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EXPERIMENTAL STUDIES ON STRENGTH AND WORKABILITY PROPERTIES OF CONCRETE BLENDED WITH E-WASTE AND FINE AGGREGATE IS REPLACED WITH SLAG SAND

Y MAHESH[1], M SRAVANTHI[2], C SASHIDHAR[3]
[1]M. Tech Student, JNTUA College of Engineering, Anantapur, AP, India.
[2]Research Scholar, JNTUA College of Engineering, Anantapur, AP, India.
[3]Professor, JNTUA College of Engineering, Anantapur, AP, India.

ABSTRACT

The proliferation of electronic waste (E-waste) has become a pressing global concern, posing substantial environmental and human health risks. To tackle this, E-waste is being considered as a substitute for traditional coarse aggregates in the concrete industry, as conventional aggregates are becoming more expensive. Additionally, slag, a by-product from various industries, can be used as a replacement for river sand in fine aggregate, offering an eco-friendly solution. This research focuses on optimizing the use of E-waste and slag sand in concrete. E-waste replaces a portion of the coarse aggregate, ranging from 0, 5, 10, 15 and 20% by weight, while slag sand entirely replaces the fine aggregate in M30 grade concrete. Fresh properties of the concrete are assessed through the Slump cone test and the compaction factor test, and the concrete strength properties, including compressive strength, tensile strength, and flexural strength, are evaluated at curing intervals of 7, 14, 21, and 28 days.

Keywords: E-waste, Slag Sand, Compressive Strength, Tensile Strength, Flexural Strength, Sustainable Concrete.

1. INTRODUCTION

1.1. GENERAL

Concrete is renowned for its widespread use in construction due to its exceptional strength, durability, and load-bearing capacity. However, a major concern associated with concrete has been its contribution to carbon dioxide emissions, primarily stemming from its cement content. As plastic production and global consumption have continued to rise, the environmental impact of plastic waste, including electronic or e-plastic waste, has gained increasing attention. E-waste encompasses a wide range of discarded electrical and electronic devices, including those intended for reuse, resale, salvage, recycling, or disposal. In many developing nations, the informal processing of e-waste has given rise to significant health and environmental risks, largely due to limited regulatory oversight. Numerous electronic components, such as CRTs, often contain hazardous substances such as lead, cadmium, beryllium, or flame retardants. Even in developed countries, the recycling and disposal of e-waste pose risks to workers and communities, necessitating strict precautions to prevent exposure to hazardous materials and the release of heavy metals from landfills and incinerator residues. India, with its thriving economy and growing population, is experiencing a surge in the consumption of electronic appliances.

Another waste product with potential for sustainable concrete production is slag, a by-product generated by various industries. Granulated BF slag, a common component in Portland slag cement, can be cleverly repurposed as a substitute for river sand in fine aggregate, offering an innovative approach to recycling slag. Frequently, slag materials consist of clusters containing both coarse and very fine particles, and they are often discarded as waste, leading to resource wastage, environmental pollution, and ecological harm. Consequently, recycling industrial waste slag is essential for sustainable development and environmental protection, with significant social implications. Utilizing slag as an alternative material in concrete not only conserves natural resources but also safeguards the environment. The findings from this study have significant implications for the construction industry, offering a novel approach to address both E-waste disposal and the efficient utilization of industrial byproducts.

1.2. OBJECTIVES OF RESEARCH

1. To substitute a portion of conventional coarse aggregate with E-waste in M30 grade concrete, aiming to mitigate environmental pollution by repurposing E-waste.
2. To minimize the buildup of discarded electronic and electrical equipment by transforming waste into socially and economically valuable raw materials using cost-effective and environmentally friendly methods.
3. To determine the optimal mix proportion that provides both excellent fresh workability and strong hardened properties for concrete.
4. To identify the most suitable proportions of E-waste and slag sand to be incorporated into the M30 grade concrete mix. This determination seeks to optimize the concrete mixture for performance and sustainability.

