Experimental Study on Eco-Friendly Geo-Polymer Paver Blocks: Utilizing Hazardous And Waste Materials

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Abstract- *This project work focuses about the making of Geo Polymer paver blocks by utilizing waste materials. Here cement is completely replaced with fly ash. Binding properties is achieved by using Geo polymer solution in the concrete instead of water. Geo-polymer is an inorganic alumina-silicate compound, synthesized from materials of geological origin or from by-product materials such as fly ash, GGBFS, etc., that are rich in silicon and aluminium. In this study, geo-polymerisation process was done by mixing sodium hydroxide and sodium silicate solution with certain ratio. Cigarette butts which is a hazardous material when littered causes water pollution and Coconut shell which is a agricultural solid waste are replaced in certain proportions in paver blocks in order to utilize the waste materials effectively. Paver blocks of size 300x150x60mm were tested with different proportions. A comparative study is done between conventional cement concrete paver blocks and geo-polymer paver blocks. Compression, flexural, split tensile and acid tests were conducted on these paver blocks and oven curing is done. The aim of this project was to make economical and eco-friendly paver blocks.*

Keywords- Alkaline solution, Cigarette butts, Coconut shell, Fly ash, Geopolymer.

I. INTRODUCTION

Concrete is the most widely used building material. Production of one tonne of cement requires about 2 tonnes of raw materials of shale and limestone, and also releases large amount of carbon dioxide (CO2) to the atmosphere that significantly contributes to Greenhouse gas emissions. The OPC production is globally contributes about 7% of the world's Carbon dioxide emission. This is adding about 1.6 billion tonnes of Carbon dioxide to the atmosphere. The reaction of a solid alumino-silicate with a highly concentrated aqueous alkali hydroxide or silicate solution produces a synthetic alkali alumina silicate material generically called a 'Geopolymer'.

Geo-polymer:

The implementation of Geopolymer technology could reduce the CO_2 emission to the atmosphere caused by cement. Geopolymer can exhibit wide variety of properties and characteristics, including high compressive strength, fast or slow setting, acid resistance. The utilization of waste materials is to be done in this environment for maintaining the ecological balance and to maintain a healthy environment. The wastes like cigarette butts and coconut shell are used in the replacement of coarse aggregate and mainly for the usage of waste materials in an effective manner.

II. OBJECTIVE

Objective of the project is to make a cost efficient and eco-friendly paver blocks using hazardous and waste materials – cigarette butts, coconut shell and fly ash.

III. MATERIAL PROPERTIES

A. Cement

Cement is used for construction as a binder material . For this study, Ordinary Portland cement of 53 grade was used for preparation of conventional paver block.

Table I: Properties of Cement

S.NO	DESCRIPTION	RESULT
1	Fineness of Cement	8%
2	Standard Consistency	32%
3	Specific gravity	3.15
4	Initial setting time	30 mins
5	Final setting time	10 hrs

B. Fly ash

Fly ash is an abundant material on the Earth. Cementitious properties are exhibited when fly ash is combined with calcium hydroxide. Fly ash is the by-product which is obtained from the coal-fired power plants. The classes of fly ash are of two types - Class F and Class C. Class F fly ash is used.

Table II: Physical properties of fly ash

Chemical Components	**Requirements as per IS:3812 in %**
$SiO_2 + Al_2O_3 + FeO_3$	70.0 Min.
SiO_2	35.0 Min.
Al_2O_3	Not specified
FeO_3	Not specified
CaO	Not specified
SO_3	3.0 Max.
Total alkali as Na_2O	1.5 Max.
LOI (Loss in Ignition)	5.0 Max.
Cl	0.05 Max.
MgO	5.0 Max.

Chemical properties of fly ash

Specific gravity of Fly ash = 2.34

C. Fine aggregate

M-Sand is used as the fine aggregate. The property of M-Sand was found to be similar when compared with natural sand.

Table III: Physical properties of Fine aggregate

Properties	**Value**
Specific Gravity	2.65 g/cc
Fineness Modulus	2.70

D. Coarse aggregate

Crushed stone - Crushed stone was used as the coarse aggregate. The properties of crushed stone are as follows.

