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Study on Behaviour of Concrete by Partial Replacement of Cement and Coarse Aggregate by GGBS, Coir Fibers, and Recycled Plastic Waste

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Abstract - *The production of waste is increasing day by day, even the suitable steps were taken to reduce its consumption. The production of solid waste causes serious concerns to the Environment. Disposal of plastic waste in an environment is considered to be a big problem due to its low biodegradability. Consequently, waste plastic recycling has become one of the major challenge in recent times. As the pollution is increasing and the environmental sustainability is affected, researchers are seeking for other materials to reduce consumption of cement with the objective of reducing the CO_2 emission. GGBS is one of the supplementary material used to replace cement. As all we know, concrete is good in compression and weak in tension. The addition of Coir fiber significantly proved improving many engineering properties like toughness, flexural strength. The research of this paper is on investigating the behavior of M25 concrete by partial replacement of plastic waste aggregate in the percentage of 10,20,30,40 to the natural coarse aggregate, 0.75% and 40% of Coir fibers and GGBS to the cement. The properties of concrete are reported by experimental results at 7, 14, and 28 days.*

Key Words: coarse aggregate, recycled plastic waste, GGBS, Coir fibre, HDPE, partial replacement.

1. INTRODUCTION

Concrete is the most widely used constructional material in the world. There is a concern to more understanding and to improve its properties. As there is development of infrastructure the production of waste also significantly increases. The solid waste comprising plastic as its main part. The disposal of waste plastic is becoming a major waste management problem. As the plastic is non-biodegradable material they will remain alive in the landfill even though they get disposed, presenting a environmental hazard. This targets to promote recycling of plastic and energy recovery. One of the significant applications of this work is in the construction industry, Where has been modified as a usable material in concrete in the form of aggregates. Since plastic have low density than the natural aggregates they can be utilized to form a lightweight concrete. India approximately produces 40million tones of solid waste annually. This is increasing at a rate of 1.5 to 2% every year. Plastic constituents 12.3% of total waste produced. More over plastic is a impermeable material, water absorption proves to less providing better workability.

The largest component of plastic waste is polyethylene, followed by polypropylene, polyethylene, terephthalate and polystyrene. Utilized plastic waste category in this research project is HDPE in varying their percentage with natural coarse aggregate. As all we know concrete is strong in compression and brittle material and have less flexural capacity. As a result cracks develop in the concrete due to the tensile stresses. Reinforcing of concrete proves the concrete to withstand the tensile and flexural stresses. More over reinforcing is done by steel and cracks are eliminated by using fibers like glass, aramid etc. which proves to be more cost. Fiber named coir derived from Tamil word 'Kayiru' is a natural fiber obtained from coconut husk. Which proves to increasing strength and eliminates crack with the usage of 0.75% of cement. The concrete industry looking for supplementary cementatious material with the objective of reducing emition of CO_2 which is harmful to environment. GGBS is the industrial by product which provide excellent binding property and serve as a replacement with 40% of cement.

In this entitled project concrete cubes were casted and tested at 7, 14 and 28 days.

1.1 General

The word 'Plastic' derives from Greek word Plastikos meaning " Capable of being shaped or moulded". Plastics are typically organic polymers of high molecular mass and often contain other substances. Plastics are categorized are thermoplastics and thermostring polymers. Thermo plastics are the plastics that, when heated, do not undergo chemical change in their composition and so can be moulded again.

Thermoplastic polymers can melt and shape only once after they have soilidified, they shows solid.

1.2 Types of recycled plastics.

- Polyethylene terephthalate (PET)
- Un plasticized polyvinyl chloride (UPVC)
- Low density polyethylene (LDPE)
- High density polyethylene (HDPE)
- Polystyrene (PS)
- Polypropylene(PP)
- Polyurethanes (PU)

- Polyamides (PA)
- Polycarbonate (PC)

1.3 Objectives

- To compare the compressive, split tensile and flexural strength of concrete with conventional concrete.
- To know the application of recycled plastic waste in construction industry.
- To reduce the pressure on naturally available aggregates by waste plastic and to reduce the emission of CO_2 during the production of cement.
- To compare the physical characteristics of recycled plastic waste with natural aggregates.
- To study the properties of fresh and hardened concrete by replacement materials.
- To produce lightweight polymer concrete.