2. LITERATURE REVIEW

According to B.H. Robinson [1], plastic trash, especially e-plastic, poses a concern to the ecosystem because it can obstruct groundwater movement and limit soil root growth. Numerous research have investigated the use of e-waste and e-plastic components in concrete to solve this issue, with each presenting a different set of results. The mechanical characteristics of concrete that contains e-plastic as an aggregate were studied by R. Lakshmi and S. Nagan [2]. Their research showed that using e-plastic in place of up to 20% of coarse material produced concrete with acceptable strength. By using e-waste particles in place of conventional aggregates, Krishna Prasanna and Kanta Rao [3] investigated how to lighten concrete. Salman Siddique et al. [4] discovered that although e-waste concrete had lower strength at all curing ages, it developed strength similarly to ordinary concrete. It has been demonstrated that adding mineral admixtures improves compressive strength. According to Pravin A. Manatkar and Ganesh P. Deshmukh [5], replacing non-metallic e-waste for coarse aggregate increased concrete's compressive strength by up to a specific percentage. In an experimental investigation, B.T. Ashwini Manjunath [6] found that using e-waste plastic as an aggregate in concrete produced materials with good compressive, tensile, and flexural strengths. E-waste was used as coarse aggregate by Sunil Ahirwar, Pratiksha Malviya, Vikash Patidar, and Vikash Kumar Singh [7], producing lightweight concrete and reducing the need for traditional materials, preserving natural resources. The use of plastics and e-waste as coarse aggregates might be profitable for the manufacturing of concrete, according to feasibility tests undertaken by Ankit [8]. According to A. Arun Kumar and R. Senthamizh Selvan [8], substituting coarse material with e-waste produced concrete with a similar strength to control concrete but lowered compressive strength when used as fine aggregate. The tensile and flexural splitting strengths of e-waste replacement mixes were also superior. According to Marian Sabău and Johnny R. Vargas [10], there was a maximum drop in compressive strength of 44% when e-plastic waste was used to replace a portion of coarse mineral aggregate. Research was done on the utilization of non-ground granulated blast furnace slag (GGBS) as a fine aggregate in concrete by Isa Yuksel, Omer Ozkan, and Turhan Bilir [11]. They stressed how the strength and durability properties of the concrete are greatly influenced by the GGBS to sand ratio. Using oxidizing Electric Arc Furnace (EAF) slag as both fine and coarse particles in concrete, Juan M. Manso et al. [12] performed laboratory research. The soundness, leaching, and accelerated aging tests on durability revealed that EAF slag concrete had respectable endurance, especially in areas with mild winter temperatures. In their study [13], Li Yun-feng, Yao Yan, and Wang Liang looked at how steel slag powder affected the workability and mechanical attributes of concrete. Their research showed that adding compound mineral admixtures to concrete that contained both steel and blast furnace slag powder may enhance the material's mechanical qualities. Steel slag was employed as a fine aggregate by Lun Yunxia, Zhou Mingkai, Cai Xiao, and Xu Fang [14] to improve the volume stability of mortar. According to their research, variables including the powder ratio, the amount of free lime, and the linear expansion rate might represent increases in volume stability. has been studied by Sean Monkman, Yixin Shao, and Caijun Shi [15].

3. MATERIALS AND METHODOLOGY

The blends are casted with the goal of giving concrete its maximum strength. The mix proportions of the different materials used in the concrete mixes are considered based on the IS 10262-2019 Code approach.

3.1. MATERIALS USED

3.1.1. Ordinary port land cement (grade 53)

The type of cement used in the study is OPC 53 grade cement. The individual properties of the cement were determined to ensure that they met the limits specified in the IS: 12269-1987 standard. The specific gravity of cement is obtained as 3.15.

3.1.2. Slag Sand

Slag sand derived at JSW Company in India, is used. Fifty percent of finer variety & Fifty percent of coarser variety is utilized in combination. For sustainability, in the present work Natural River sand is not used. Slag sand is tried as total fine aggregate. Slag sand belonging to Zone II are used. The specific gravity of slag sand is 2.65.

