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The effect of waste electronic plastics and waste marble dust as a partial aggregate replacement on concrete

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Abstract

Concrete is the most abundant material used in construction on present scenario where aggregates comprise of about three-fourth volume of concrete. On 2019, 28 Mt of E-waste generation was recorded in Nepal and its management has created a burden to the landfill sites. Also, marble dust is a waste obtained during processing and installation of marble which can be used as filler or fine aggregate in concrete for strength enhancement. Utilization of crushed E–waste plastics and waste marble dust in concrete will introduce a green and environment friendly method of construction without any compromise in the utility parameter and would represent positive effect to minimize the environmental degradation and replace naturally available aggregates which are continuously been used. The strength effects of waste electronic plastics and waste marble dust as aggregate replacement in concrete was studied in this research. For this study, 12 sets of concrete mixes were prepared with constant water cement ratio of 0.55. Marble dust was used as a sand replacement at 2.5%,5%,7.5% and 10% by volume of sand. Further 2 sets of 4% and 6% replacement of sand by marble dust was prepared to find out the optimum value as 5% replacement showed greater compressive strength. E-wastes plastics were then used as replacement to coarse aggregate at 1%, 2%, 3%, 4% and 5% along with 5% replacement of sand by waste marble dust. The workability test, compressive strength and flexural test of the mixes were determined. Based on the study, result showed that the compressive strength at 5% replacement of sand by marble dust was maximum while E-waste plastics replaced up to 4% had compressive strength greater than that of nominal mix concrete of grade M20. Flexural strength also increased of concrete containing E-plastic than that of normal concrete.

1. Introduction

Electronic Wastes are the unwanted waste materials that has been discarded and has a harmful effect on environment. Marble dust are the waste obtained during sawing, shaping, and installation of marble which can be used in concrete for strength enhancement. The use of natural aggregates on construction materials such as sand and stones has resulted in its reduction and hence finding other alternative aggregate sources has a wide scope. Use of natural aggregates in construction works has also resulted in depletion of natural resources, increased pollution and flooding, lowered groundwater level and affected marine life.

In 2019, the global generation of E-wastes was 53.6 MT of e-waste, which on average is 7.3 kg per capita [1]. Also, the global generation of e-waste grew by 9.2 MT since 2014 and is projected to grow to 74.7 MT by 2030 doubling in only 16 years. Only 20% of E-wastes are documented to be collected and recycled properly [2]. On context of Nepal, E-wastes of 28 metric kilotons was produced in the year 2019 and an average per person generation was 900gm of E-waste [3]. The Solid Waste Management Act 2011 also does not separately mention management of E-waste as it does for industrial and hazardous waste. Hence, finding alternate ways to reuse the waste plastics from E-waste is very important for environmental sustainability. On the other hand, marble dust is an industrial by-product and a waste obtained during production and installation of marble which has negative impact on the environment. If the suitability is

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confirmed, use of marble dust on concrete would significantly reduce the volume of waste pile in the dumping sites along with the decreased use of mineral aggregate in the concrete. Marble dust being a limestone origin has chemical behavior similar to that of Cement as shown in Table 1 and can be used as fine aggregate in concrete for strength enhancement. Previously researchers have tried to utilize e plastics and waste marble dust as filler as well as an aggregate replacement. [4] researched on replacing the coarse aggregate by e-waste and found that replacement of e-waste along with fly ash showed better strength than to that of only replacing aggregates with e-wastes. Both mix had decrease in strength up to 33%. [5] studied sustainable use of slurry marble partially replacing Portland cement by marble slurry up to 25 and concluded that replacement of 10% achieved concrete grade of M40. Marble dust was used as fine aggregate by [6] and found that replacement of sand with marble dust achieved compressive strength 10% greater at 28 days.

Table 1: Chemical Composition (%) of cement and waste marble dust

Chemical Composition	Cement	Marble Dust
Calcium Oxide (Cao)	65.3	41.54
Silicon di oxide (SiO2)	22.06	5.87
Aluminium Oxide (Al2O3)	6.13	0.56
Iron Oxide (Fe2O3)	2.57	0.8
Sulphur Trioxide (SO3)	1.25	0.11
Magnesium Oxide (MgO)	0.81	15.55
Potassium Oxide (K2O)	0.45	0.073
Sodium Oxide (Na2O)	0.9	0.07

In this study the main objective is to find out the effect of using waste electronic plastic as a partial coarse aggregate replacement and waste marble dust (WMD) as a partial fine aggregate replacement by volume on hardened properties of Concrete(M20). This study also targets at reducing the use of natural resources aggregates on concrete and minimize environmental impacts caused by e waste plastics and waste marble dust.

