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Original Article

Feasibility Study on Mechanical Properties of Concrete using Construction Waste as the Partial Replacement of Coarse and Fine Aggregates

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Abstract - *The non-hazardous solid waste was resulting from construction and demolition activities is defined as Construction andDemolition debris(C& D). The generation of these wastes is impossible to prevent. Still, this waste generation can be adopted as an alternative material that can be controlled or reduced in construction sites. these waste materials can be utilized in various fields of Construction. In the present study, an investigation is carried out to find the feasibility of using waste generated from construction fields, such as demolished concrete, glass, plastic, etc.*

This paper investigates the mechanical properties of concrete using the above construction waste such as glass, plastic and demolished concrete by partially replacing fine aggregates and coarse aggregate. All three waste in a single stretch for a sample. Samples of concrete specimens (Cubes, Cylinders and Prisms) were cast for M25 grade by partially replacing plastic and glass as fine aggregate from 0% to 20%, while demolished concrete as coarse aggregate from 0% to 20%. Several laboratory tests were carried out to evaluate these replacements on the properties of the normal concrete mixes. these tests include workability, compressive strength, flexural strength and indirect tensile strength (splitting). Test results revealed that the three waste materials could be successfully reused as partial substitutes for sand or coarse aggregates in concrete mixes.

Keywords - *Alternative material, Construction and Demolition debris (C & D), Glass, Plastic, Demolished concrete.*

1. Introduction

Waste and debris are generated during Construction, renovation, and demolition of buildings, roads, bridges, etc. This generated isgenerally defined as Construction and demolition (C&D). C&D materials include concrete, asphalt, wood, metals, glass, gypsum, plastics and salvaged building components. This C&D waste is bulky, heavy and inert, and a mixture of various materials of different characteristics; as such, it is a challenging task to handle. It is difficult to choosea suitable disposal method to dispose of this waste. To achieve the sustainable goals for our common future, C&D waste generation and handling issues have been focused on various sustainable practices in the construction industry. in handling C&D waste, Reduce, Reuse, Recycle (3Rs) philosophy is highly useful. Developedcountries generate 500 to 1000 kg per capita per year of building & construction waste. in European, Countries are estimated to be 175 million tonnes/year according to the study. Also, according to the study, it was mentioned that a very small percentage of waste from the construction industry is reused or recycled, the majority being deposited or used as a landfill. india is also enjoying a construction boom likeotherdeveloping countries.It is appropriate to link the generation of C&D waste with the growth of the construction industry and related issues with india's rapid growth in construction activities. To manage construction waste, it is also essential to study C&D waste generation and to handle to develop accurate data and establish sustainable methods.

Fig. 1 Hierarchy of Waste

Nowadays, new and innovative research is continuously advancing using these waste materials. For safe and economic disposal of waste materials, these research efforts try to match society's needs. the utilization of these construction wastes saves natural resources and dumping spaces and helps to maintain a clean environment. the current study concentrates on those waste materials, specifically glass waste, plastics and building construction waste to be used as substitutes for conventional materials, mainly aggregates, in Ordinary Portland cement concrete (OPC) mixes.

Malek Batayneh et al. (2007) investigated an experiment on concrete mixes using selected waste materials. themain aim of their study was to find relative advantages, disadvantages and reuse of construction waste materials in the construction industry, such as crushed concrete waste, plastics and glass. Based on the test results, it was concluded that prior waste and recycling management plans should be developed to sustain environmental, economic, and social development principles for any construction project to start work.

By partial replacement of fine aggregates with crushed glass aggregates, there was an improvement in strength. Still, the high alkali content ofsuch aggregates would affect the long-term durability and strength, which need long-term investigation. By replacing plastic and crushed aggregates, there was slump loss as the percentage increased, but in the case of glass, there was no such significant effect onthe slump.Apart from partial replacement of glass to aggregates, this can also be used for aesthetical purposes, which give shiny clean finishing effect on the surface of the concrete product. Finally, test results revealed lower compressive strengthand splitting-tensile strength than that of normal concrete using natural aggregates with 20% replacement of plastic and crushed concrete was used in concrete. therefore, it is recommended that lower strength up to 25 MPa concrete with recycled materials of lower strength can be used in certain civil engineering applications, especially in non-structural applications.

