STRENGTH AND SUSTAINABILITY ASSESSMENT OF CONCRETE BLENDED WITH E-WASTE AND MARBLE POWDER

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ABSTRACT

The global construction industry is increasingly adopting sustainable practices to address environmental concerns and material scarcity. This study investigates the partial replacement of fine aggregates and cement in concrete with electronic waste (E-waste) and marble powder, respectively, aiming to develop a green and cost-effective concrete mix. The experimental program includes the preparation of multiple concrete mixes with varying proportions of E-waste and marble powder. The mechanical properties—such as compressive strength, flexural strength, and split tensile strength—are evaluated at different curing periods. The results show that incorporating up to a certain percentage of E-waste and marble powder can enhance strength properties while significantly reducing environmental impact by diverting non-biodegradable waste from landfills. This study highlights the potential of these industrial byproducts in producing eco-friendly concrete, supporting circular economy goals in the construction sector.

1. INTRODUCTION

Rapid urbanization and technological advancements have led to a surge in construction activities and electronic consumption, generating massive amounts of construction debris and E-waste. These materials, if not properly managed, contribute to land pollution, toxic leachates, and resource depletion. At the same time, the cement industry is responsible for approximately 8% of global CO_2 emissions. This dual challenge has encouraged researchers to explore sustainable alternatives to conventional construction materials.

Among these, E-waste (primarily non-recyclable plastic and PCB fragments) offers a potential substitute for fine aggregates, while marble powder, a byproduct of the marble industry, shows promise as a partial replacement for cement. Both materials are readily available, inert, and non-biodegradable—making them ideal candidates for value-added reuse in concrete.

This research focuses on assessing the strength and sustainability performance of concrete mixes containing E-waste and marble powder. The primary objective is to evaluate how these replacements affect mechanical properties and whether they can meet the performance criteria of structural and non-structural applications. By using waste as a resource, this study contributes to waste minimization, material conservation, and environmentally sustainable construction practices.

2. LITERATURE REVIEW

Sunil Ahirwar et.al The waste materials that come from the construction field can also be reused that gives better economic and environmental benefit. Sunil Ahirwar along with his colleagues tried to make the best out of e-waste as they inappropriately found rapid disposal of Electronic-waste. So, they tried the including the e-waste into coarse aggregate replacement. The aim of their study was the investigation of the change in mechanical Behaviour & Properties of concrete when the addition of E-Waste is done in concrete. The Coarse aggregate is replaced partially by E-waste in 0% to 30% proportions. They also included 10, 20, and 30 Percent of flyash partially replacing the cement. As per the tests conducted on various specimens made with different percentage inclusions of e-waste and fly ash as partial replacement of coarse aggregate and cement respectively, they have come to results: 30% of cement replacement with fly ash along with electronic waste gives the best result. The strength of concrete increased by 17.8% by the inclusion of 7.5% e-waste. Many favorable results were obtained like concrete is lightweight and thus the weight of the structure is reduced. Workability was increased as increase in percentage inclusion of e-waste. Makes concrete more flexible and hence bear seismic loads. They concluded that E- waste can be used replace the coarse aggregate somewhere between 10 – 20%.

Manikandan et.al Manikandan along with his team focused on the improper disposal of e-waste. In our Country (India), primary source of Electronic waste generated was from public & private sector which are 70% from the total waste being generated. The annually estimated generation of E-waste was around 4,00,000 tons. It is found that most of the e-waste generated is from cities like Bombay, Delhi, Bengaluru, and Madras was estimated approx. 10,000 , 9,000, 8,000 ,and 6,000 Tonnes Respectively. only 4% of total waste generated is recycled per annum, it’s a disappointment. So, they made efforts for usage of E-waste components as for partially replacing the coarse(10-12) mm Aggregate. The major conclusions drawn by them are: Density of Electronic Waste as Replacement of Coarse or Fine Aggregate in concrete is less when compared to Existing Normal or Conventional concrete as resulting in the lightweight blocks emerge which also reduced the cost of concrete blocks. Up to 15% replacement is allowable as it increased compressive strength and durability compared to conventional concrete.

2.3 Objective of the study

The present study deals with the replacement of coarse aggregate with E-waste in the range of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% and replacement of cement with marble powder by 15% in the preparation of M20 grade concrete mix.