2. Experimental program

Waste marble dust and E-waste plastics were chosen as aggregates replacement for making of concrete cubes of mix at different proportions. 9 concrete cubes were prepared for each mix to check compressive strengths at 7,14 and 28 days respectively. Initially, the range of proportion of marble dust was 2.5, 5.0, 7.5 and 10% respectively replacing fine aggregate. As 5% replacement showed the greatest strength, further two mixes at 4% and 6% replacements were tested in order to find out the optimum replacement level. E-waste plastics were added at 1, 2, 3, 4 and 5% respectively replacing coarse aggregate to the optimum mix from previous sets i.e., 5% replacement of sand by waste marble dust.

2.1. Materials

The cement used was Ordinary Portland cement (OPC): 53grade Cement, with fineness of cement 6.68%. Quarry sand was used after washing which confirm the grading of IS 383-1970. Aggregates passing through 20 mm down size were used whose grading confirms to that of IS 383-1970. E-waste plastics used in the study were collected from local electronic repair store and shredded to required size i.e., passing through 20mm sieve to replace coarse aggregate. Marble waste was collected from construction site at Baluatar and was used as partial replacement of fine aggregates. The marble waste was generated during cutting of marble slabs into required shapes and sizes at site.

2.2. Mix proportions

Nominal mix design for M20 concrete, i.e., 1:1.5:3 proportion of cement, sand and coarse aggregate were used respectively. The water-cement ratio provided was 0.55 to ensure sufficient workability. Further, on next mixes, waste marble dust was used as partial replacement of natural river sand. The replacement was done a range of 2.5% to 10%. After the optimum value was obtained, the use of E-waste plastics as coarse aggregate replacement was done at a range from 1% to 5% with the optimum mix. Table 2 shows details of mix proportions.

2.3. Specimen preparation and test method

The study focused on examining fresh property of concrete with slump value test and hardened properties with compressive and flexural strength test. Workability test was carried out for all the mixes using a metal mould in the shape of a conical frustum known as a slump cone or Abrams cone as per IS 1199-1959.

Cubes of 150 mm size were cast and compacted for 7,14- and 28-days compressive strength test. After 24 hours, the samples were taken out from moulds and immersed in water for curing.

Also, concrete specimen for flexural strength was prepared with dimensions 150mm width, 150mm depth and 700mm length and tested for 28 days flexural strength.

3. Result and discussions

3.1. Workability

Workability test was conducted as per IS 1199:1959. The workability of normal mix concrete was obtained

Table 2: Details of mixing criteria

S.N.	Symbol	Description
1	MD 0	Control Mix
2	MD 2.5	Marble Dust-2.5 % replacement of sand
3	MD 4	Marble Dust-4 % replacement of sand
4	MD 5	Marble Dust- 5 % replacement of sand
5	MD 6	Marble Dust- 6 % replacement of sand
6	MD 7.5	Marble Dust-7.5 % replacement of sand
7	MD 10	Marble Dust-10 % replacement of sand
8	MD5 E0 or MD5	Marble Dust-5 % replacement of sand & E-plastics- 0% replacement
9	MD5 E1	Marble Dust-5 % replacement of sand & E-plastics- 1% replacement of coarse aggregate
10	MD5 E2	Marble Dust-5 % replacement of sand & E-plastics- 2% replacement of coarse aggregate
11	MD5 E3	Marble Dust-5 % replacement of sand & E-plastics- 3% replacement of coarse aggregate
12	MD5 E4	Marble Dust-5 % replacement of sand & E-plastics- 4% replacement of coarse aggregate
13	MD5 E5	Marble Dust-5 % replacement of sand & E-plastics- 5% replacement of coarse aggregate

67mm. It can be observed that workability of the mix decreases with the addition of waste marble dust as shown in Figure 1. The decrease in workability is because of waste marble dust angular form and smaller size that absorbs more water than sand.

