Development of Self Curing Geopolymer Concrete Incorporating Expanded Polystyrene, Recycled Coarse Aggregate and Rubber Crumbs

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Abstract - Sustainable building production includes the effective usage of natural materials by the processing of waste materials. The present work aims to use different waste materials, such as fly ash, industrial waste pond ash, rubber crumbs from rubber tires, recycled coarse aggregate from building waste. In doing so, the goal of reducing building costs will be achieved and can help to solve the issues connected with its disposal, particularly the environmental concerns of the area. Throughout this project, Rubber Crumbs (RC) and Recycled Coarse Aggregate (RCA) were partly substituted instead of coarse aggregate with a percentage of 10, 15, 20, and 5, 10, 15, which were found to improve the flexural strength of concrete. Such products may also be used for renewable building purposes.

Keywords: Geopolymer, fly ash, GGBS, Pond ash, Recycled Coarse aggregate, Rubber Crumbs, Expanded Polystyrene

I. INTRODUCTION

Concrete is a construction substance composed of a fine and coarse aggregate, confined to a fluid material that solidifies after some period. Concrete production is not environmentally sustainable and thus alternate, environmentally safe products are defined for use in concrete. Extensive work has been carried out across the globe to find an effective binder to partly or fully substitute for cement. The challenge or issue is that cement is an active hydraulic a system that can react directly with water to create hydration products. To express these binders, Davidovits formulated the term 'Geopolymer.' The issue of waste management is growing severe. There is a lot of toxic waste whose capacity has not been recognized and is being lost in vain. We ought to figure out their ability and utilize them without dumping. Waste products developed by manufacturers in different ways, such as fly ash, pond ash, etc., may be used as resource-saving concrete structures and can also help to address the issue of waste disposal. Owing to its non-biodegradable nature, the waste tires contained have been a point of concern for various solid wastes. The use of scrap rubber in the preparation of concrete was considered to be alternative disposal of such waste to protect the environment. Building and demolition waste contributes up to 40% of all waste produced worldwide. The recycled aggregate is used as the most fitting substitute for the normal, coarse aggregate.

Geopolymer concrete utilizes amorphous glassy alumina silicate mineral compounds enabled by alkali actuators to create long-chain sialates through polymerization to shape a binder to eliminates the motion of cement. The benefit of this form of concrete is that no water is needed for curing and cures at ambient or elevated temperatures. In all realistic uses, the geopolymer concrete may be used. The process is conducted at room temperature by incorporating mixtures. The replacement of rubber crumbs up to 5 percent contributes a reasonable compression strength, underlined by **Z Yahya et.al (2018).** As the proportion of rubber crumbs rises, their strength appears to decrease. Weight gain in marine exposure for all geopolymer samples. The higher rubber crumb content increases the geopolymer porosity and results in an increase in sample weight and decreases the strength. The impact of recycled coarse aggregates decreases the slump value by rising the amount of the RCA, **Saravanakumar (2018)** has concluded. The recycled coarse aggregate of the geopolymer showed greater strength than the standard recycled coarse aggregate. RCA substitution provides reasonable strength in comparison to geopolymer concrete up to 20 percent. **R. Vandhiyan et.al (2016)** investigated how an increase in concrete mixed EPS bead levels reduces the strength of the concrete compressive, flexural, and tensile. All EPS concrete without any special bonding agent has good workability and can be easily compacted and finished. The EPS efficiency level is 10%. With an increase in the percentage of EPS beads, concrete density was decreased. It also suggested that expanded polystyrene concrete has potential for non-structural uses, such as wall panels, partition walls, etc**. Dr. R. N. Krishna (2014)** claimed that geopolymer concrete has a slump value greater than Portland cement concrete. Extended polystyrene and glass fiber application reduces concrete workability. Increased sodium hydroxide concentration leads to increased compressive strength when exposed to the ambient treatment. In contrast with ordinary Portland cement, the flexural strength of geopolymer concrete with glass-fiber and polystyrene treated was improved. The temperature in the geopolymer mass formed is constant **(S. Vaidya et.al (2011))**. For an improvement of the durability, the compressive strength of the geopolymer concrete improved. The findings of the cylinder check demonstrate that during the mixing of additives the fresh geopolymer blend undergoes an exothermic reaction. The elastic modulus and the Poisson's ratio were considered to be appropriate.