1. To study the effect of adding different percentages of coarse aggregates replacement with E-Waste (0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%) and 15% cement replacing with marble powder.
2. To determine the workability of freshly prepared concrete by Slump Test.
3. To determine the compressive strength of cubes at 7, 14, 28 days curing

3. EXPERIMENTAL WORK

3.1 Materials Used

- Cement
- Coarse Aggregates
- Fine aggregates
- Water
- E waste (Electronic waste)
- Marble dust

Cement

Cement used in the investigation was found to be Ordinary Portland Cement (53 grade) confirming to IS: 12269 – 1987.

Table. 1: Physical properties of cement.

Property	Result
Standard Consistency	34%
Initial Setting Time	41min
Final Setting Time	315min
Specific gravity	3.10

Aggregates

Coarse aggregates: The coarse aggregate used is from a local crushing unit having 20mm nominal size. The coarse aggregate confirming to 20mm well-graded according to IS:383-1970 is used in this investigation.

Fine aggregates: The fine aggregate used was obtained from a nearby river course. The fine aggregate confirming to zone – II according to Is 383-1970 was used.

Table .2: Physical properties of fine aggregates & coarse aggregates.

Property	CA	FA
Water absorption	0.7%	0.3%
Specific gravity	2.67	2.55
Impact value	8%	-
Crushing value	14.21%	-

Water

Water is an important ingredient of concrete as it participates in the chemical reaction with cement. Water cement ratio used in the mix is 0.50.

E – Waste (Electronic waste)

E-waste refers to electronic products nearing the end of their "useful life" for example, computers, televisions, VCRs, stereos, copiers, and fax machines. Many of these products can be reused, refurbished, or recycles. In this project this e-waste were crushed and used in the place of 20mm coarse aggregate.

Table .3 Physical properties of E – waste.

Properties	Values
Water absorption	0.04
Specific gravity	1.21
Crushing value	2.35%

Marble dust

Marble Powder is obtained from the transformation of pure limestone. The purity of marble depends upon the color of the marble. Since the ancient times, marble is widely used in monuments and historical buildings for decorative purpose. In India, tonnes of marble waste has been produced from the industries. But there are some impurities present in the waste that cannot be easily deposed off. Such type of impurities mixed with soil and water. When they mixed with soil it reduces the porosity and permeability of the soil. Also, if it mixes with water it pollute the water and make the water unfit for use. So, it is necessary to use the waste in functional manner.

Table. 4: Physical properties of marble powder.

Property	Value
Specific gravity	3.06
Fineness value	3%

3.2 METHODOLOGY

For this research project ordinary Portland cement of grade 54, river sand is used as fine aggregate, natural crushed aggregate is used as a coarse aggregate and crushed e-waste plastic of which is passed from 20 mm sieve and retained on 4.75 mm sieve is employed in this research project. As per IS 10262:2019 mix design is done. M20 mix prepared which contain 0% to 35% electronic waste as partial replacement to coarse aggregate along with this 15% Marble dust as a partial replacement of Cement. Once design of mix has been prepared then 150*150*150mm cubes is casted for these mixes, 9 cubes for each mix is casted which is going to tested after 7,14 and 28 days of curing i.e. total 81 cubes is casted.

3.3 Mix design

3.3.1 Mix Proportions

M20 grade of concrete is considered. Natural coarse aggregate is replaced with E-Waste with various percentages 0%, 5%, 10%, 15%, 20%, 25%, 30% & 35%. Cement is replaced with marble dust by 15%. The mix design for concrete is carried out as per IS 10262. Details of mix proportion for M20 concrete given below:

Table. 5: Individual weight of materials M20 grade.

Item name	**For 1 cube (gms)**
Cement	1496.88
Fine aggregates	2494.8
Coarse aggregates	5613.3
water	748.44

3.3.2 Mixed design proportions for Marble dust & E-Waste Concrete

- In this research work 15 Standard cubic specimens of size 150mm (nine sample for each percentage) were casted for the compressive strength of concrete and it was kept under curing for 7, 14 days & 28 days of age. Total cubes for compressive strength testing was 81 (9 cubes * 9 proportions).
- Mass of ingredients required will be calculated for 9 no's cubes assuming 10% wastage
- Volume of the Cube = $9*1.10*(0.15)^3 = 0.0334125\ m^3$

Table. 6: Material proportions cubes (M20).