Table IV: Properties of Crushed Stone

PARTICULARS	**TEST VALUES**
Specific gravity	2.72
Water absorption	0.5%
Fineness modulus	6.7

Coconut shell - Coconut shell (CS), is a form of agricultural solid waste. It is one of the most promising agro wastes with its possible uses as coarse aggregate in the production of concrete. Statistical data of coconut production shows that, India is producing nearly 27% of total world production and the annual production of coconut is reported to be more than 12 million tons. Crushed Coconut shell is used as the coarse aggregate. The aggregates passing through 12.5mm sieve and retained in 10mm sieve was used in this investigation.

Cigarette butts - Cigarette Butts (CBs) of different brands and sizes were collected from dry receptacles. The CBs were disinfected at 105 ºC for 24 hours and then stored in sealed plastic bags. Cigarette butt takes 18 months to 10 years to degrade itself.

E. Sodium hydroxide

Generally the Sodium Hydroxide is available in solid state by means of pellets and flakes. Flake form was used in the project. According to the purity of the Sodium Hydroxide the cost varies. Since our Geo-polymer is homogeneous material and its main process is to activate the Sodium Silicate, it is recommended to use around 94% to 98% purity.

Table V: Properties of Sodium Hydroxide

Flakes size	**Specific gravity**	**Purity**
3mm	2.13	98%

F. Sodium silicate

The Sodium Silicate which is available in gel form was obtained. They are stable in alkaline and neutral solutions.

Table VI: Properties of Sodium Silicate

Composition	**% by mass**
Na_2O	7.5 – 8.5
SiO_2	25 – 28
Water	65.3 – 37.5
Specific gravity	1.53
pH	Neutral

IV. MIX DESIGN

PREPARATION OF GEOPOLYMER CONCRETE:

A. Alkaline solution

Sodium Hydroxide flakes are taken and dissolved in water at the rate of 8 molar concentrations. It is strongly recommended that the Sodium Hydroxide solution and Sodium Silicate gel must be mixed and prepared 24 hours prior to use and also if it exceeds 36 hours it terminate to semi solid liquid state. And hence the prepared solution should be used within the specified time.

B.Molarity calculation

Sodium hydroxide flakes are dissolved in water to make a solution with the required concentration. The concentration of Sodium Hydroxide solution varies in different molar. The mass of NaOH solids in a solution varies according to the concentration of the solution.

For instance, NaOH solution with a concentration of 8 molar consists of 8 x 40 = 320grams of NaOH solids per litre of water, were 40 is the molecular weight of NaOH. Water is the major component for preparing alkaline solutions. The mass of NaOH solids was measured as 262grams per Kg of NaOH solution with concentration of 8 molar.

C. Mix proportion

The size of the mould: 300x150x60 mm
Therefore,
Volume of the mould = 0.3x0.15x0.06 = $2.7x10^{-3}$ m^3
For M20 grade concrete the mix ratio is **1: 1.5: 3**

D. Casting and curing of samples

The experimental investigation was carried out on the specimen to study the strength-related properties of Geopolymer concrete. The specimen size is 300mm x 150mm x 60mm respectively. The oven curing is done at 60ºC for 24 hours. Minimum three specimens were casted for each mix.

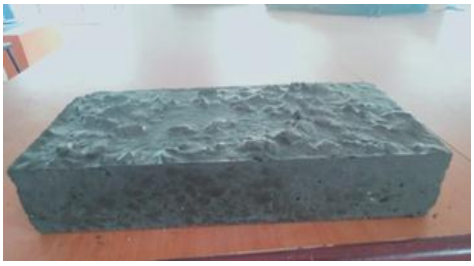

Figure 1: Paver block specimen

V. EXPERIMENTAL DETAILS

TEST ON CONCRETE

A. Workability

The property of fresh concrete is indicated by the amount of internal work required to compact the concrete without bleeding or segregation.

Depending upon the water cement ratio in the concrete mix, the workability may be determined by the following two methods.