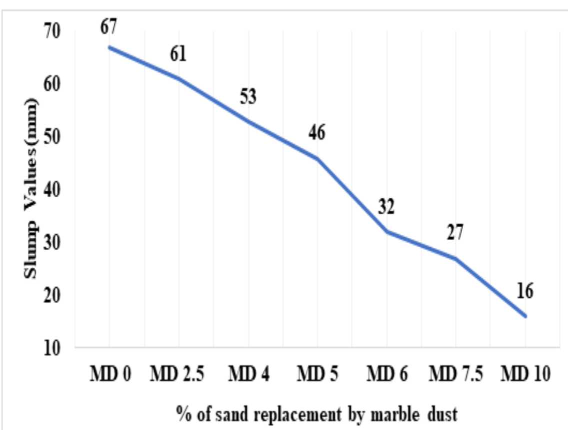

Figure 1: Workability test for different percentage of Waste Marble Dust

Also, on addition of E-plastics, the workability of the mix showed nonlinear increment as shown in Fig 2. The increase in workability is due to smooth and slippery nature of E-plastics. E-plastics does not absorb water and does not have any binding properties, hence increases the water content and the workability of the concrete. The slump values at 1%, 2%, 3%, 4% and 5% replacement of coarse aggregate by E-plastics were 48mm, 53mm, 57mm, 61mm and 65mm respectively as shown in Figure 2.

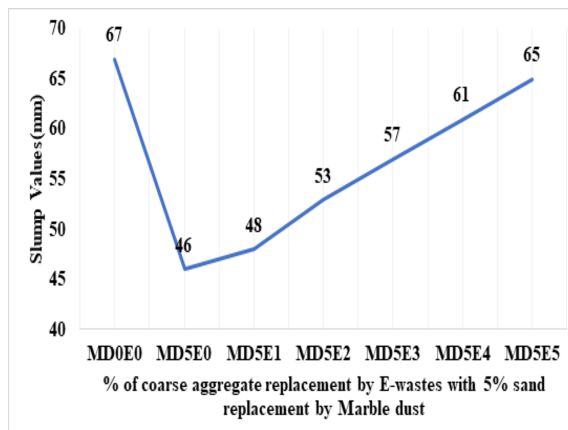

Figure 2: Workability test for different percentage of E-Wastes

3.2. Compressive strength

For a normal mix concrete of M20, the compressive strength of 21.23 MPa was obtained at 7 days. At 14 days and 28 days of curing period, compressive strength was 25.88 MPa and 28.89 MPa respectively. With addition of waste marble dust, compressive strength gradually increased up to 5% replacement of sand. On further replacement, compressive strength decreased and at 10% replacement, the strength was less than the nominal grade concrete. The compressive strength for replacement of sand by waste marble dust at 2.5%, 4%, 5%, 6%, 7.5%, and 10% was 30.18 MPa, 30.65 MPa, 32.44 MPa, 31.33 MPa, 30.37 MPa and 28.77 MPa respectively for curing period of 28 days as shown in Figure 3. The increase in strength up to 5% replacement is due to smaller size, angular form and cementitious behaviour of waste marble dust which helped in better bonding. The decrease in strength after 5% replacement can be due to decrease in workability of the mix which decreased on addition of waste marble dust. Decrease in workability resulted in rough and non-uniform mix of concrete resulting decrease in strength. Also, the chemical composition of waste marble dust contains

Magnesium oxide at 15.5% which decreases the strength at higher mix proportions.

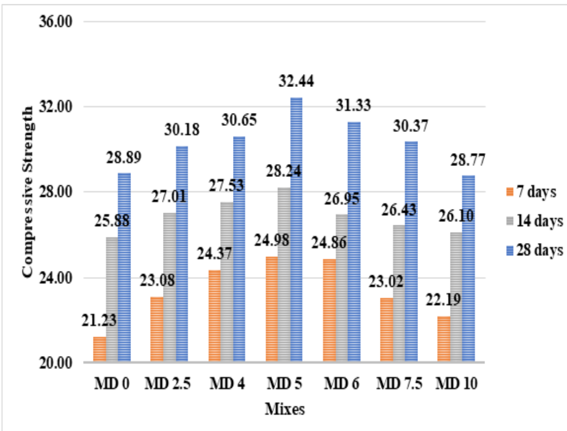

Figure 3: Compressive strength test for different percentage of Waste Marble Dust

The next sets of mixes were addition of E-plastics with this optimum value i.e., 5% of sand replacement by waste marble dust. On addition of E-plastics to the optimum mix from previous set, it was discovered that the compressive strength decreased with increased percentage of E-plastics as shown in Figure 4. The compressive strength at 1%, 2%, 3%, 4% and 5% replacement of coarse aggregate by E-plastics with replacement of 5% sand by waste marble dust was found to be 31.17 MPa, 30.34 MPa, 29.63 MPa, 28.95 MPa and 27.13 MPa respectively while for a normal mix concrete, it was 28.89 MPa. The decrease in strength on addition of E-plastics was due to flaky and elongated structure of E-plastics and inability of E-plastics to absorb water which increases the water cement ratio and thus decreases the strength.