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II. MATERIALS USED

A. Fly Ash:

In thermal plants, the fly ash is the product of the burning of pummeled fuel. Kinds of fly ash are Class F and C. Ash that tumbles at the bottom of the firebox of the evaporator is referred to as the bottom cup. The primary cause of the fly ash is electrostatic precipitators or some other molecular filters in present coal-fired power plants before the flue gases enter the fuel cells.

Table I Properties of Fly ash

S.no	Properties	Values
1.	Specific gravity	2.16
2.	Consistency	29%

B. Ground Granulated Blast Furnace Slag

The structure of slag is remarkably different depending on how the crude materials are produced during the iron production process. Silicate and aluminum contaminants are combined with a change in the shoot heater, which reduces the consistency of the slag. The movement includes the majority of a mix of calcareous and forsterite or dolomite now and then, because of the creation of pig iron. The slag skims on the iron in the effect radiator and is expanded for the section. Slow cooling of slag condenses results in the development of a variety of Ca-Al-Mg silicates into an inert crystalline material. The slackening breaking should be immediately cooled or stifled at 800 ° C to avoid the crystallization of merwinite and melilite to obtain a no bad slackening reactivity or hydraulicity.

Table II Properties of GGBS

CHARACTERISTICS	TEST RESULT
Fineness (M / Kg)	390
Specific Gravity	2.85
Particle Size (Cumulative %)	97.10
Insoluble Residue (%)	0.49
Magnesia. Content (%)	7.73
Sulphide Sulphur (%)	0.50
Sulphite Content (%)	0.38
Loss on Ignition (%)	0.26
Manganese Content (%)	0.12
Chloride content (%)	0.009
Glass Content (%)	91
Moisture Content (%)	0.10
Chemical Moduli	
$CaO + MgO + SiO_2$	76.03
$(CaO + MgO) / SiO_2$	1.30
CaO / SiO_2	1.07

C. Aggregate:

The fine aggregate of 4.75 mm with a specific gravity of 2.65 and a local crushed coarse aggregate maximum size of 20 mm with a specific gravity of 2.7 has been used.

Table III Properties of Fine Aggregate

S.no	Properties	Values
1.	Specific gravity	2.37
2.	Fineness modulus	2.9

Table IV Properties of Coarse Aggregate

S.no	Properties	Values
1.	Specific gravity	2.71
2.	Fineness modulus	5.29
3.	Bulk density	1568 kg/m^3 (Compacted) 1312 kg/m^3 (Loose)
4.	Impact factor	22.08%
5.	Crushing value	34.67%
6.	Water absorption	4.47%

D. Alkaline Solution:

A solution was chosen for a mixture of sodium hydroxide and sodium silicate. Sodium hydroxide and sodium silicate in pieces or pellets form are available monetarily. In the current investigation, the preparation of soluble arrangements for a 12 M centralization was rendered utilizing sodium pellets for 98% virtue.

E. Pond Ash

Pond ash is a built-in structure for removing two types of coal ignition items from fossil fuel power plants: bottom ash and fly ash. The combination of this is pond ash. The pond also called an impoundment for the surface, uses gravity to remove large particles from wastewater from the power station (estimated to be suspended solids).

Table V Properties of Pond ash

S.no	Properties	Values
1.	Specific gravity	2.16

F. Recycled Coarse Aggregate

Up to 40 percent of all waste generated comes from construction and demolition waste. Recycled waste may be used to substitute a fine and coarse aggregate. This can lead to 60 percent less in weight and 50 percent less mineral depletion.

Table VI Properties of Recycled Coarse aggregate

S.no	Properties	Values
1.	Specific gravity	2.37
2.	Fineness modulus	7.1 kg/m^3
3.	Impact factor	23.39%

G. Rubber Crumbs:

Rubber crumb is the name given for the reduction in uniform grain forms of scrap or other rubber.

The utilization or advantage of crumb rubber is pressure engrossing layers that lessen the intelligent splitting as a result of its flexible properties. Crumb is made up of various elastic mixtures, a wide range of types of dark carbon, fillers, like silica and mud. Synthetic mixtures and minerals added to allow or accelerate vulcanization. Elastic produced from scrap car and truck tires is reused from the rubber crumb. The steel and tire ropes are expelled during the reprocessing procedure and transformed into the granulate forms.