3.1.3. Coarse aggregate

The coarse aggregates originate from a combination of naturally existing rock fragments and crushed granite. Concrete strength qualities may also be affected by the coarse aggregate form. As per IS: 383-1970, in the study, two proportions of coarse aggregate are used as 20 mm down aggregate. The specific gravity of the 20mm down aggregate is obtained as 2.74.

3.1.4. Water

The primary ingredient in making concrete is water. Concrete was mixed and cured using drinkable water. Oils, acids, alkalis, salts, biological matter, and other pollutants that might harm concrete should not be present in the water used to mix concrete, including the free water on the aggregates.

3.1.5. Super Plasticizer

In order to make high-strength concrete, Super Plasticizers (SP) are added to fresh concrete to enhance its workability and enable the water content to be dropped. Conplast SP 430 Dis is the Super plasticizer utilized in this investigation.

3.2. METHODOLOGY

In this study to evaluate the effects of E-waste and Slag sand as partial replacement to coarse aggregate and fine aggregate respectively four stages are given below.

1. Determination of workability properties (Slump cone, Compaction factor) of conventional M30 grade concrete at fresh state.
2. Determination of strength properties (Compressive, Split tensile, Flexural) of conventional M30 grade concrete at 7, 14, 21 & 28 days.

3. Determination of workability properties (Slump cone, Compaction factor) of concrete replacement with E-waste and slag sand at fresh state.
4. Determination of strength properties (Compressive, Split tensile, Flexural) of concrete with E-waste and slag sand at hardened state at 7, 14, 21 & 28 days.

A total five group of specimens (0, 5, 10, 15 & 20%) are casted, each group consists 3 cubes, 3 cylinders and 3 beams. Five groups are used for measuring the workability properties and strength properties.

1. Cube specimens of 150X150X150mm are prepared to determine compressive strength of conventional concrete, Concrete with E-waste at 0, 5, 10, 15 & 20%, and slag sand as 100% replacement to fine aggregate.
2. Cylindrical specimens of diameter 150mm and length 300 mm are prepared to determine split tensile strength of plain concrete, Concrete with E-waste at 0, 5, 10, 15 & 20%, and slag sand as 100% replacement to fine aggregate.
3. Beam specimens of 500X100X100 mm are prepared to determine flexural strength of plain concrete, Concrete with E-waste at 0, 5, 10, 15 & 20%, and slag sand as 100% replacement to fine aggregate.

4. RESULTS & DISCUSSIONS

4.1. FRESH PROPERTIES OF CONCRETE

The workability properties of freshly mixed concrete were assessed through both the slump cone test and the compaction factor test for all five groups of concrete mixes. The results followed trends for the conventional concrete mix, the slump value measured 75 mm. interestingly, as the proportion of E-waste gradually replaced coarse aggregate at rates of 0%, 5%, 10%, 15%, and 20%, the slump value steadily increased. At the 20% E-waste replacement level, the slump value reached 95 mm depicted in figure 1.

A similar trend was observed in the compaction factor test. The conventional concrete exhibited a compaction factor of 0.81. However, as the coarse aggregate was progressively substituted with E-waste at the specified rates (0%, 5%, 10%, 15%, and 20%), the compaction factor exhibited a gradual increase. At the 20% E-waste replacement level, the compaction factor measured 0.89 depicted in figure 2.

Table 1. Variation of Slump

% of E-waste	Slump in mm	Workability property
0	75	Medium
5	81	Medium
10	86	Medium
15	90	Medium
20	95	Medium

Table 2. Variation of Compaction factor

% of E-waste	Compaction Factor	Workability property
0	0.81	Low
5	0.83	Low
10	0.84	Low
15	0.87	Medium
20	0.89	Medium