Abdessamed et al. (2020) studied an experiment on demolished concrete as a partial replacement for coarse aggregates to produce new concrete.the percentage of replacements is 50%, 75% and 100% of recycled concrete aggregates as coarse aggregates. the tests conducted are rheological parameters, compressive strengths, and tensile strength and durability tests like water permeability, water absorption and chemical attacks. the test results revealed that recycled concrete aggregates are suitable for obtaining structural concrete. To anticipate the strength of the recycled aggregates concrete, linear regression was developed between the strength of the material and the number of cycles of concrete recycling. the results concluded that recycling demolished concrete plays a key role as a valuable resource for aggregates supply to the concrete industry in meeting the challenge for sustainable development.

Subhash et al. (2017) investigated a study on the performance of water-soaked Recycled Coarse Aggregates (RCA) in replacement levels of 0%, 25%, 50%, 75% and 100% to Natural Coarse Aggregates (NCA in concrete. To achieve compressive strength, suitable performance enhancement techniques to RCA based concrete were attempted, at least equal to or more than that for no RCA based concrete (control concrete). in their study RCA based concretes were in the range of 50% and 100%. Tests were also conducted ti find the feasibility of using Recycled Fine Aggregates (RFA) with appropriate modifications to serve as fine aggregates in mortar and concrete. Results revealed that to serve as fine aggregates to the extent of 100% replacement levels in mortars and concretes using RFA blended with river sand fractions and RFA with Iron Ore Tailings (IOT) fractions have given good results.

In their study, Suman Saha and Rajasekaran C mainly focused on the feasibility of using recycled coarse aggregate and finding strength characteristics of concrete. instead of ordinary Portland cement, they have taken Portland Pozzolana Cement (fly ash based). A comparative study was made between Ordinary Portland Cement and Portland Pozzolana Cement on recycled aggregate concrete's strength characteristics. the test results of this investigation show there is a significant loss of compressive strength (24 %),flexural strength (26 %) and splitting tensile strength (21 %) of concrete were observed when the replacement percentage level of NCA increases for both types of mixes.It was concluded that to obtain cleaner environment use of demolition waste as coarse aggregate will lead to a significant reduction of the consumption of natural resources, and up to 25 % replacement of recycled coarse aggregate for natural coarse aggregate is acceptable for the production of the concrete.

2. Objectives of Work

This study aims to determine the feasibility of using construction waste materials such as demolished concrete to partially replace coarse aggregate, glass and plastic as the fine aggregate in concrete mixes.Also, utilizing this waste can reduce disposal problems.

3. Methodology

Themechanical properties like compressive strength, splitting tensile strength and flexural strength were studied using demolished concrete as the partial replacement of coarse aggregate, plastic and glass as the partial replacement of fine aggregateby casting different specimens like a cube, cylinder and prism. For M25 concrete mix the total number of 45 cubes of dimension (150mm x150mm x 150mm), 45 cylinders of dimension (150mm x 30mm) and 45 prisms of dimension (100mm x 100mm x 500mm) was cast and tested under laboratory conditions. the mix proportions of materials were calculated as per IS 456-2000 using indian Standard Mix Design (IS:10262-2009) for M25 grade.thestrength of concrete was tested after 3, 7 and 28 days of normal curing, respectively.

The demolished concrete for this investigation was collected from one demolished building. Demolished concrete was broken into small pieces similar to coarse aggregate such that passing through 20 mm IS sieve and retaining in10 mm IS sieve. the aggregate used here is cleaned thoroughly such that cement mortars sticking to the aggregates are removed, and aggregates are saturated before use.

Tempered glass of solar panels was collected and broken into small pieces such that it is passing through a 4.75 mm IS sieve so that it approves the fine aggregates standard size as mentioned in the IS code (IS:383-1970). the sieve analysis was carried out, and the range of sieve size used for this fraction of glass was 150 micron to 4.75mm.

Waste plastics in Construction, such as PVC that cannot be degraded further, has been shredded into fine particles. For the present study, shredded plastic as a partial replacement of fine aggregate was collected from one of the plastic industries in Mysuru. the size of shredded plastic was found to be less than 2mm. Ordinary Portland cement of 53- grade was used as it satisfied the requirements of IS: 12269-1987, and results have been tabulated. the coarse aggregate was crushed granite of igneous origin with a size range of 10 mm - 25mm. For this study, the maximum size used was 20mm and is less than one-third of 100mm, the smallest dimension of the specimen.the fine aggregate chosen was between 4.75mm - 150 microns. M-sand was used as the fine aggregate. the sieve analysis of fine aggregate was conducted, and it was found to satisfy Zone 2 according to IS 383-1970.

