EXPERIMENTAL INVESTIGATION ON STRENGTH PROPERTIES OF CONCRETE MADE WITH SUSTAINABLE MATERIALS

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Abstract - *Cement is always a valuable material in the construction industry. Because of the massive development of infrastructure, there is currently a shortage of concrete materials, so we must develop alternatives to concrete. The aim of our current study is to partially replace cement with groundnut shell ash (GSA) and GGBS and also coarse aggregate is partially replaced with E-waste (Waste Printed Circuit Boards). In this experimental study, cement is replaced by 0%, 5%, 10%, 15%, 20%, 25%, 30% percentage with GSA and GGBS by weight. Results show that use of 15% GSA and 15% GGBS gives as optimum result so 30% use of cement can be reduced. Then using optimum mix, four mixes of concrete with replacement of natural coarse aggregate by (0%, 5%,10%,15% and 20%) Waste Printed Circuit Boards (WPCB) are carried out. Tests are conducted for coarse aggregates, workability of fresh concrete (Slump test and compaction factor test), strength of hardened concrete (Compressive strength and Split tensile strength test) and nondestructive testing for hardened concrete for M20 concrete using IS method. Test results indicated that the use of 15% GSA and 15% GGBS partial replacement of cement in concrete with use of 10% replacement of natural coarse aggregates with WPCB resulted in improvement in mechanical strengths and can be effectively used in structural concrete. Later at 15% and 20%, the compressive strength and split tensile strength of the concrete goes on reducing.*

Key Words: **GGBS, GSA, WCPB, E-Waste**

1. INTRODUCTION

Global consumption of concrete is second solely to water. There is massive development of infrastructure in developing countries like India, due to which there is increased demand for raw materials. Also huge quantities of agricultural and electronic wastes are generated every year in India. The predominant component used in concrete is cement. The increase in demand of cement accounts to the increased price for cement. However, the manufacturing of cement poses a threat to the environment. Over the years, many waste materials like fly ash and ashes produced from various agricultural wastes such as palm oil waste, rice husk ash, millet husk ash have been tried as pozzolana or secondary cementations materials.

Groundnut shell is an important cash crop produced in large quantities in India. The groundnuts production volume amounted to about 10.14 million metric tons in the country during fiscal year 2022, down from 10.25 million metric tons in fiscal year 2021[1]. The utilization of groundnut shell ash will promote waste management at little cost and reduce pollution by these wastes.

1.2 SCOPE OF THE STUDY

In our country, there is a shortage of materials due to the increased development of infrastructure [2]. Also, production of one ton of cement emits one ton of carbon dioxide to the environment. Keeping in view, this study is focussed on reducing production of cement and also reducing disposal of waste generated from various fields like agriculture and industries [2]. In this project, we have replaced cement partially with Granulated Ground Blast-furnace Slag (GGBS) and Groundnut Shell Ash (GSA) and coarse aggregate with Waste Printed Circuit Boards (WPCB). Groundnut is the major crop in India. Hence there is a large amount of groundnut shell available as a waste. The replacement of cement with GSA not only reduces pollution caused by cement, but also helps in management of groundnut shell waste.

1.3 PROBLEM DEFINITION

NEED FOR PARTIAL REPLACEMENT OF CEMENT WITH GGBS AND GSA

The huge increase in construction activities has resulted in depletion of raw materials. In addition to that production of cement remains the major cause for pollution. Hence many researches have been conducted to find out the materials which can be used as the best substitute for the conventional concrete materials. To address the aforementioned problems faced by the concrete industry, and to make it more sustainable, the use of WPCB as the replacement of coarse aggregate has been adopted with great success over past few years. Use of the waste materials not only helps in getting them utilized in cement, concrete and other construction materials, but also has numerous indirect benefits such as reduction in landfill cost, saving in energy, and protecting environment from possible pollution effect. It also helps in reducing the cost of concrete manufacturing

2. MATERIALS PROPERTIES, TESTS & MIX DESIGN

2.1 MATERIALS

As per the standard code of practice, the properties of materials used for making concrete are determined in the laboratory. The various materials used are Ordinary Portland Cement of Grade 53, Ground Granulated Blast-furnace Slag, Groundnut Shell Ash, Fine Aggregate, Coarse Aggregate and Printed Circuit Boards. The main objective behind studying the material properties is to check the compliance with codal requirements and to enable an engineer to design a cement concrete mix for a high strength.

A brief description of various materials used in the experiment are discussed below:

2.2 CEMENT

In the present investigation OPC 53 Grade NAGARJUNA brand cement conforming to IS:

12269-(1987) is used. The various properties of cement like fineness, normal consistency, initial setting time and specific gravity of cement are found out. Measures were taken to store the cement properly in order to prevent deterioration of its properties due to contact with moisture.

2.3 GGBS

Ground-granulated blast-furnace Slag (a by-product of iron and steel-making) is manufactured by extinction of melted iron slag from a furnace in water or steam, to supply a glassy, granular product then dried and made into a fine powder. Ground granulated furnace slag is a building material and high in CSH (calcium salt hydrates) that may be a compound that will increase the strength, sturdiness and look of the concrete.