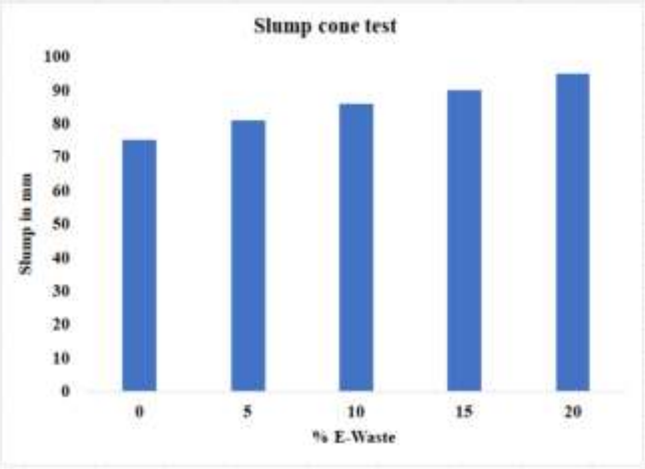

Fig 1. Variation of Slump

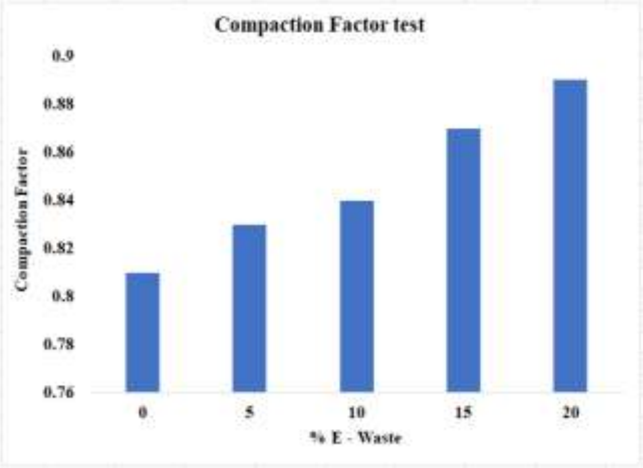

Fig 2. Variation of Compaction factor

4.2. HARDENED PROPERTIES OF CONCRETE

The table 3 presents the compressive strength data for curing periods of 7, 14, 21, and 28 days. It is evident that the conventional mix achieved a compressive strength of 36.57 N/mm². Notably, the mix incorporating 10% E-waste replacement in conjunction with 100% slag sand as a substitute for natural sand surpassed all other mixtures, attaining a compressive strength of 39.54 N/mm², depicted in figure 3. This represents an enhancement of 8.122% in compressive strength at 28 days.

Table 3. Variation of Compressive strength

% of E waste	7 Days	14 Days	21 Days	28 Days
0	15.48	21.13	26.48	36.57
5	16.80	23.58	27.56	37.67
10	17.89	24.61	28.98	39.54
15	16.12	22.17	26.22	38.17
20	14.23	20.65	24.54	35.89

