AN EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN AND COARSE AGGREGATE WITH E-WASTE

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ABSTRACT

An experimental study is made on the utilization of E-waste particles as coarse aggregates in concrete with a percentage replacement ranging from 0 %, to 20% i.e. (0%, 5% ,10%, 15%, and 20%) on the strength criteria of M25 Concrete. Compressive strength, Tensile strength and Flexural strength Concrete with and without E- waste plastic as aggregates was observed which exhibits a good strength. Also the study continuous by replacing metakaolin with cement in percentage of 10% and the mechanical properties are compared with e-waste and metakaolin and without metakaolin. The feasibility of utilizing E-waste plastic particles as partial replacement of coarse aggregate has been presented. In the present study, compressive strength was investigated for Optimum Cement Content and 15% E-plastic content in mix yielded stability and very good in compressive strength of 53 grade cement. Increase in split tensile strength is almost insignificant whereas gain in flexural tensile strength have occurred even up to 15 % replacements. E-waste seems to have a more pronounced effect on the flexural strength than the split tensile strength.

***Keywords**: E- waste, Concrete, Metakaolin, Compressive strength.*

I. INTRODUCTION

The management and recycling of E plastic waste is rapidly growing as it is a valuable resource of IT industries and it is very hazardous substances and with low recycling rate. The Utilization of e plastic waste materials is a partial solution to environmental and ecological problems. As the use of E plastic waste will reduces the Aggregate cost and provides a good strength for the structures and roads. It will reduces the landfill cost and it is energy saving. The e plastic waste consists of discarded plastic waste from the old computers, TVs, refrigerators, radios; these plastics are non-biodegradable components of E plastic waste as a partial replacement of the coarse or fine aggregates. Electronic waste materials are one of the quick increasing waste materials in the planet. Every year approximately 50 million tons of E-Waste is formed. Unnecessary computers, mobile phones along with additional electrical and electronic wastes gives useless results. Therefore it’s significant to exist alert of E-Waste here adding to the additional substantial wastes. Production of huge quantity of concrete is depleting natural raw material sources. Here this project effort M mix up design be formed with understudy of normal coarse aggregate by E-waste material ranges like 0%, 5%, 10%, 15%, 20% and also cement is replaced by metakaolin with 0% and 10%.

The use of these materials in concrete come from the environmental constraints in the safe disposal of these products. Use of E-waste materials not only helps in getting them utilized in cement, concrete and other construction materials, it helps in reducing the cost of cement and concrete manufacturing, but also has numerous indirect benefits such as reduction in landfill cost, saving in energy, and protecting the environment from possible pollution effects.

OBJECTIVE OF WORK

The present work of partial replacement of cement with metakaolin and coarse aggregate with e-waste aims following objectives.

- To find the best suitable dosage of E-waste to incorporate in concrete.
- The influence of E-waste and metakaolin on fresh and hardened properties of SCC.

- To determine the percentage growth rate in hardened properties like compressive strength, split tensile strength.
- To study the durability characteristics of E-waste Concrete using metakaoline as a mineral admixture.

II. LITERATURE REVIEW

Some research publications are pertaining to this thesis given as follows.

Ashwini Manjunath B T (2016)

This paper investigated, the use of Electronic plastic waste material like coarse aggregate in concrete with different ranges like 0%, 10%, 20% and 30% with M20 grade of concrete mix. By comparing the obtained consequences with conventional concrete at twenty eight days, it is reported to there is considerable reduction in compressive strength, split tensile strength and flexural strength of concrete due to E-Waste. This proves so as to the power of concrete get concentrated while coarse aggregate was replace with E-waste plastic particles.

Shoba Raj kumar, B Nithya (2016)

Here this paper, the research was achieved to find the replacement of coarse aggregate using Electronic waste in M25 grade concrete mix design. Polystyrene aggregate retained on 10mm sieve was used as E-waste material in different ranges like 10%, 15% and 20%. They conducted various tests in laboratory. The tests are; compression test, split tensile test and flexural test of concrete should be determined. Hence they recommended with the intention of Electronic waste aggregate be able to be used as understudy of natural coarse aggregate up to 10%.

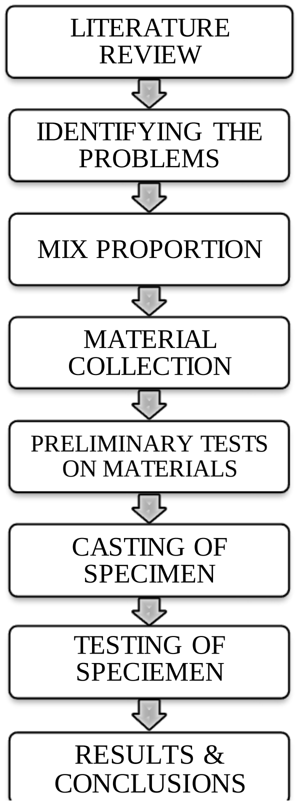
Megha Rani A, Dr.P.G. Bhaskaran Nair, Anisha G Krishnan(2017)

In this work, E-waste is used as partially replacement to the coarse aggregate. They conducted various tests in laboratory. The tests are; compression test, flexural test of concrete should be determined. Hence they finished with the intention of electronic waste aggregate be able to be used as understudy of natural coarse aggregate up to 10%.