2. EXPERIMENTAL PROGRAMME:-

The main objective of this programme is casting of concrete cubes and to compare the mechanical properties of concrete for fresh and hardened concrete with the partial replacement of coarse aggregates by recycled plastic waste (10%,20%,30% and 40%) and cement by GGBS (40%) and coir fibers(0.75% to2%). The plastic waste concrete is manufactured by proposing to specification, casted and cured. The tests were carried out for these concrete cubes at 7, 14 and 28days.

2.1 MIX DESIGN

Proposed nominal mix in this entitled research is M_{25} as per IS 456-2000 with w/c ratio of 0.40. Mix proportion per cubic meter is represented in the table 1.

Table -1: Sample Table format

Quantities per m^3 of concrete					
Mix designation	0%	10%	20%	30%	40%
w/c ratio	0.4	0.4	0.4	0.4	0.4
Water [kg]	197	138	138	138	138
Cement[kg]	345	207	207	207	207
Fine aggregate[kg]	866.3	866.3	866.3	866.3	866.3
Coarse aggregate[kg]	1110.9	999.8	888.7	777.7	666.6
Recycle plastic aggregates [kg]	0	37.44	74.89	112.3	149.8
Coir fibers [kg]	0	2.58	2.58	2.58	2.58
GGBS [kg]	0	138	138	138	138

2.2 MATERIALS

2.2.1 Cement:

The cement is a binder, a substance that self and hardened and can be bind other materials together. The compositions of cement is OPC 53 confirming to 12269:1987 used for casting. Various properties of cement are shown in table 2.

Table-2: Composition of cement

Composition	**% content**
Lime(CaO)	60-67
Silica(Sio_2)	17-25
Alumina($Al2O_3$)	3-8
Iron oxide(Fe_2O_3)	0.5-6
Magnesia(MgO)	0.1-4
Alkalies	0.4-1.3
Sulphur	1-3

Table 3: Properties of cement

Sl. no.	**Characteristics**	**Values obtained**	**Standard values**
1	Normal consistency	30%	_
2	Initial setting time	56 mins	Not less than 30mins
3	Final setting time	600mins	Not more than 600mins
4	Specific gravity	3.11	3.15

2.2.2 Fine aggregate:

Fine aggregates used in this experiment is locally availably natural sand which is sieved as per IS383:1970. It is defined by size, being finer than gravel and coarser than silt. **Sand** can also refer to a textural class of soil or soil type; i.e. a soil containing more than 85% sand-sized particles (by mass).The properties of FA is tabulated in table 4.

Table 4: properties of fine aggregate

Sl no.	Characteristics	Values
1	Type	Natural
2	Specific gravity	2.65
3	Fineness modulus	2.69
4	Water absorption	1.01

2.2.3 Coarse aggregate:

The coarse aggregate sizes are larger than 4.75mm. A maximum size up to 40mm is used for coarse aggregate in most structural applications, while for mass concreting purposes such as dams, size up to 150mm may be used. The material used in this programme is natural crushed Stone of 20mm down size and specified as per IS 383:2970.

Properties of CA is tabulated in table 5.

Table 5: properties of coarse aggregates

Sl no.	Characteristics	Values
1	Type	Crushed
2	Specific gravity	2.67
3	Water absorption	0.8%
4	Moisture content	0.3%
5	Size	20mm down size

2.2.4 Water:

Water plays an important role in concrete production (mix) in that it starts the reaction between the cement, pozzolanic and the aggregates. It helps in the hydration of the mix. In this research, the water used was distilled water free from organic matter and PH value should be between 6-7.