1. Slump Test

2. Compaction Factor Test

MECHANICAL PROPERTIES

Tests on hardened concrete

To evaluate the strength properties for different mixes used in this project, the following tests were performed.

- Compressive strength
- Split tensile strength
- Flexural strength test

A. Compressive strength test

The specimens removed from mould after 24 hours, remoulded carefully and were kept in ambient conditions. The surface of the testing machine was to be cleaned before testing of the specimen. The specimen was placed in 1800 KN capacity compression testing machine in such a manner that the load could be applied compression testing the cube. The specimen was aligned centrally on the machine. The ultimate load at which the specimen failed was recorded.

Test specimen : Paver block

Size of specimen : 300mm x 150mm x 60mm

Formula

Compressive strength = Load / Area N/mm^2
= P / A

Figure 2: Compression strength test

B. Split Tensile strength

The Split Tensile strength is one of the important and basic properties of the concrete. The concrete is not usually resist the direct tension because of its low tensile strength and brittle nature. The test was conducted as per IS: 15658: 2006 codal provisions. The specimen was laid horizontally in the compression testing machine. The load was applied at a uniform rate until the sample fails. The load was noted at a failure. The formula for Split Tensile strength was calculated as follows,

Split Tensile strength, T = 0.637 x k x (P/S) N/mm^2

Where,

P – Failure load N

S – Area of the failure in mm^2

C. Flexural strength

Flexural strength, also known as fracture strength or modulus of rupture. It is a mechanical parameter for brittle material and is defined as a material's ability to resist deformation under load.

The test was conducted as per IS: 15658: 2006 codal provisions. The Flexural strength was measured as Modulus of Rupture. The specimen should be placed in the machine in such a manner that the two point loading should be applied in the uppermost surface as cast in the mould. The test specimen was cured for 28 days and tested for maximum load. The formula for Flexural strength was calculated as follows

Flexural strength F_b = 3Pl / 2bd^2 in N/mm^2

Where,

F_b – flexural strength, in N/mm^2

P – Maximum load, in N

l – distance between central lines of supporting rollers, in mm

b – average width of block, measured from both faces of the specimen, in mm

d – average thickness, measured from both ends of the fracture line, in mm

DURABILITY PROPERTIES

Acid attack on Geopolymer concrete

The Acid attack was carried out on the concrete cubes of size 300mm x 150mm x 60mm. The paver blocks were dried in normal room temperature of 27º C ± 2º C after 28 days of curing, the specimens were taken out and allowed to dry for one day, and the weight (W_1) of cubes was noted. The Sulphuric acid solution was prepared by adding 5.0% Hydrochloric acid of 1 N (by volume of water) to 20 litres of distilled water. The paver blocks were then immersed in the acid solution.

After taking out from immersion and drying, the surfaces of the paver blocks were cleaned and they were kept in room temperature for a period of 24 hours, the weight (W_2) of concrete cubes was noted. The Compressive strength and loss of weight were calculated by using the formulae,

Formula

Compressive strength = Load / Area N/mm^2

= P / A

where,

P is Ultimate load (load of failure) in Newton

A is Area of cube in mm^2.