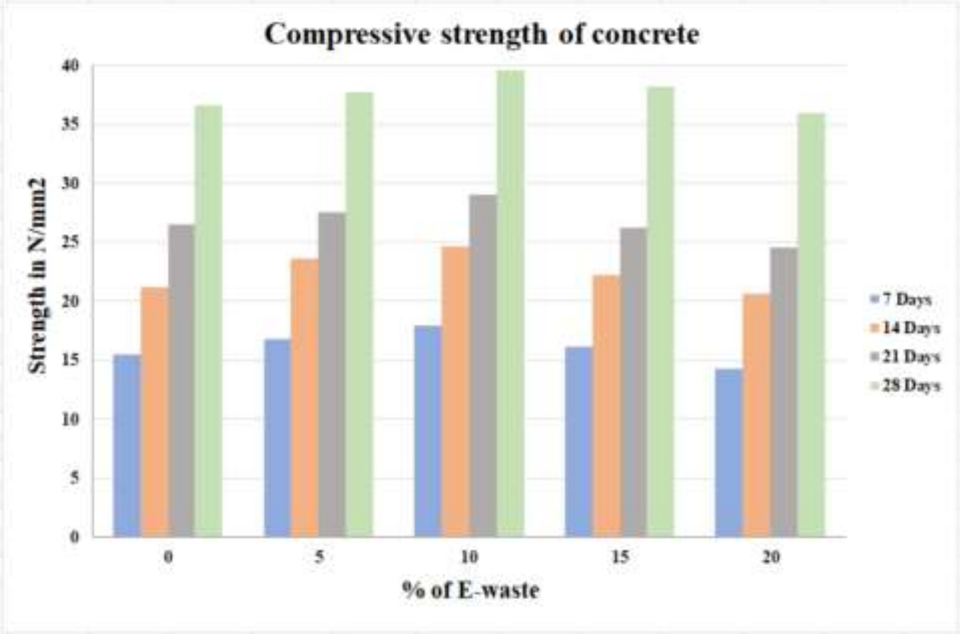

Fig 3. Variation of Compressive strength

The table 4 presents the split tensile strength values for curing periods of 7, 14, 21, and 28 days. It is evident that the conventional mix exhibited a split tensile strength of 4.87 N/mm². Remarkably, the mix incorporating 10% E-waste replacement alongside 100% slag sand as a substitute for natural sand outperformed all other mixtures, achieving a split tensile strength of 5.34 N/mm², depicted in figure 4. This represents an enhancement of 9.65% in split tensile strength at 28 days.

Table 4. Variation of Split tensile strength

% of E waste	7 Days	14 Days	21 Days	28 Days
0	4.28	4.67	4.75	4.87
5	4.52	4.81	4.89	5.01
10	4.72	5.02	5.12	5.34
15	4.62	4.73	4.88	5.14
20	4.53	4.63	4.77	5.03

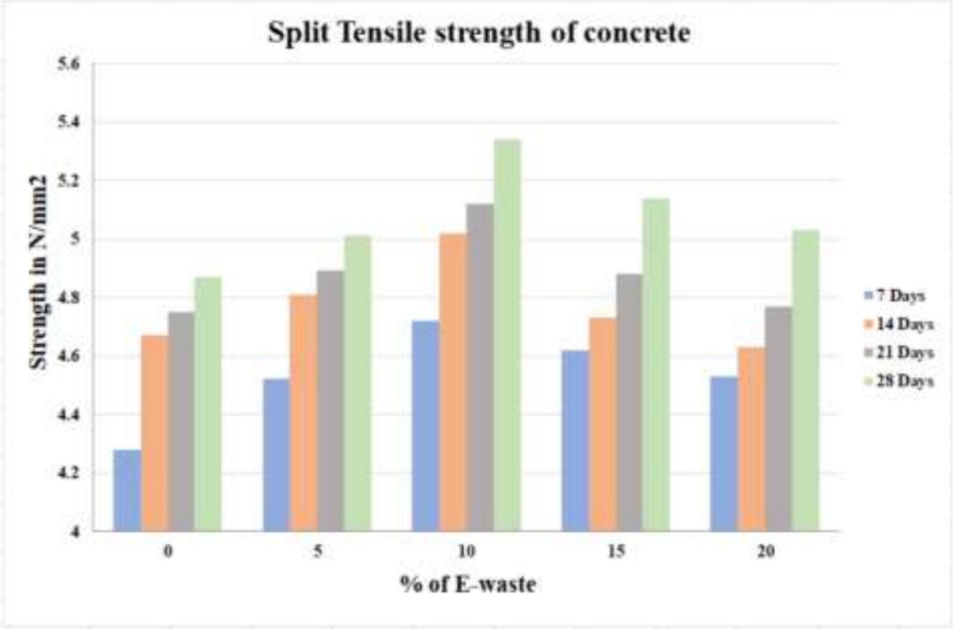

Fig 4. Variation of Split tensile strength

The table 5 presents the flexural strength values for curing periods of 7, 14, 21, and 28 days. It is evident that the conventional mix achieved a flexural strength of 8.23 N/mm². Notably, the mix incorporating 10% E-waste replacement in conjunction with 100% slag sand as a substitute for natural sand surpassed all other mixtures, attaining a flexural strength of 9.11 N/mm², depicted in figure 5. This represents an enhancement of 10.69% in flexural strength at 28 days.