2.3 GROUNDNUT SHELL ASH

GSA is collected from a location nearby Anantapur, Andhra Pradesh. The Groundnut shells are sun-dried and the powdered form is Groundnut shell ash. The ash is grounded to IS Sieve size 75µ. The shells are sun dried and then ground using rice milling machine to reduce its size. The ash is obtained by burning of ground nut shells on an iron sheet or iron tin in an open air under normal temperature. After burning of ground nut shell, ash will generate. This ash is cooled and after used to sieve through Indian standard sieve of 75 microns.

The chemical composition of Cement, GGBS and GSA is tabulated in table 2.

Table 2.1. Comparative Analysis of Chemcial Composition of Cement, GSA, GGBS

INGREDIENTS	OPC CEMENT	GSA	GGBS
CaO	66.67	10.91	40
SiO2	18.91	33.36	35.3
Fe2O3	4.94	2.16	0.35
Al2O3	4.51	1.75	14.1
SO3	2.5	6.40	0.05-2.4
MgO	0.87	4.72	8.2
K2O	0.43	16.18	0.4
Na2O	0.12	9.30	0.8
CO3	-	6.02	0.13
HCO3	0.44	9.20	-
MnO	-	0.23	0.5
P2O3	<0.9	-	<0.1

2.4 FINE AGGREGATE

Based on the size of grains, fine aggregate may be classified as coarse, medium and fine sands. Depending on the particle size distribution code of practice IS:383-2016, fine aggregates are graded into four zones. The grading zones become progressively finer from grading zone I to IV.

Various experiments such as sieve analysis, determination of specific gravity and bulking of

Sand is carried out to determine the properties of fine aggregate. Test results are found to be within the ranges specified as per the Indian Standard.

2.5 COARSE AGGREGATE

Coarse aggregate passing through a 20mm nominal size sieve is used in this study. Various experiments are conducted to find specific gravity and sieve analysis of coarse aggregate. The results obtained are within the range of Indian Standards.

2.6 PRINTED CIRCUIT BOARDS

The WPCBs from television sets are used in our study. The WPCB chips of size less than 20mm are used as coarse aggregate. Tests are conducted to find out the particle size analysis of PCB.

Figure2.6.1. WPCB Boards collected from nearby locality

3. RESULTS AND DISCUSSION

1 COMPRESSIVE STRENGTH OF MOTAR

The compressive strength of cement gives the idea about the basic cement strength. It gives the assurance for using from this test, you can find how much cement is required and how much strength it will get. The compressive strength of cement is also the basic data needed for mix design. Cement, basically, is known by its compressive strength. Cement is identified by its grade like 53 grade, 43 grade, and 33 grade of cement. This grade indicates the compressive strength of cement, i.e. 53 grade of cement indicates that compressive strength of cement cube after 28 days of curing will be 53 N/mm2 (MPa) or 530 kg/cm2.

Fig -3.1: **Cube Moulds for finding Compressive strength**

For different mix proportions of cement with GGBS and GSA the compressive strength of cement is found.

Table 3.1 Compressive strength of cement for various mix proportions

S.No	Mix Proportion (Cement: GGBS : GSA)	Compressive strength after 7 days of curing	Compressive strength after 28 days of curing
1	0% mix	13.4	16.63
2	90:5:5	8.37	18.8
3	80:10:10	5.31	17.17
4	70:15:15	5.25	17.1
5	60:20:20	3.67	11.27
6	50:25:25	2.36	9.39
7	40:30:30	1.43	8.85

3.2. COMPRESSIVE STRENGTH OF CONCRETE

To study the effect on compressive strength, 15 cubes (size 150mm x 150mm x 150mm) each for calculated material weight for different percentage of WPCB chips concrete and tested at 7 days and 28 days. The average compressive strength results at 7 days and 28 days curing are shown in Table 4.3.

Table 3.2 : Compressive Strength Test Results at 7 Days and 28 Days

SNo	% of Coarse Aggregate replaced by WPCB	Average Strength (MPa)	
		7 Days	28 Days
1	Conventional Mix	17.88	27.5
2	0%	17.03	26.2
3	5%	18.6	28
4	10%	19.5	28.5
5	15%	16.9	25.8
6	20%	14.26	22.4

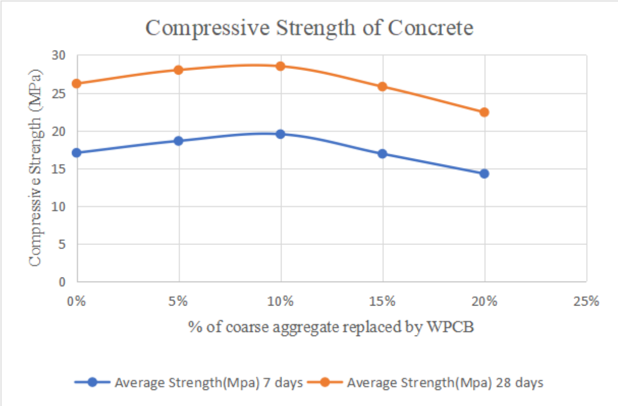

Figure 3.2 Comparison of Average Compressive strength of various mixes

3.3 SPLIT TENSILE STRENGTH

To study the effect of tensile strength, 15 cylinders (size 150mm x 300mm each) for calculated material weight for different percentage of WPCB are casted and tested at 7 days and 28 days