MP - Ewaste	**0%-0%**	**15%-0%**	**15%-5%**	**15%-10%**	**15%-15%**	**15%-20%**	**15%-25%**	**15%-30%**	**15%-35%**
Cement (Kgs)	13.4712	11.45052	11.45052	11.45052	11.45052	11.45052	11.45052	11.45052	11.45052
Marble powder (kg)	0	2.02068	2.02068	2.02068	2.02068	2.02068	2.02068	2.02068	2.02068
water (lit)	7.409556	7.409556	7.409556	7.409556	7.409556	7.409556	7.409556	7.409556	7.409556
Fine aggregate (Kgs)	22.4532	22.4532	22.4532	22.4532	22.4532	22.4532	22.4532	22.4532	22.4532
E waste (kg)	0	0	2.5259	5.05197	7.577955	10.10394	12.6299	15.1559	17.68189
Coarse aggregate (Kgs)	50.5197	50.5197	47.9938	45.46773	42.9417	40.4157	37.8898	35.3638	32.83781

3.3.3 Sample Production

The cement, fine and coarse aggregates were weighted according to mix proportion of M_{20}. All are mixed in a bay until mixed properly and water was added at a ratio of 0.5. The water was added gradually and mixed until homogeneity is achieved. Any lumping or balling found at any stage was taken out, loosened and again added to the mix.

For the second series of the mixture, the marble dust was added at 5%, 10%, 15%, 20% ,25%, 30% and 35% by weight of coarse aggregates and the marble dust was added 15% by the weight of cement. Immediately after mixing, slump test was carried out for all the concrete series mixture. A standard 150×150×150mm cube specimen were casted.

The samples were then stripped after 24hours of casting and are then be ponded in a water curing. As casted, a total of (91) 150×150×150mm cubes specimens were produced.

3.3.4 Curing

The method of curing adopted was the ponding method of curing and produced samples were cured for cubes at 7days, 14days, 28 days and beams at 28days.

3.4 Test for Fresh Properties of Concrete (Workability Test)

Slump Test

which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability, nor is it always representative of the placability of the concrete. It is not a suitable method for very wet or very dry concrete. It does not measure all factor contributing to workability. The slump test was carried in accordance with B.S:1882 PART2:1970.

3.5 Test for Harden Properties of Concrete

Compressive Strength of Concrete (IS 516-1959)

The compression test was conducted according to IS 516-1959. This test helps us in determining the compressive strength of the concrete cubes. The obtained value of compressive strength can then be used to assess whether the given batch of that concrete cube will meet the required compressive strength requirements or not. For the compression test, the specimen's cubes of 15 cm x 15 cm x 15 cm were prepared by using hwa concrete as explained earlier. These specimens were tested under universal testing machine after 7 days, 14 days and 28 days of curing. Load was applied gradually at the rate of 140kg/cm^2 per minute till the specimens failed. Load at the failure was divided by area of specimen and this gave us the compressive strength of concrete for the given sample.

4. RESULTS AND DISCUSSIONS

4.1 Comparative graphs for E-waste and Coarse aggregates

The results for material test on, water absorption test, specific gravity test, aggregate crushing value test, aggregate impact value test are given below.

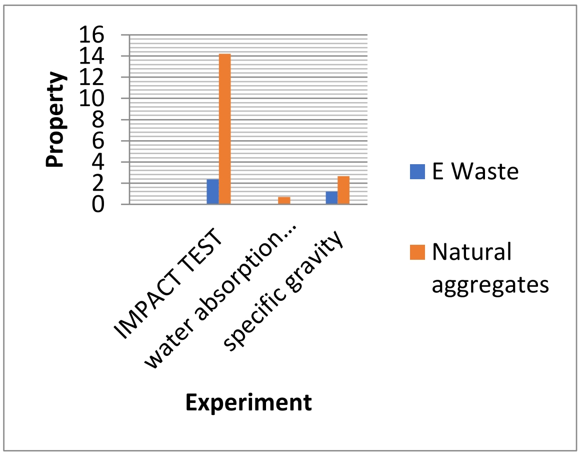

Fig. 1: Aggregates and E waste comparison with testing.

From the above graph, it observe that the mechanical properties (Crushing & Impact value) of e waste more than normal natural aggregates. The water absorption value of E- waste approximately zero.