This result showed that by using 5% of waste marble dust as a fine aggregate in concrete, E-waste plastics up to 4% can be added to the mix without compromising the compressive strength of the nominal grade concrete of M20. This was a major finding of this study.

3.3. Flexural strength

Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending. From the compressive strength test, it was verified that the replacement of 5% sand by waste marble dust with replacement of coarse aggregate up to 4% E-plastics showed 28-days compressive strength greater than that of normal mix concrete. So, flexural strength test was carried out on the comparison of the nominal M20 concrete with that of the one mixed with 5% waste marble dust and 4%

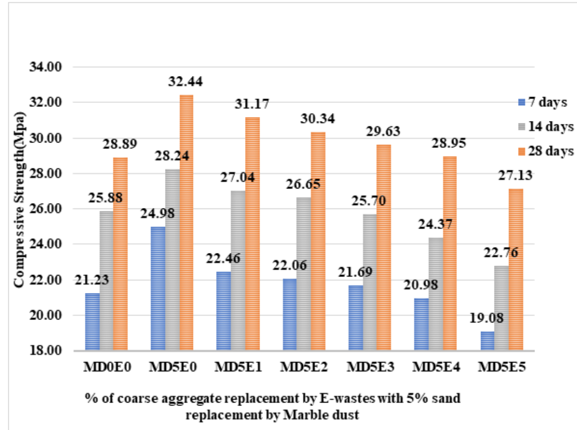

Figure 4: Compressive Strength test for different percentage of E-Wastes and 5% replacement of Marble Dust

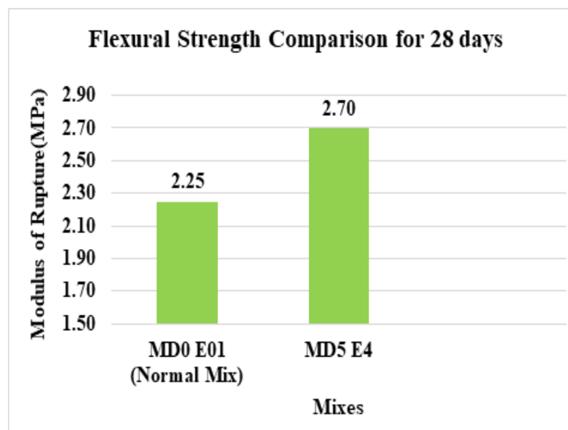

Figure 5: Flexural strength test comparison

E-plastics. 3 samples for each mix were prepared and average value was found out.

From Figure 5, it can be observed that the average modulus of rupture of the concrete mixed with waste marble dust and E-plastics is greater than that of the unmixed concrete. This might be because of the angular shape of waste marble dust resulting in high bonding effect. Also, E-plastics fibers being fibrous material, bridge over the cracks developed during the process of flexure cracking and provide further resisting strength before the complete failure. The experimental setup for compressive strength test and flexural strength test is shown in Figure 6 and 7 respectively.

4. Conclusion

The purpose of this study was to examine the strength effects of waste electronic plastics and waste marble

Figure 6: Experimental setup for compressive strength test

Figure 7: Experimental setup for flexural strength test

dust in concrete. The workability of concrete decreases with the increase in percentage of waste marble dust and increases with increased percentage of E-waste plastics. The reason for this was because of the smaller size of particles of WMP which required high volume of water for wetting and mixing of particles and due to absence of binding properties of E-waste plastics. The test results also showed that waste marble dust can be used as a fine aggregate material in concrete up to 7.5% which increases the compressive strength of concrete as compared to nominal mix grade of M20. Highest strength was observed at 5% usage of waste marble dust. The flexural strength was greater of the concrete mix consisting waste marble dust and E-waste plastics than that of normal concrete. Increase in flexural strength was due to cementitious nature of waste marble dust and fibrous nature of E-waste plastics which bridges over the cracks. As the study was carried out on M20 grade, the usage of this type of concrete can be done on structures bearing less loads such as PCC works on grounds, kerb stones on roads etc. Evaluation of strength at longer duration can be carried out to find long term effect of waste marble dust and E-waste plastics in concrete. The durability characteristics should be studied in future to ensure suitability of this type of concrete.

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