Loss of weight = (W_1 – W_2) / W_1

where,

W_1 is Initial weight of the concrete specimen

W_2 is Final weight of the concrete specimen

VI. RESULT AND DISCUSSION

DENSITY TEST AT AN AGE OF 28 DAYS

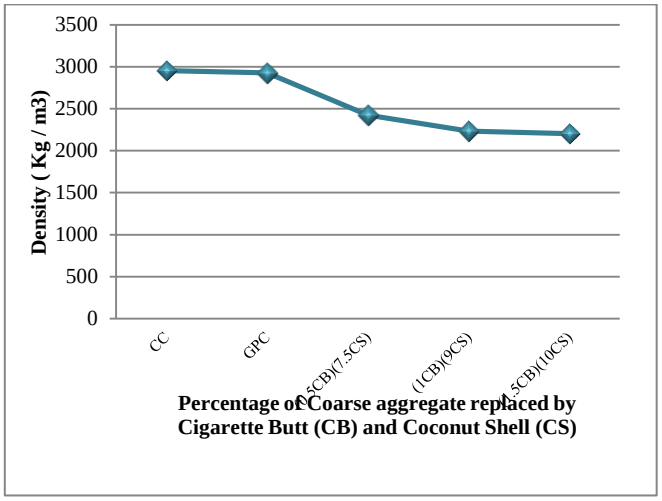

Figure 3: Density of Conventional paver block and Geopolymer paver block

From the Figure 3, it is observed that the variation of density is in decreasing order for higher mix ratios. It is also observed that the density of Conventional paver block is nearer to the Geopolymer paver block.

MECHANICAL PROPERTIES

A. Compressive Strength at an age of 28 days

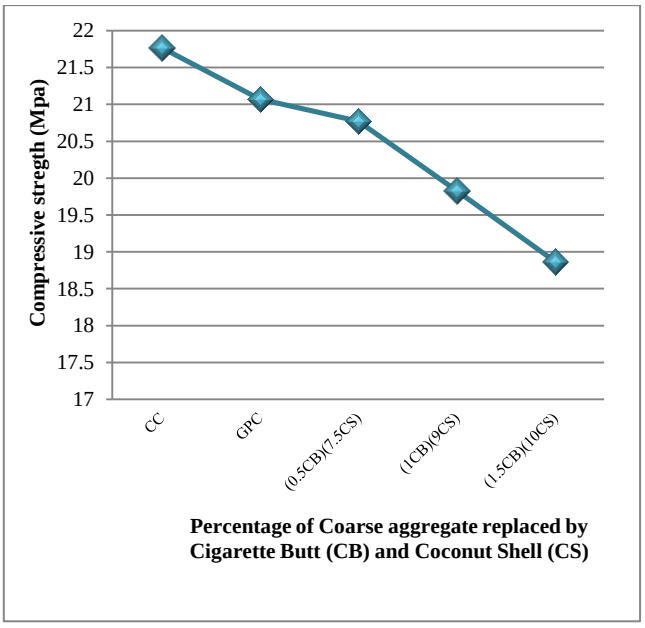

Figure 4: Compressive strength of Conventional paver block and Geopolymer paver block

From the Figure 4, it is observed that the variation of compressive strength is in decreasing order for higher mix ratios. It is also observed that the compressive strength of Conventional paver block is nearer to the Geopolymer paver block.

B. Split Tensile Strength at an age of 28 days

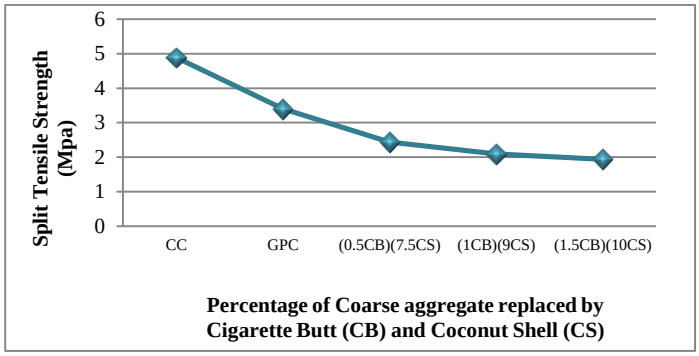

Figure 5: Split Tensile Strength of Conventional paver block and Geopolymer paver block

From the Figure 5, it is observed that the variation of Split Tensile Strength is in decreasing order for higher mix ratios. It is also observed that the split tensile strength of Conventional paver block is nearer to the Geopolymer paver block.