4.2 Fresh Properties of Concrete

Slump Test

The Slump test was performed on the E-Waste & Marble concrete to check the workability of it at different replacements viz. 5 % - 35% by coarse aggregates and 15% by Cement, the following results were obtained, according to which it can be concluded that with the increase in % E - Waste from 0 to 35 % , workability increases. The results obtained for Slump test are shown below in Table 7.

Table. 7: Results of slump test.

Mix	Marble dust% - Ewaste%	Slump value (cm)
M1	0% - 0%	60
M2	15% - 0%	70
M3	15% - 5%	73
M4	15% - 10%	77
M5	15% - 15%	82
M6	15% - 20%	84
M7	15% - 25%	87
M8	15% - 30%	90
M9	15% - 35%	95

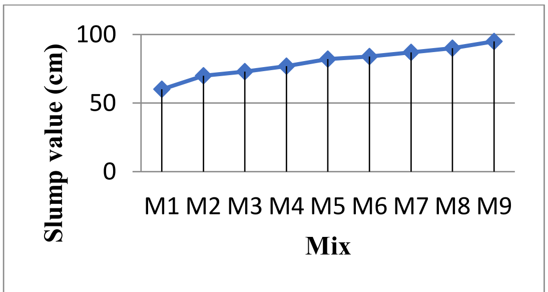

Fig. 2: Slump test results.

The above fig. 2 shows the slump results. It was observed that, the slumps increases as the E-WASTE content were increased in the mix.

4.3 Harden properties of concrete

Compressive Strength Test

The compressive strength test was performed on the cubes of size 15 cm x 15 cm x 15 cm to check the compressive strength of E - Waste & MD concrete and the results obtained are given in Table 8.

Table. 8: Results of compressive strength test.

Mix	Marble dust% - Ewaste%	Compressive strength of cubes (Average results)		
		7 days (N/mm^2)	14 days (N/mm^2)	28 days (N/mm^2)
M1	0% - 0%	15.32	20.1	24.2
M2	15% - 0%	17.57	22.86	26.45
M3	15% - 5%	17.02	22.57	25.98
M4	15% - 10%	16.53	21.21	24.31
M5	15% - 15%	14.95	19.48	22.92
M6	15% - 20%	12.68	17.72	20.43
M7	15% - 25%	11.21	15.37	18.23
M8	15% - 30%	9.32	13.82	16.43
M9	15% - 35%	8.5	12.68	15

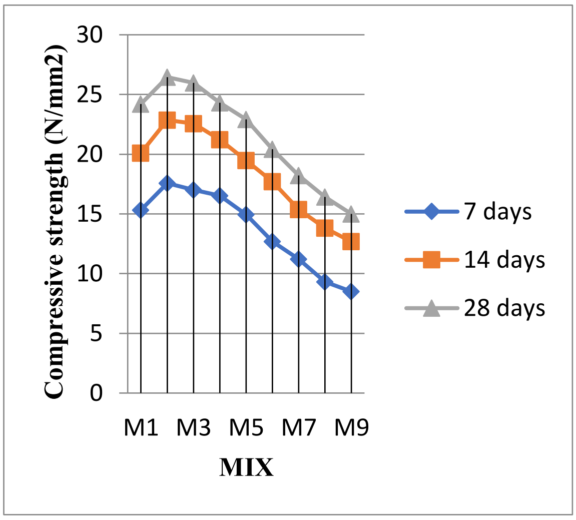

Fig. 3: Compressive strength v/s mix.

From the above results it was observed that with the increase in percentage of E-Waste from 5% and 10% in concrete the compressive strength more than control mix (M1).

5. CONCLUSIONS

The experimental investigation confirms that E-waste and marble powder can be effectively used as partial replacements for fine aggregates and cement, respectively, in concrete production. At optimal replacement levels, the modified concrete demonstrates comparable or enhanced compressive, flexural, and tensile strengths relative to conventional concrete. Moreover, the utilization of these waste materials promotes sustainability by reducing landfill burden, conserving natural resources, and lowering the carbon footprint of concrete.

The findings support the feasibility of integrating non-biodegradable and industrial waste into mainstream construction materials without compromising performance. However, proper sizing, treatment, and proportioning of E-waste are essential to ensure workability and long-term durability.

In conclusion, the adoption of E-waste and marble powder in concrete provides a practical approach toward achieving green construction goals, supporting environmental stewardship and circular economy initiatives. Future studies may explore durability characteristics, life cycle assessment, and field-scale validation to broaden the scope of application in real-world infrastructure projects.

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