Table VII Properties of Rubber crumbs

S.no	Properties	Values
1.	Specific gravity	1.28
2.	Fineness modulus	4.2
3.	Bulk Density	688 kg/m^3 (Compacted) 539 kg/m^3 (Loose)

H. Expanded Polystyrene Beads

Polystyrene (PS) is a material made from monomer styrene of pleasant fragrance. Polystyrene used as an operator of a self-relieving operator. For each unit weight, it is a reasonable gum. Polystyrene is one of the most commonly used plastics, with an annual production size of a matter of a few million tons. Polystyrene can normally be simple but can be hued with dyes. It is used as a warm hydro separator and enclosure.

Table VIII Properties of Expanded Polystyrene

S.no	Properties	Values
1.	Specific gravity	0.011
2.	Fineness modulus	6.86 kg/m^3

III. MIX DESIGN

There is no mix design standard code as such for geopolymer concrete. But due to tireless efforts of various researchers we have several guidelines for mix design using empirical methods. Various guidelines were referred like **Dr.V. Sreevidya et.al (2011), Subhash V. Patankar et.al (2015),** and arrived at the Mix design for 1 m^3 concrete.

Table IX Mix design

Binder	Fine aggregate	Coarse aggregate
425 kg	630 kg	1249 kg
1	1.48	2.95

Table X Mix proportion

Materials	CGPC (%)	SCGPC 1 (%)	SCGPC 2 (%)	SCGPC 3 (%)
Fly Ash	50	50	50	50
GGBS	50	50	50	50
M – Sand	100	75	75	75
Pond Ash	0	25	25	25
Coarse Aggregate	0	85	75	65
Rubber Crumbs	0	5	10	15
Recycled Coarse Aggregate	0	10	15	20
Expanded Polystyrene	0	0.2	0.2	0.2

A. Mixing of Geopolymer concrete

Natural mix of the fly ash, fine aggregates, and coarse aggregates everything into a container, the soluble solution was then used to make up the geopolymer concrete. The concrete of Geopolymers was soft, with a shiny feel.

B. Test Specimen:

In order to determine the compressive strength at 7 days and 28 days, the trial system included measuring 16 cubes to size 150 mm. 16 Cylinders in scale 150 x 300 mm became mounts to evaluate the tensile strength divider at 7 days and 28 days and three 100x100x500 mm prisms in dimension, at flexural strength tests at 28 days.

C. Curing

Internal cure relates to the way that concrete hydration happens owing to the absorption of extra water within the mixing atmosphere. The technique applies to the process. Usually, solid procedures are relieved for conditions that ensure water is not lost from the surface, i.e. the restoration is carried out 'from the outside to the inside.' Interestingly, "Internal curing" considers the relieving of the internal supplies (as soaked lightweight fine total, superabsorbent polymers, or wood filaments) made from the "inner to outer" element. 'Inner healing' is often referred to as 'self-curing.' '

IV. RESULTS AND DISCUSSION

A. Compressive Strength

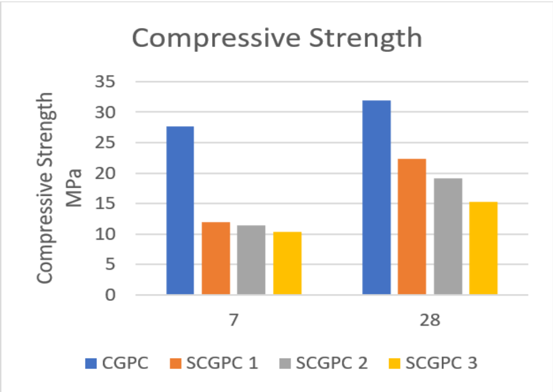

Fig-1 Compressive strength

In a compressive testing device, the cube specimens were tested and the compressive strength of the concrete was observed to decrease as the proportion of rubber crumb and RCA was raised. We should then accept at least 5% of rubber crumbs and 10% of RCA used as a combined substitution.