2.2.5 Coir fiber:

Coir fibers is a natural fiber with diameter ranging between 0.3mm to 0.8mm and length of 6cm

Fig-1 Coir fiber

2.2.6 GGBS:

GGBS is a granular material formed when molten iron blast furnace slag is rapidly chilled by immersion of water. Chemical composition table 6.

Table 6: Composition of GGBS

Composition	% content
CaO	40
SiO_2	35
$Ai2O_3$	10
MgO	8

2.2.7 HDPE recycled plastic aggregates:

HDPE is a hydrocarbon polymer prepared from petroleum by a catalytic process. It is a kind of thermoplastic, which is famous for its tensile strength. Its unique properties can stand high temperatures. These plastic waste is collected from locally available industries which are obtained from disposal sites, crushed and modified into required sizes.

Fig-2 HDPE recycled plastic aggregates

Table 7: properties of recycled plastic waste aggregate

Sl.no	Characteristics	Values
1	Physical state	Solid
2	Specific gravity	0.9
3	Water absorption	Nil
4	Density	374.47 kg/m^3
5	Moisture content	Nil
6	Heat resistance	120^0 c
7	Size	12.5mm

2.3 TEST CONDUCTED

2.3.1 Workability:

Workability is a term associated with freshly prepared concrete. This can be defined as the ease with which concrete can mixed, placed, compacted and finished. Slump test and compaction factor test are the most commonly used

methods of measuring 'workability' of concrete in a laboratory or at site of work. These are used conveniently as a control tests and gives an indication of uniformity of concrete from batch to batch. Vertical settlement of a standard cone of freshly prepared concrete is called 'slump'. Compaction factor is a measure of density of concrete to which a fresh concrete mix can be compacted for a standard energy input relative to the theoretical maximum density corresponding to zero air content.

Fig-3 Slump test

2.3.2 Compressive strength:

Testing hardened concrete plays an important role in controlling and conforming the quality of cement concrete work. The main factor in favour of the use of concrete in structures is its compressive strength. One of the important properties of the hardened concrete is its strength which represents its ability to resist forces. The compressive strength of concrete is defined as the load which causes the failure of specimen per unit cross section on compression under given rate of loading. Concrete was casted in the specimen of size 150x150x150mm for the proposed mix proportion. The test results was carried at 7, 14 and 28 days.

Fig-4 Compression test

2.3.3 Split tensile:

Concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However the determination of tensile strength is necessary to determine the load at which the concrete members may crack. The cracking is a form of tensile failure. Cylindrical mould of size 150mm dia and 300mm height is used to prepare the concrete specimen. The test were carried out.

Fig-5 Split tensile test

2.3.4 Flexural strength:

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 500x100x100mm concrete beam.

Fig-6 Flexural strength

3. TEST RESULTS AND DISCUSSION

2.3.1 Workability

It is assessed by slump and compaction factor value shown in table 7.

Table 7: slump and compaction factor values

Sl. no	% of plastic replaced	% of coir fiber	% of GGBS	Slump value	Compaction factor
1	0	0.75	40	85	0.83
2	10	0.75	40	87	0.87
3	20	0.75	40	88	0.87
4	30	0.75	40	88	0.89
5	40	0.75	40	90	0.90

2.3.2 Compressive strength test

% of materials added	7 days N/mm2	14 days N/mm2	28 days N/mm2
0% (normal concrete)	19.55	29.55	32.66
10%P+0.75% coir+40%GGBS	19.85	23.55	28.88
20%P+0.75% coir+40%GGBS	21.77	25.22	30.08
30%P+0.75% coir+40%GGBS	22.75	25.42	30.66
40%P+0.75% coir+40%GGBS	20.22	21.19	22.30