C. Flexural strength at an age of 28 days

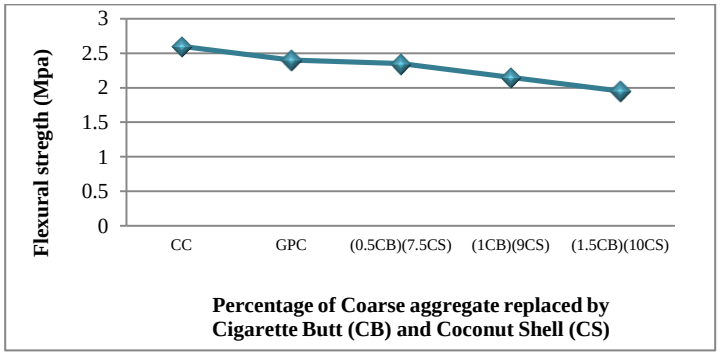

Figure 6: Flexural strength of Conventional paver block and Geopolymer paver block

From the Figure 6, it is observed that the variation of Flexural strength is in decreasing order for higher mix ratios. It is also observed that the flexural strength of Conventional paver block is nearer to the Geopolymer paver block.

DURABILITY PROPERTIES

Acid test

After casting and curing, specimens were immersed in acid solutions. The concentration of hydrochloric acid is 5%. The evaluation is conducted after 28 days from the date of immersion. Solutions are kept at room temperature. The weight of the specimen before and after immersion in acid and the compressive strength of the specimens immersed in HCl

are also noted. The comparison of compressive strength of specimens with conventional M20 grade of concrete is done.

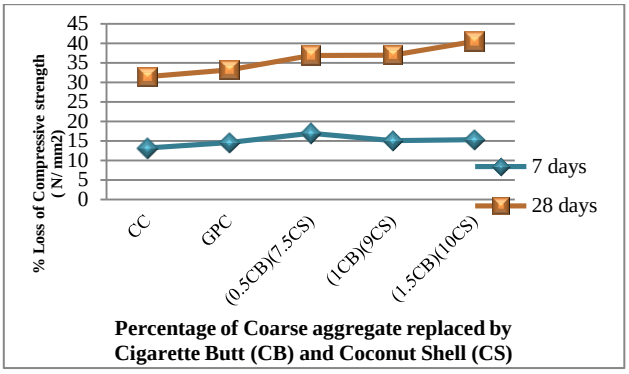

Figure 7: Percentage loss of compressive strength after acid immersion

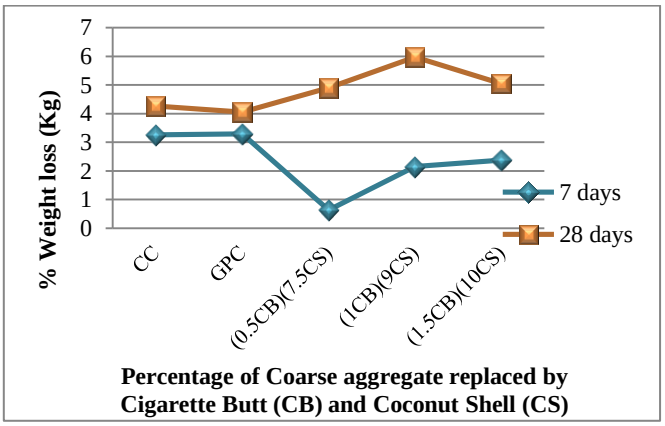

Figure 8: Percentage weight loss

The weight and the compressive strength of the paver blocks are decreased to a smaller extent when immersed in acid solution.

VII. CONCLUSION

The Fly Ash based Geopolymer concrete was found to be more economical and environment friendly. The Geopolymer concrete reduces the emission of Greenhouse gases like CO_2 up to 80% in the atmosphere.

- Use of coconut shells as aggregate in a certain ratio results in lightweight concrete.
- Use of Cigarette Butts in the concrete serves as an environmental hygiene.
- Cost of Geopolymer paver blocks is found to be 3 times lower than the Conventional concrete paver blocks.
- The Geopolymer concrete achieved rapid strength gain in 7 days and thus it is an option for rapid construction.
- It has a very strong chemical resistance. Hence, corrosion is not likely to occur with this concrete.
- Oven curing is done to get an optimized compressive strength.
- Geopolymer concrete offers environmental protection by means of up cycling low-calcium fly ash and blast furnace slag, waste/by-products from the industries, into a high value construction material needed for infrastructure developments.
- The optimum percentage of the CB is 1% and CS is 9% (only as per the testing result).

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