According to IS: 456-2000, water used for mixing and curing concrete shall be clean and free from harmful amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be harmful to concrete or steel. Portable water was used that was found satisfactory for mixing concrete.
Superplasticizer used for this study was Fosroc Conplast SP 430. the dosage recommended by the manufacturer varies between 1-2% by the weight of cement. in the present investigation, different dosages of superplasticizers were selected for the desired workability.

4. Experimental Investigation

An experimental programme was carried out in the present study to determine the various properties of materials like cement, sand, aggregate, glass, plastic &demolished concrete. the table below shows the test values of various materials.

Table 1. Properties of cement

Properties	Test values	As per IS:269-2015
Standard consistency,%	29	-
initial Setting time, min	90	More than 30
Final Setting time, min	190	Less than 600
Specific Gravity	3.15	3.15
Fineness, %	6	Not more than 10

Table 2. Properties of sand

Properties	Test values
Specific gravity	2.57
Fineness modulus	2.83
Bulk density, kg/m^3	1651.2

Table 3. Properties of coarse aggregate

Properties	Test values	As per IS:383-1970
Specific gravity	2.57	2.4-3.0
Water absorption (%)	0.2	0.1-2.00
Impact value (%)	24.52	Shall not exceed 30 for aggregate used for concrete, including wearing surfaces.
Crushing value (%)	26.81	Shall not exceed 30 for aggregate used for concrete, including wearing surfaces.
Abrassion value (%)	26.66	Shall not exceed 30 for aggregate used for concrete, including wearing surfaces.

Table 4. Properties of demolished concrete

Properties	Test values	As per IS:383-1970
Specific gravity	2.52	2.4-3.0
Water absorption (%)	1.2	0.1-2.00
Impact value (%)	26.54	Shall not exceed 30 for aggregate used for concrete, including wearing surfaces.
Crushing value (%)	29.39	Shall not exceed 30 for aggregate used for concrete, including wearing surfaces.
Abrassion value (%)	29.12	Shall not exceed 30 for aggregate used for concrete, including wearing surfaces.

Table 5. Properties of glass

Properties	Test values
Specific gravity	2.5
Fineness modulus	2.68
Bulk density, kg/m^3	1967.9

Table 6. Properties of plastics

Properties	Test values
Specific gravity	1.4
Bulk density, kg/m^3	1442.3

Table 7. Mix proportion for per cum of concrete

Percentage replacement (%)	0	5	10	15	20
Cement (kg/m^3)	316.20	316.20	316.20	316.20	316.20
Fine aggregate (kg/m^3)	720.73	684.70	648.65	612.61	576.57
Glass (kg/m^3)	0	18.02	36.04	54.06	72.07
Plastic (kg/m^3)	0	18.02	36.04	54.06	72.07
Coarse aggregate (kg/m^3)	1203.38	1143.21	1083.04	1022.87	962.70
Demolished concrete (kg/m^3)	0	60.17	120.34	180.60	240.68
Water (litre)	158.10	158.10	158.10	158.10	158.10
w/c ratio	0.5	0.5	0.5	0.5	0.5

Table 8. Fresh properties of concrete

Percentage replacement (%)	0	5	10	15	20
Slump (mm)	47	45	44	41	40
Density (kg/m^3)	2486.30	2434.70	2403.10	2368.00	2324.40

V. RESULTS AND DISCUSSION

Forty-five samples of 150 mm cubes, 150 mm diameter and 300 mm length cylinders, and 100 mm × 100 mm × 500 mm prisms are prepared and tested for compressive strength, split tensile strength and flexural strength, respectively, at 3, 7 and 28days. the results of the concrete mix's hardened properties are shown in Tables 7, 8 and 9 and Figs 2,3 and 4.

Table 9. Compressive strength of concrete (N/mm^2)

Percentage Replacement (%)	Compressive Strength (N/mm^2)		
	3days	7 days	28 days
0	12.02	21.60	29.62
5	14.30	22.60	31.04
10	17.50	23.10	33.26
15	18.50	23.59	34.02
20	13.02	20.10	30.04