Table 3.3: Tensile Strength Test Results at 7 Days and 28 Days

SNo	% of Coarse Aggregate replaced by WPCB	Average Strength (MPa)	
		7 Days	28 Days
1	Conventional Mix	2.8	4.3
2	0%	2.49	3.9
3	5%	2.76	4.4
4	10%	3.75	5.6
5	15%	2.32	3.73
6	20%	1.65	2.56

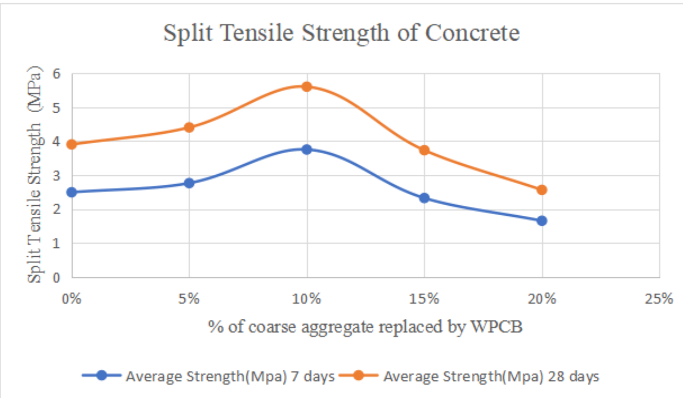

Figure 3.3 Comparison of Average Compressive strength of various mixes

3.4 REBOUND HAMMER TEST

The Rebound Hammer test results after 28 days of curing if concrete cubes are tabulated as follows:

Table 3.4 Rebound Hammer Test Results

S No	Mix Proportion	Average Rebound Number	Compressive strength (MPa)	Quality of Concrete
1	0%	28	22	Fair
2	5%	29.5	24	Fair
3	10%	31	26	Fair
4	15%	24	18	Fair
5	20%	20	14	Fair

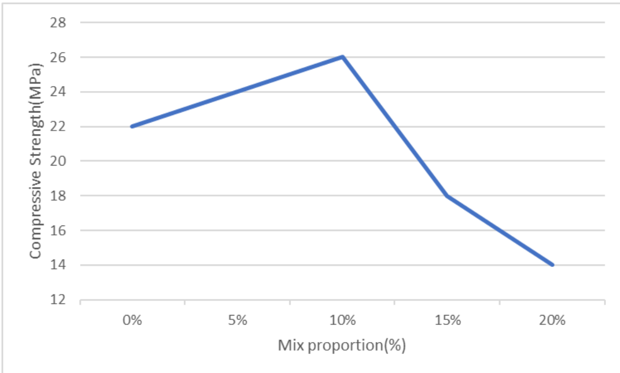

Figure 3.5 Compressive Strength corresponding to Rebound Number

It can be seen that upto 10% partial replacement of coarse aggregate with WPCB, the average rebound number increases and hence the compressive strength. After that it has shown a decrease in rebound number.

4. CONCLUSIONS

The present study is undertaken to investigate the strength properties of concrete cubes and cylinders containing different percentages of Waste Printed Circuit Boards. Casted cubes and cylinders are tested at 7 and 28 days.

On the basis of the present study, the following conclusions can be drawn:

Based on Compressive strength of mortar results, it is found that use of 15% GSA and 15% GGBS gives optimum result. So 30% use of cement can be reduced.

By the partial replacement of coarse aggregate by WPCB, the compressive strength of concrete increases up to 10%

replacement. However replacing beyond 10% of coarse aggregate by WPCB, the compressive strength decreases progressively.

By the partial replacement of coarse aggregate by WPCB, the split tensile strength of concrete increases up to 10% replacement. However replacing beyond 10% of coarse aggregate by WPCB, the split tensile strength decreases progressively.

By the partial replacement of coarse aggregate by WPCB, the slump value in slump cone test is decreasing as it clearly indicates that the workability is decreasing from 0% to 20% replacement of coarse aggregate by WPCB.

Due to partial replacement of coarse aggregate by WPCB, the compaction factor in compaction factor test shows an overall decrease, which clearly indicates that the workability also decreases due to partial replacement of coarse aggregate by WPCB from 0% to 20%.

It can be seen that up to 10% partial replacement of coarse aggregate with WPCB, the average rebound number increases and hence the compressive strength. After that it has shown a decrease in rebound number.

Therefore, we can conclude that there is a scope for replacement of Coarse Aggregate with WPCB. Up to 10% of replacement with WPCB, there can be effective increase in strength of concrete. Furthermore, cement can also be replaced effectively up to 30% of replacement with GGBS and GSA. Hence, it finally results in saving economy, E- waste management and also provides an environment friendly solution.

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