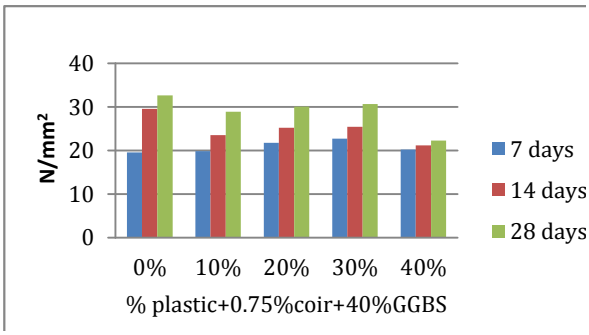

Fig-7 Graph of Compressive strength between conventional concrete and plastic concrete

2.3.3 Split tensile strength

% of materials added	7 days N/mm2	14 days N/mm2	28 days N/mm2
0% (normal concrete)	1.7	2.67	3.54
10%P+0.75% coir+40%GGBS	1.49	1.93	2.35
20%P+0.75% coir+40%GGBS	2.20	2.36	2.71
30%P+0.75% coir+40%GGBS	1.86	2.38	2.76
40%P+0.75%coir +40%GGBS	1.70	2.01	2.40

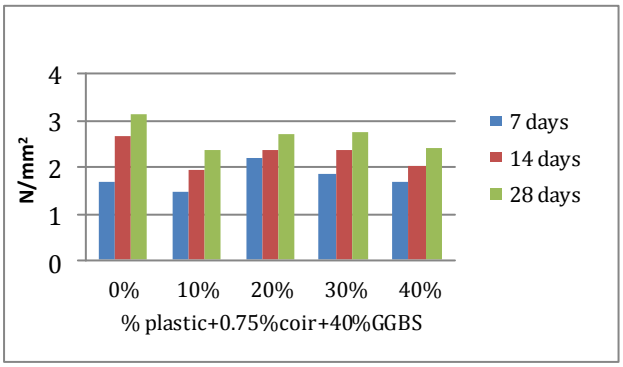

Fig-8 Graph of Tensile strength between conventional concrete and plastic concrete

2.3.4 Flexural strength

% of materials added	7 days N/mm2	14 days N/mm2	28 days N/mm2
0% (normal concrete)	5.0	5.5	7.25
10%P+0.75% coir+40%GGBS	4.5	6.0	8.0
20%P+0.75% coir+40%GGBS	5.5	6.5	8.25
30%P+0.75% coir+40%GGBS	6.0	7.0	9.5
40%P+0.75% coir+40%GGBS	4.5	5.25	5.25

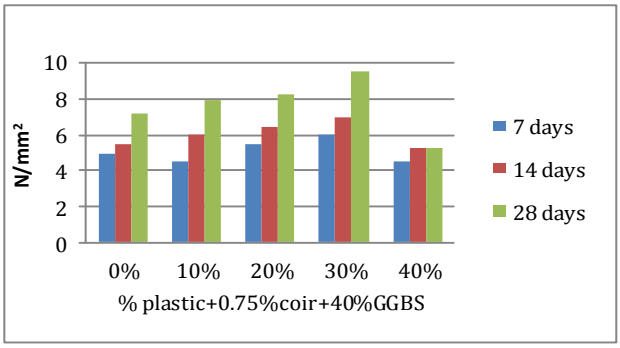

Fig-9 Graph of Flexural strength between conventional concrete and plastic concrete

4. CONCLUSIONS

- Plastic can be replaced upto 30%, GGBS upto 40% and coir fiber upto 0.75%.
- The strength of concrete is compared with conventional concrete and it is observed that compressive strength is achieved upto 90% and tensile strength upto 80%.

- Flexural strength achieved is more than the conventional concrete due to the incorporation of coir fibers.
- This research proves the concrete to be lightweight and minimizes the plastic to reach landfills.
- Utilization of GGBS upto 40% reduces the heat of hydration which is favourable to plastic which do not melt and gain high early strength.

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