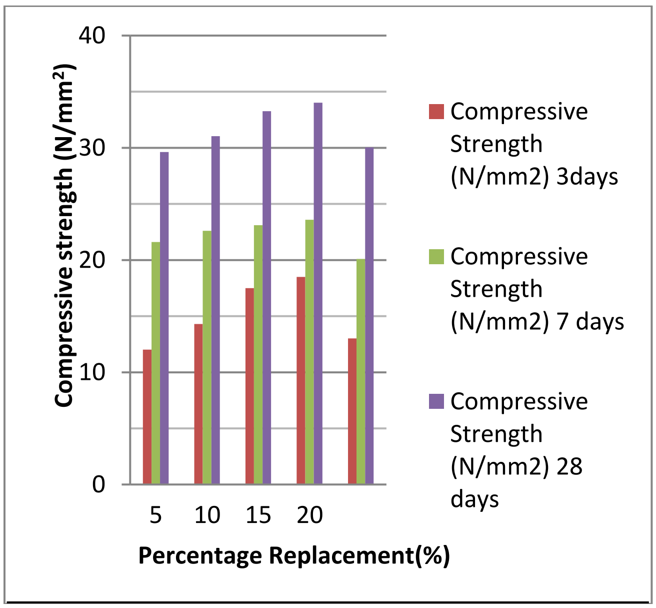

Fig. 2Compressive strength of concrete

Table 10. Split Tensile strength of concrete (N/mm²)

Percentage Replacement (%)	Split Tensile Strength (N/mm²)		
	3days	7 days	28 days
0	1.81	2.43	3.07
5	1.87	2.50	3.25
10	1.90	2.57	3.30
15	1.92	2.60	3.34
20	1.72	2.32	3.10

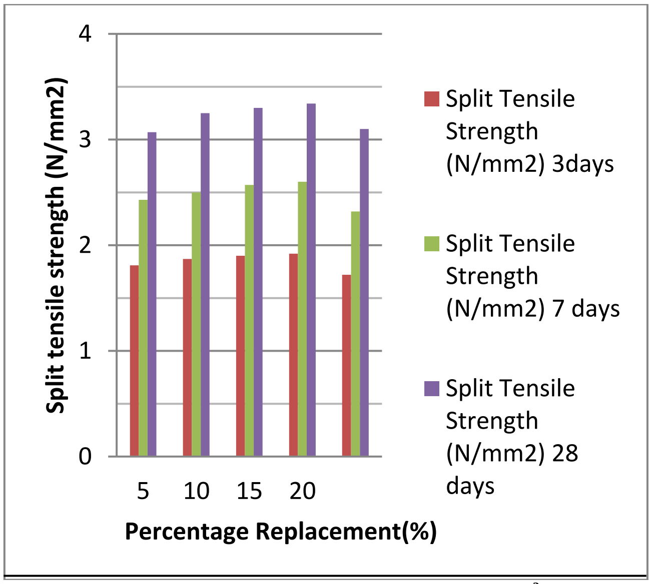

Fig. 3 Split Tensile strength of concrete (N/mm²)

Table 11. Flexural strength of concrete (N/mm²)

Percentage Replacement (%)	Flexural Strength (N/mm²)		
	3days	7 days	28 days
0	3.28	3.38	3.45
5	3.38	3.46	3.58
10	3.50	3.60	3.67
15	3.62	3.71	3.78
20	3.30	3.35	3.40

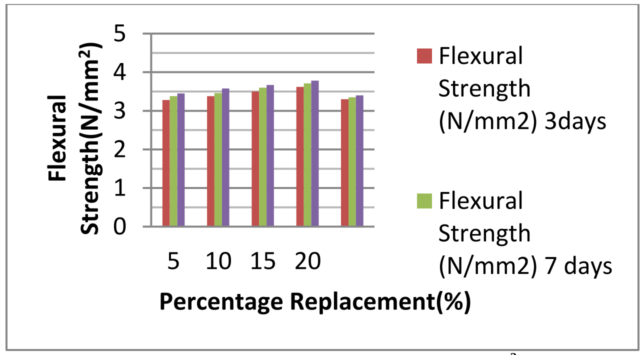

Fig. 4 Flexural strength of concrete (N/mm²)

6. Conclusion

This present study was mainly carried out to find the feasibility of using construction waste material such as glass plastic demolished concrete in concrete mixes. This study highlights an overview of the reuse of waste material in Construction. Based on the study, it can be concluded that:

- The use of demolished concrete as partial replacement of coarse aggregate, glass and plastic as partial replacement of fine aggregate has influenced the engineering properties of concrete.
- Where there is a comparative cost advantage this concrete, this shows reasonable structural characteristics and can be encouraged.
- With the increase in the percentage of replacement mainly due to plastic usage, there is a reduction in the density of concrete.
- The compressive strength, tensile strength and flexural strength increased with an increase in the percentage of replacement up to 15% and then strength decreases further replacement, i.e., 20% replacement.
- So up to 15%, the replacement can be done for the load-bearing structures. the above percentage can be increased to 20% for non-load-bearing structures.

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