B. Split Tensile Strength

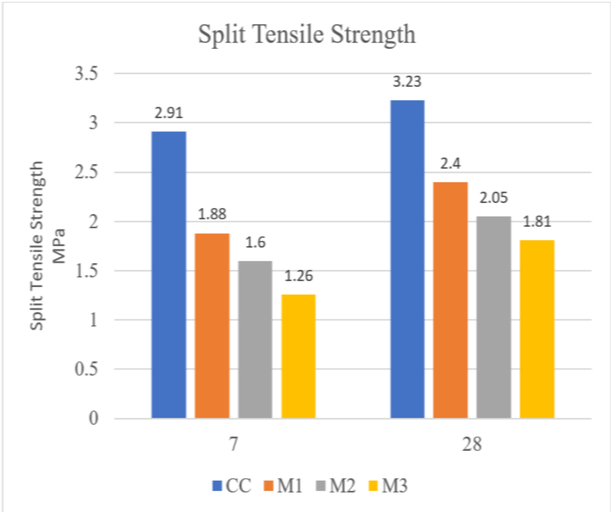

Fig-2 Split Tensile strength

In the compressive testing machine, the cylinder specimens were examined. The load is measured at the cylinder periphery and the split tensile strength has been observed. The quality is often decreased as opposed to the standard geopolymer concrete alluded to by different authors, the rise in the amount of Rubber crumbs and RCA decreases the strength of the concrete.

C. Flexural Strength

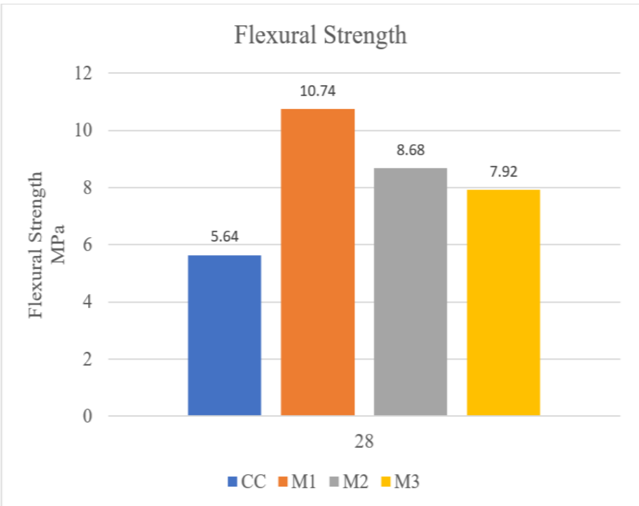

Fig-3 Flexural strength

Prisms were tested for flexural strength and the bending intensity for the SCGPC-1 combination was found to be substantially improved. The standard mix for grade M30 was made. The above tests minimize the compressive strength and split tensile strength of the concrete but display a significant improvement in flexural strength than the traditional mix.

D. Sem Analysis:

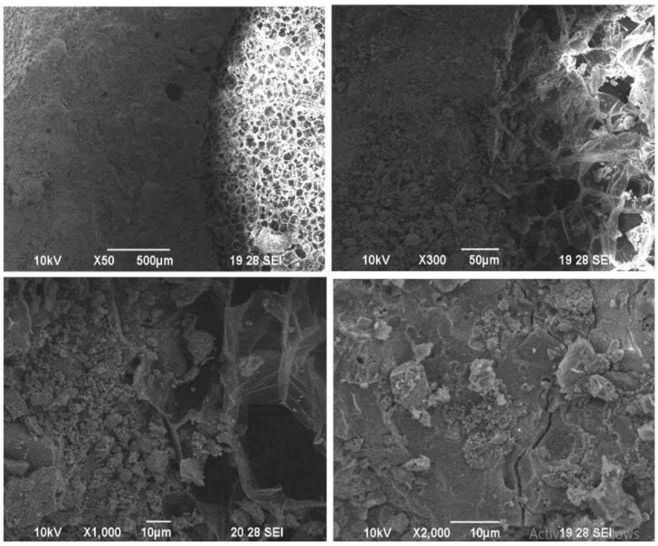

Fig-4 Sem Analysis

The light patches display less thick, mostly eps areas and the particles surrounding them are well-hydrated and well linked, demonstrating their self-curing existence. The irregular concrete structure shows not very good compactness. Besides, the CSH particle form does not exist and therefore the formed product can be entirely different than CSH combinations. The area to the right is largely void, and the materials are poorly filled and measured. Rubber crumbs may have inhabited this region. The surface has already been created with cracking and traction forces. During crushing this concrete was not broken.

V. CONCLUSION

The conclusion obtained from the above figures (Fig1, Fig-2, Fig-3) can be inferred that the optimal proportion of waste content used is a mixture of SCGPC 1 (Rubber crumbs 5 percent, RCA 10 percent). The higher rubber crumbs and RCA naturally decrease the concrete 's strength parameter. While the strength of the cement is diminished by the compressive and the broken tensile power, its flexural strength is greater than the average geopolymer concrete, which is why we can use it for producing wall panels. The concrete is self-curing with the use of expanded polystyrene. The workability of the concrete is identical to the nominal concrete.

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