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INFLUENTIAL ASSESSMENT OF MACRO SYNTHETIC FIBERS ON MECHANICAL PROPERTIES OF CONCRETE CONTAINING E- WASTE COARSE AGGREGATES

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Abstract- In this modern era, concrete has become a basic construction material whose production on large scale, is leading towards the huge usage of natural resources. That is why, the natural resources are going on depletion consistently. To overcome this fact, it has become essential to find out alternate resources for the ingredients of concrete. Usage of non-biodegradable waste items is one of the sustainable solutions. However, some researchers are working on the fruitful utilization of electronic waste in concrete as a partial substituent for coarse or fine aggregates. Basically, electronic wastes or E-wastes are any electronic appliances that have paid off their effective working life e.g. discarded old computers, CDs, VCRs, TVs, radios. In this experimental-based investigation, shredded electronic waste materials are utilized as coarse aggregates in concrete with a constant volume replacement of 30%. Moreover, to overcome the brittle nature of concrete, polypropylene macro synthetic fibers are used in concrete. Results show that the fibrous materials have a better effect on the mechanical performance of E-waste aggregated concrete. The addition of 0.75% fibrous material in concrete increases the compressive strength of E-waste aggregated concrete about 30% while tensile strength increases about 75% as compared to the reference specimen. Main purpose of this research work is to reduce the high consumption of natural resources of ingredients of concrete by the utilization of E- waste material as coarse aggregates in concrete.

Keywords- macro synthetic fiber, reference specimen, relative density, shredded E-waste.

1 Introduction

In the construction industry, concrete is a highly used building material. High compressive strength and adorable durability of concrete are the basic reasons behind its immense usage in the construction industry. Conventional concrete is a mixture of cement, sand, crushed stones, and water. That is why the huge consumption of concrete is leading towards the depletion of natural resources around the globe [1]. Being a citizen of this global village, it is our responsibility to save the natural resources for maintaining the matchless beauty of our planet.

In this undeniable scenario, several researchers are struggling to seek out new suitable resources for the ingredients of concrete. Effective utilization of recycled aggregates, by-products of various industries, waste materials, synthetic aggregates, etc. in concrete production, is the fruitful effort of researchers. Usage of those waste materials makes our environment healthy. Since from last few decades, many researchers are working on the effective usage of electronic waste materials in concrete production [2]. Electronic waste is the non-biodegradable waste that consists of discarded old computers, CDs, VCRs, TVs, radios etc – basically, any electronic appliances that have completed their working life.

Manjunath et al. [3] replaced the coarse aggregate of conventional concrete with electronic waste coarse aggregate upto 30% by volume. It is observed that compressive strength of concrete reduces with the increase of percentage of E-waste aggregate. But its split tensile strength increases upto 17% at 20% replacement. Kalpana [4] replaced the fine aggregate of conventional concrete with electronic waste in powdered form upto 30% by volume. It is observed that all strengths of modified concrete become optimum at 20% replacement of fine aggregate of E-waste material. It is also observed that use of E-waste in conventional concrete somehow reduces its brittle nature by improving its ductility.

Roy et al. [5] stated that the workability of concrete increased by adding E-waste coarse aggregate. Compressive strength reduces by increasing the percentage of E-waste. But, the compressive strength can be improved by using fly ash as a substitute of cement. So, there are multiple advantages of using fly ash in the e-waste aggregated concrete. On one side, it improves the strength of concrete while simultaneously on the other side; it causes a reduction in usage of cement and gives economical results as compared to conventional concrete.

Khubaib et al. [6] stated that the use of polypropylene fiber in concrete causes reduction in the workability as well as in compressive strength of concrete. At 0.5% (by concrete volume) usage of polypropylene fiber in concrete, the compressive strength reduced about 10% while split tensile strength improved about 8% as compared to conventional concrete. Guerini et al. [7] investigated the influence of polypropylene macro synthetic fiber and steel fiber usage in concrete. In that work, it is observed that the usage of steel fibers in concrete causes more bleeding as compared to macro synthetic fiber. Moreover, macro synthetic fibers highly improve all the strengths of concrete as compared to steel fiber. Results become optimum at the usage of 1% of fibers in concrete.