Table 5. Variation of Flexural strength

% of E waste	7 Days	14 Days	21 Days	28 Days
0	5.31	7.84	7.91	8.23
5	5.62	8.16	8.27	8.43
10	5.88	8.82	8.95	9.11
15	5.53	7.73	7.92	8.33

20	5.01	7.49	7.67	7.95

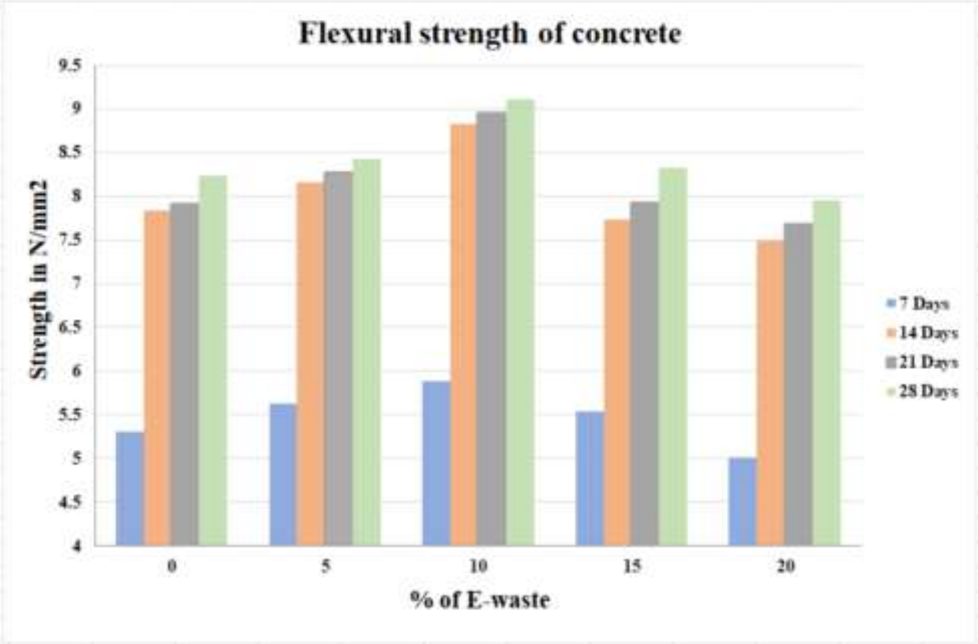

Fig 5. Variation of Flexural strength

5. CONCLUSIONS

After analyzing the workability at fresh state and strength properties over the curing period of 7, 14, 21 & 28 days the following conclusions are made.

1. The Workability results show that for the conventional concrete mix, the slump value measured as 75 mm. interestingly, as the proportion of E-waste gradually replaced coarse aggregate the slump value steadily increased and reached 95 mm maximum at the 20% E-waste replacement.
2. The Workability results show that for the conventional concrete mix, the compaction factor value measured as 0.81. Interestingly, as the proportion of E-waste gradually replaced coarse aggregate the slump value steadily increased and reached 0.89 maximum at the 20% E-waste replacement.
3. The workability properties varied due to the presence of E-waste, which has smooth surfaces. These smooth surfaces increase the overall smoothness and surface area of the particles, thereby allowing the concrete paste to maintain its fresh state for a longer duration.
4. The mix incorporating 10% E-waste replacement in combination with 100% slag sand as a substitute for natural sand achieved the highest compressive strength, reaching 39.54 N/mm². This represents an improvement of 8.112% in compressive strength at 28 days curing compared to conventional mix.
5. Among all the mixtures, the combination of 10% E-waste replacement and 100% slag sand as a replacement for natural sand yielded the highest split tensile strength, measuring 5.34 N/mm². This represents an enhancement of 9.65% in split tensile strength at 28 days curing compared to conventional mix.
6. The mix featuring 10% E-waste replacement along with 100% slag sand as a substitute for natural sand displayed the highest flexural strength among all combinations, reaching 9.11 N/mm². This represents an improvement of 10.69% in flexural strength at 28 days curing compared to conventional mix.

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