder ratio = 0.4
Ratio of sodium silicate solution to sodium hydroxide pellets = 2.5
Grade = M30
Molarity = 8M

Step 2: CALCULATION OF AGGREGATES

Combined volume of aggregate = 75 % of density= (75/100)*2400 = 1800 kg/m^3
Fine aggregate = 40% of total volume of aggregate = 720 kg/m^3 Coarse aggregate = 60% of total volume of aggregate= 1080 kg/m^3

Step 3: CALCULATION OF BINDER QUANTITY

Alkaline liquid / binder = 0.4
Alkaline liquid = 0.4 * binder
Binder quantity + alkaline liquid + aggregate = 2400

Material	Weight Per m^3	Total Quantity Required
Fly ash	321.43	75
GGBS	107.14	25
Coarse aggregate	1080	250
NaOH flakes	13.85	3
Na_2SiO_3	114.284	26
Fine aggregate	360	110
Printed circuit boards	360	75

Binder quantity + alkaline liquid = 2400- aggregate = 2400 – 1800 = 600 kg/m^3

Step 4: CALCULATION OF ALKALINE QUANTITY

Alkaline liquid = 0.4 * 428.57 = 171.428 kg/m^3
We know that, Ratio of sodium silicate solution to sodium hydroxide = 2
Na_2SiO_3 = 2 NaO
In case of 8M NaOH solution , Since the molecular weight of NaOH pellets. For 8M solution = 8*40 = 320 gms.
For 1 litre of water , 320 gms of NaOH pellets to give total weight of 1320 gm of sodium hydroxide solution.
Total NaOH pellets to be dissolved = (57.142 * 0.32)/1.32 = 13.85 kg/m^3
Weight of water to be taken = (13.85*1)/0.3 = 43.28 kg/m^3.

Step 5: CALCULATION OF WEIGHT OF MATERIAL PER m^3:

Fly ash = 75 % of binder quantity
= (75/100)* 428.57
= 321.43 kg/m^3
GGBS = 25 % of binder quantity
= (25/100)*428.57
=107.1425kg/m^3
Coarse aggregate = 1080 kg/m^3 NaoH flakes = 13.85 kg/m^3 Na_2SiO_3 = 114.284 kg/m^3

FA + PCB

0% PCB + 100% SAND = 720 kg/m^3
15% PCB + 85% SAND = 108 kg/m^3 of pcb + 612 kg/m^3 of sand
30% PCB + 70% SAND = 216 kg/m^3 of pcb + 504 kg/m^3 of sand
40% PCB + 60% SAND = 288 kg/m^3 of pcb + 432 kg/m^3 of sand
50% PCB + 50% SAND = 360 kg/m^3 of pcb + 360 kg/m^3 of sand

5. EXPERIMENTAL TEST RESULTS

5.1. TESTS CONDUCTED ON FINE AGGREGATE

The following tests are conducted on fine aggregate

1. specific gravity
2. water absorption
3. Sieve analysis

1. specific gravity Result :-
The specific gravity of fine aggregate = 0.53
Water absorption of fine aggregate = 20.83 %

SIEVE SIZE	WEIGHT RETAINED (kg)
4.75 mm	0.028
3.35 mm	0.068
2.36 mm	0.021
1.18 mm	0.649
600 micron	0.189
300 micron	0.088
150 micron	0.14
pan	0.002

TABLE 3.3 SIEVE ANALYSIS RESULT FOR RIVER SAND

5.2. TESTS CONDUCTED ON COARSE AGGREGATE

The following tests are conducted on coarse aggregate

1. specific gravity
2. water absorption

Result :-
The specific gravity of fine aggregate = 0.25
Water absorption of fine aggregate = 1.85 %

5.3. TESTS CONDUCTED ON PRINTED CIRCUIT BOARDS

The following tests are conducted on printed circuit boards

1. specific gravity
2. water absorption
3. sieve analysis

SIEVE SIZE	WEIGHT RETAINED (kg)
4.75 mm	0.3
3.35 mm	0.095
2.36 mm	0.398
1.18 mm	0.16
600 micron	0.018
300 micron	0.014
150 micron	0.006
pan	0.012

TABLE 3.4 SIEVE ANALYSIS RESULT FOR PCBs

Result :-

The specific gravity of fine aggregate = 1.2 Water absorption of fine aggregate = 7.5

5.4. WATER ABSORPTION TEST:

30 % printed circuit board :

Weight of cube before immersing W_d = 9.098 kg Weight of cube after immersing W_W = 9.214 kg

% Water absorption = $(W_W - W_d)/(W_d)$ *100

=(9.214–9.098)/9.098*100

=0.0127*100

= 1.27 %

30 % printed circuit board :

Weight of cube before immersing W_d = 8.441 kg Weight of cube after immersing W_W = 8.607 kg

% Water absorption = $(W_W - W_d)/(W_d)$ *100

=(8.607–8.441)/8.441*100

=0.01967*100

= 1.967 %

DURABILITY PROPERTIES:

5.5. WATER ABSORPTION TEST :

30 % printed circuit board :

Weight of cube before immersing W_d = 9.098 kg Weight of cube after immersing W_W = 9.214 kg

% Water absorption = $(W_W - W_d)/(W_d)$ *100

=(9.214–9.098)/9.098*100

=0.0127*100

= 1.27 %

30 % printed circuit board :

Weight of cube before immersing W_d = 8.441 kg Weight of cube after immersing W_W = 8.607 kg

%Water absorption= $(W_w - W_d)/(W_d)$ *100

=(8.607–8.441)/8.441*100

= 0.01967 *100

= 1.967 %

6. Result and Discussion

6.1 Summary

Based on the test results the following conclusions were made.

1. With the Elimination of the use of Portland cement the emission of carbon dioxide has been greatly reduced which results in the reduction of environmental pollution.
2. The addition of printed circuit board shows increase in compressive strength upto 30% replacement. After 30 % the compressive strength starts to decrease.
3. The compressive strength was found to be increased by 15% with addition of PCB's than the conventional Geopolymer concrete.
4. The split tensile strength was found to be increased by 20% with addition of PCB's than the conventional Geopolymer concrete.
5. The flexural strength was found to be increased by 30% with addition of PCB's than the conventional Geopolymer concrete
6. Rate of increase of compressive strength and split tensile strength with respect to age of concrete is more significant incase of ambient curing at room temperature in comparison with heat curing at 60˚C.Heat curing resulted in enhancement of compressive strength and split tensile strength at early age only.The effect of heat curing on the increase in compressive strength and split tensile strength is not much significant after 7 days.
7. The Geopolymer concrete showed high performance with respect to strength. The geopolymer is good workable mix. High early strength was obtained in Geopolymer mix. The increase in percentage of fine aggregate and coarse aggregate increase the compressive strength upto optimum level. This may be due to high bonding between aggregate and alkaline solution. The compressive strength was found to be decrease beyond optimum mix. This may be due to increase in volume of voids.
8. The use E-waste in concrete is possible to improve its mechanical properties and can be one of the economical ways for their disposal in environmental friendly manner.
9. The specimens have been cured in ambient temperature condition rather than accelerated curing to check the suitability of Geopolymer concrete for cast in-situ conditions.

10. Geopolymer concrete has excellent properties as also be used in road works because of its very early attainment of strength.

6.2 Recommendation for Future Project

1. Used in road works because of its very early attainment of strength.
2. Used in the manufacture of precast structures because of high strength development.
3. Can be used in areas where high degree of fire resistance is needed.
4. The addition of PCB's decrease the dead weight of structures, hence it can be used in light weight structures.

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