In this experimental-based investigation, shredded electronic waste materials are utilized as coarse aggregates in concrete with a constant volume replacement of 30%. Shape, size, and roughness of shredded electronic waste aggregates are relatively matching with that of the natural coarse aggregates. Shredded electronic waste coarse aggregates are much lighter than the natural coarse aggregates and have relative density (ratio of density of sample to density of reference) of 1.03 which results in the production of lightweight concrete. As, concrete is strong in compression but weak in tension, that is why polypropylene macro synthetic fibers are used to overcome the brittle nature of concrete.

2 Experimental Program

2.1 Materials

In this experimental-based research work, Ordinary Portland Cement (OPC) of grade 43 is used. Sand of Lawrance pur (local area) is used in this work. Crushed stones of Margalla hills are used as natural coarse aggregates (NCA) in concrete production. After purchasing the electronic waste from a local market from Rawalpindi, manufacturing of shredded electronic waste coarse aggregates (ECA) is performed in a nearby local factory. Gradation [8] of both NCA and ECA is kept almost the same. Their characteristics [9] are given in Table 1. Properties of MSF are given in Table 2.

Table 1 Properties of aggregates

Property	Sand	NCA	ECA
Bulk density (kg/m³)	1612	1578	524
Water absorption (%)	0.9	0.7	1.2
Specific gravity	2.66	2.69	1.04
Max. aggregate size (mm)	4.75	19	19
Min. aggregate size (mm)	-	4.75	4.75

Table 2 Properties of macro synthetic fiber (MSF)

Property	Result
Shape of fiber	Crimped
Fiber length (mm)	50
Fiber diameter (mm)	0.8
Modulus of elasticity (MPa)	> 5000
Tensile strength (MPa)	> 450
Specific gravity	0.91
Melting point (^{o}C)	160

Clean potable water is used for concrete production. In order to keep the slump value 80 mm – 100 mm, a high range water reducing admixture (sika viscocrete – 20 he) is used [10]. Gradation curves of fine aggregates and both types of coarse aggregates are shown in Figure 1. Overview of shredded E-waste coarse aggregates and MSF is given in figure 2.

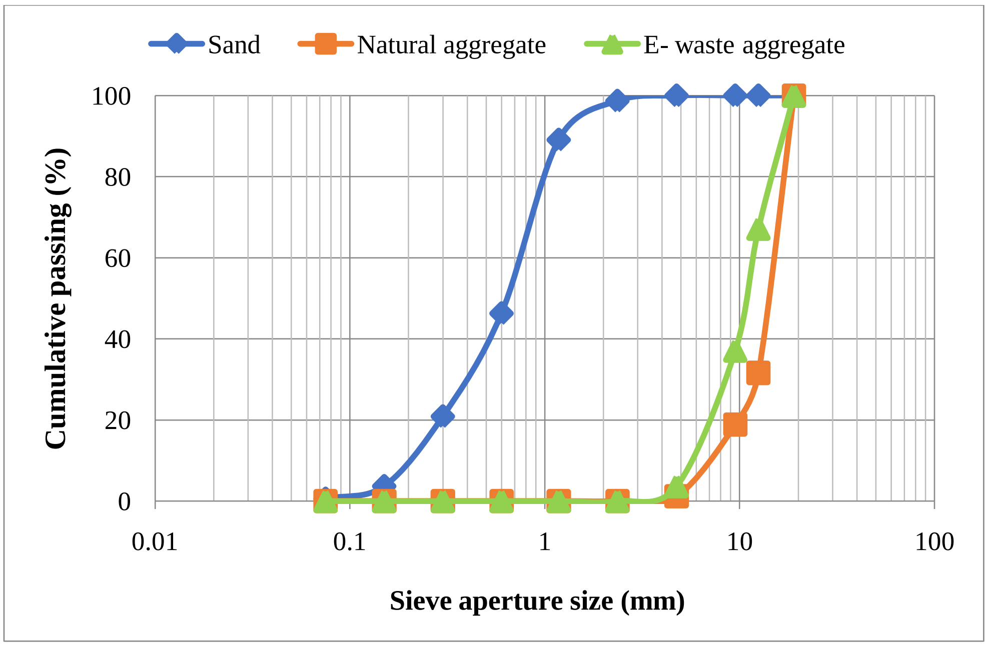

Figure 1: Gradation curves of aggregates

a) b) c) d)

Figure 2: a) 30% E- waste aggregate b) Macro synthetic fiber (MSF) c) Compressive tested d) Split tensile tested cylinder

2.2 Composition of concrete mixes

In this experimental-based research work, total of 14 mixes are prepared by using 0% and 30% of E-waste coarse aggregates as shown in Table 3. First mix that contains no E-waste and no fiber is taken as control or reference specimen in the whole research work. Amount of macro synthetic fiber is used at 0.25%, 0.5%, 0.75%, 1.0%, 1.25%, and 1.5% by volume of concrete. Effect of each amount of fiber on concrete is studied by conducting various tests. Moreover, a constant water-cement ratio of 0.4 is used for all mixes. To keep the workability same, a high range water reducing admixture is used. For all mixes, the slump value is kept in the range of 80 – 100 mm. To design the composition of ingredients of concrete mix, ACI 211.1-91 [11] is used. Detail of all mix proportions, is presented in Table 3.

Table 3- Details of mix proportions (1:1.6:2.3)

Mixture ID	E-waste (%)	Fiber (%)	OPC (kg/m³)	Sand (kg/m³)	NCA (kg/m³)	E-waste (kg/m³)	Fiber (kg/m³)	Water (kg/m³)	Super-plasticizer (kg/m³)
E0 (Ref.)	0	0	430	690	990	0	0	172	1.72
E0MSF0.25	0	0.25	430	690	990	0	2.27	172	1.72
E0MSF0.5	0	0.5	430	690	990	0	4.55	172	1.72
E0MSF0.75	0	0.75	430	690	990	0	6.82	172	1.72
E0MSF1.0	0	1.0	430	690	990	0	9.11	172	2.15
E0MSF1.25	0	1.25	430	690	990	0	11.38	172	2.15
E0MSF1.5	0	1.5	430	690	990	0	13.65	172	2.15
E30	30	0	430	690	720	105	0	172	2.15
E30MSF0.25	30	0.25	430	690	720	105	2.27	172	2.58
E30MSF0.5	30	0.5	430	690	720	105	4.55	172	2.58
E30MSF0.75	30	0.75	430	690	720	105	6.82	172	2.58
E30MSF1.0	30	1.0	430	690	720	105	9.11	172	3.02
E30MSF1.25	30	1.25	430	690	720	105	11.38	172	3.02
E30MSF1.5	30	1.5	430	690	720	105	13.65	172	3.02

3 Research Methodology

3.1 Preparation of concrete specimens

A mechanical mixer of 0.15 m^3 capacity is used for the mixing of concrete ingredients. First of all, fine and coarse aggregates are mixed in the mixer in the presence of half water. After 4 minutes, cement and fibers are added to the revolving mixer with the addition of remaining half water. Whole mixing phenomenon is completed within 10 minutes.

3.2 Testing of concrete specimens

Mechanical performance of each concrete mix is verified on the basis of compressive strength test and split tensile strength. To perform the compressive strength test, 150 mm diameter x 300 mm height cylinders are cast and tested according to the specification of ASTM C39/C39M [12]. To perform the split tensile test, 150 mm diameter x 300 mm height cylinders are cast and tested by obeying the specification of ASTM C496/C496M [13]. For each concrete mix, three specimens are cast and tested.

4 Results and discussions

4.1 Density

By investigating the density of concrete mix designs, it is observed that the addition of 30% E-waste coarse aggregate is causing reduction in density of concrete about 15% as compared to that of conventional concrete. Density values of all mix designs, under investigation, are shown in the graph below. Actually, the density value of E-waste coarse aggregate is 524 kg/m^3 which is much lower as compared to natural coarse aggregates (1578 kg/m^3). Due to this reason, the density of E-waste aggregated concrete is relatively low as compared to conventional concrete.

However, the addition of fibrous material is impacting different effects on the density values of conventional concrete mixes and E- waste aggregated concrete mixes. It is evident from the following graph that the addition of macro synthetic fiber (MSF) is causing reduction in the density value of conventional concrete but enhancing the density value of E-waste aggregated concrete. Main reason behind this phenomenon is density of MSF which is 910 kg/m^3. So, density value of MSF is greater than that of the E-waste coarse aggregate (524) but less than that of natural aggregates (1578).

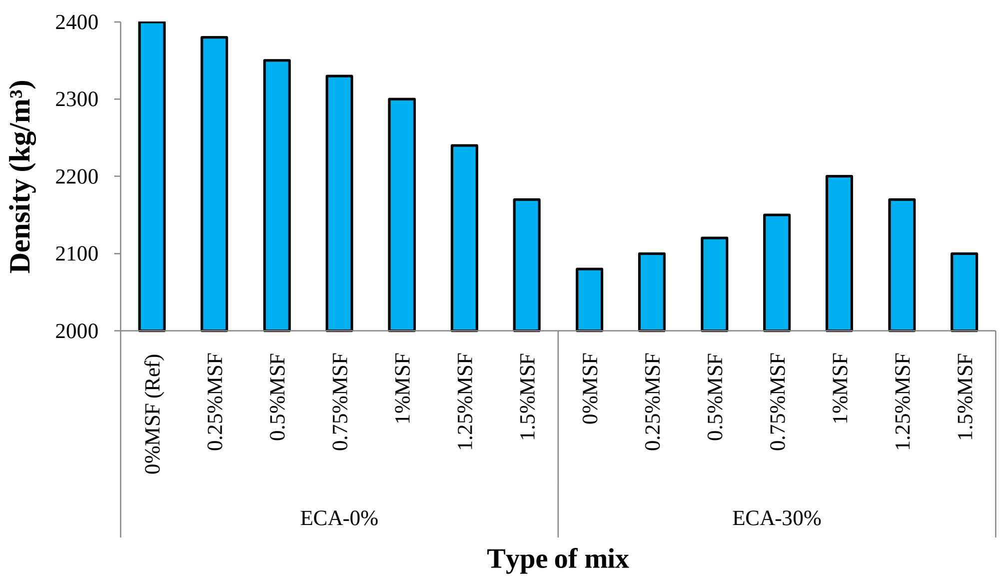

Figure 3: Density values for all type of mixes with varying volume fractions of MSF

4.2 Compressive strength

Compressive strength values of all mix designs, under investigation, are shown in graph below. It is observed that 30% replacement of E-waste coarse aggregates with natural coarse aggregates in conventional concrete is causing reduction in compressive strength about 15%. However, it is evident from the graph that addition of macro synthetic fiber (MSF) is causing high increment in compressive strength value of both conventional and E-waste aggregated concrete specimens.

It is evident from figure 2(c), macro synthetic fibers are trying to hold together the concrete matrix in a well manner. Being in 3D random orientations in concrete matrix, the macro synthetic fibers are strengthening the concrete core matrix and confronting the disintegrating force acting from any direction. That is why, the fibrous material is causing increment in the compressive strength value of both conventional concrete and E- waste aggregated concrete about 30% at 0.75% amount of MSF by volume. However, after 0.75% amount, the compressive strength of both of the concrete goes on reduction. Because after that specific amount of fibrous material, the fibrous material creates hurdles to achieve proper compaction and finally that heavy fibrous concrete have to face segregation which results reduction in its strength.

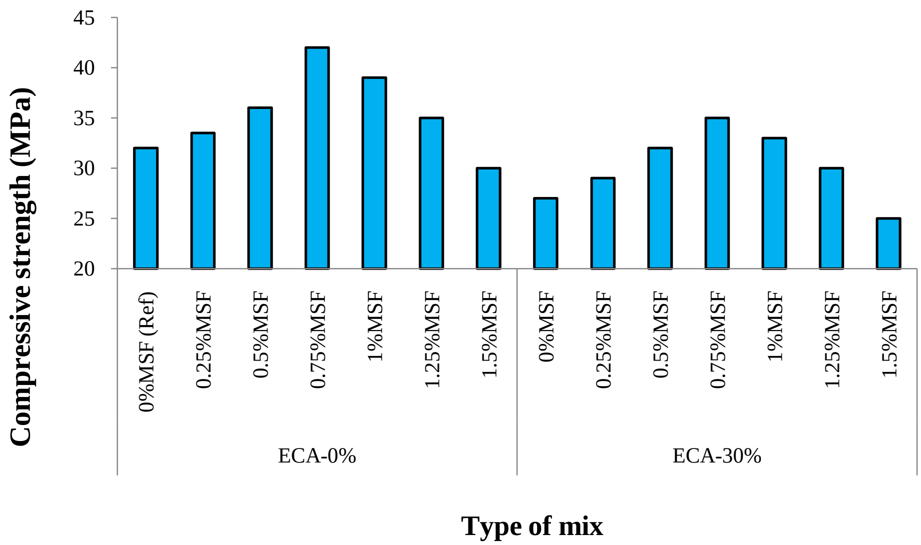

Figure 4: Compressive strength values for all type of mixes with varying volume fractions of MSF

4.3 Split tensile strength

Split tensile strength values of all mix designs, under investigation, are shown in graph below. It is observed that the 30% replacement of E-waste coarse aggregates with the natural coarse aggregates in conventional concrete is causing reduction in split tensile strength about 10%. However, it is evident from the graph that the addition of macro synthetic fiber is causing a huge increment in split tensile strength value of both conventional and E-waste aggregated concrete. It is evident from figure 2(d), macro synthetic fibers are trying to hold together the concrete matrix in well manner. Half portion of cylinder is showing the 3D random orientation of macro synthetic fibers in concrete matrix. Due to their high elasticity and random orientation, the macro synthetic fibers are highly confronting the splitting force. That is why, the fibrous material is causing tremendous increment in the tensile strength value of both conventional concrete and E- waste aggregated concrete about 150% at 1% amount of MSF by volume. However, after 1% amount, the tensile strength of both of the concrete goes on reduction. Because after that specific amount of fibrous material, the fibrous material creates hurdles to achieve proper compaction and finally leads toward segregation which results in reduction in strength.

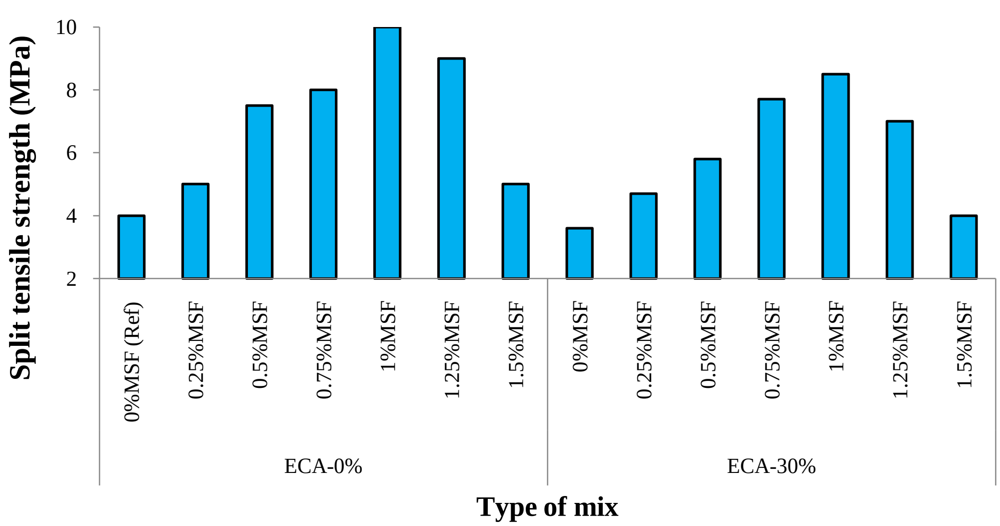

Figure 5: Split tensile strength values for all type of mixes with varying volume fractions of MSF

5 Conclusion

In this experimental-based study, the mechanical performance of conventional concrete and the concrete incorporated with E-waste coarse aggregate is studied. Amount of E-waste coarse aggregate is kept 30% by volume of natural coarse aggregate. Following conclusions can be made by this experimental based investigation:-

- Electronic waste (E- waste) coarse aggregates are much lighter in weight as compared to natural coarse aggregate. They have density about 1.04 which leads to the production of lightweight concrete.
- Density of concrete is reduced, by replacing natural coarse aggregate with 30% E-waste coarse aggregate, about 15%. Addition of fibrous material also reduces the density of conventional concrete but increases in the case of E- waste aggregated concrete mixes.
- 30% replacement of E- waste coarse aggregate with the natural coarse aggregate is causing reduction in compressive strength value of concrete about 15% as compared to conventional concrete. However, the addition of fibrous material has been increasing the compressive strength upto 30% of both conventional and E- waste aggregated concrete. Compressive strength of both type of concrete becomes optimum at 0.75% of macro fiber.
- 30% replacement of E- waste coarse aggregate with the natural coarse aggregate is causing reduction in split tensile strength value of concrete about 7% as compared to conventional concrete. However, the addition of fibrous material has been hugely increasing the split tensile strength upto 150% of both conventional and E-waste aggregated concrete. Split tensile strength of both types of concrete becomes optimum at 1% of fiber.

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