P.K. Roy, Devanshjain, Vijay meshram (2019)

In this paper, it has been experimental that the coarse aggregate is replaced by E-waste and also cement is replaced by fly ash. They conducted compression test in laboratory, these test give poor strength of concrete. When fly ash content added to E-Waste concrete, workability increase is observed. It is reported that when fly ash is adding in the place of cement, the result is good.

III. METHODOLOGY



MATERIALS USED :

The Materials used for the study are :

i) Cement
ii) Fine Aggregate
iii) Coarse Aggregate
iv) E-waste
v) Admiexture
vii) Water

i) Cement

Ordinary Portland Cement (OPC) grade 53 as per IS:12269:1999 was used in this study. The physical properties of the cement conform to IS: 12269:1999 and have been tested at the Concrete Laboratory of Anamacharya Institute of Technology and Science, Kadapa.

ii) Fine Aggregate

Sand used in this experimental program was locally procured. It was tested for various physical properties in accordance with IS 2386 (Part 3) - 1963. Fine aggregate was natural sand conforming to zone III of IS 383-2016 passing through 4.75 mm size sieve. The specific gravity and fineness modulus are found to be 2.59 and 2.64.

iii) Coarse Aggregate

Aggregate is a granular material such as sand, gravel, crushed stone, crushed stone hydraulic cement concrete used with a hydraulic cementing agent to produce concrete or mortar. Aggregates are divided into many classifications based on their sizes. Crushed stone with 20 mm aggregate is used as coarse aggregate in the concrete mix.

iv) E-Waste

The E-Waste material of printed circuit boards are used. The printed circuit boards were crushed and considered as replacement of coarse aggregate substitute retaining the mix as the same. The divided particle size of E-Waste is 20mm. the specific gravity of E-waste is 1.81. The E-waste is collected from E-waste recycled shop, Hyderabad.

Fig 1. E-waste

v) Admixture

Metakaolin is also called as artificial mineral admixture. Metakaolin was collected from the area of Chennai. The specific gravity test was conducted in laboratory. The specific gravity of Metakaolin is 2.53.

vi) Water

The water used for mixing the concrete components, casting and curing the samples shall not contain impurities which, if present, may adversely affect the strength of the concrete as per IS:3025:1964 (Parts 22 and 23) and IS:456: 2000.

Detailed description of the materials used and their physical properties has been presented. The mix design for M25 grade of concrete according to IS: 10262-1982 has been designed.

Table 1 Mix design for M25 grade concrete

Cement	F.A	C.A	Water
524.31 kg	672.36 kg	928.08 kg	199.24
1	1.28	1.77	0.38

E-waste is replaced in percentages of 0, 5, 10,15 and 20 and the mix designs are as follows :

Conventional Concrete – 1 : 1.28: 1.77

Conventional Concrete with 5%replacement – 1 : 1.28 : 1.72

Conventional Concrete with 10%replacement – 1 : 1.28 : 1.67

Conventional Concrete with 15%replacement – 1 : 1.28 : 1.62

Conventional Concrete with 20%replacement – 1 : 1.28 : 1.57

Metakaolin is replaced 10% in cement and E-waste is replaced in percentages of 0, 5, 10,15 and 20 and the mix designs are as follows :

Conventional Concrete – 1 : 1.28: 1.77

Conventional Concrete with 5%replacement – 0.9 : 1.28 : 1.72

Conventional Concrete with 10%replacement – 0.9 : 1.28 : 1.67

Conventional Concrete with 15%replacement – 0.9 : 1.28 : 1.62

Conventional Concrete with 20%replacement – 0.9 : 1.28 : 1.57

IV. EXPERIMENTAL INVESTIGATION

The following steps are performed in this phase.

1. Design of concrete mix
2. Mixing of concrete
3. Test Specimens
4. Preparation of Moulds
5. Harden properties of concrete
6. Observations and test Results

1. Design of concrete mix

The mix design for M25 mix is explained in the (Mix Design).

2. Mixing of concrete

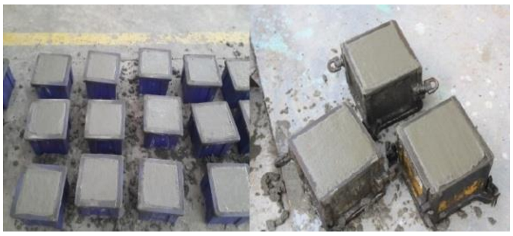


Fig 2. Mixing of concrete

3. Test specimens

4. Preparation of moulds

Fig 3. Preparation of moulds

5. Hardened properties of concrete

The compressive strength, tensile strength and flexural strengths of the used samples was measured with a compressive testing machine and flexure beam apparatus.

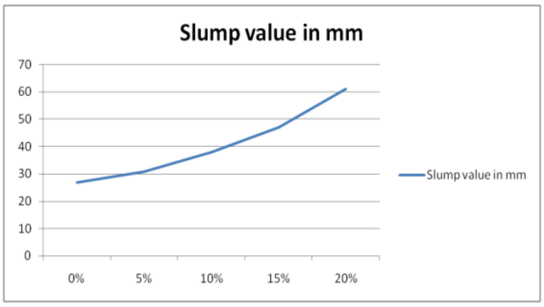
V. RESULTS & DISCUSSIONS

The results completed in the present investigation are reported in the form of tables and graphs for various fresh properties and harden properties of concrete for various percentage of E- waste as a partial replacement to Coarse aggregate in concrete by 0%, 5%, 10%, 15% and 20 % are worked out and tabulated in the tables below and further more the procedure is repeated by replacing metakaolin in the place of cement with 10%.

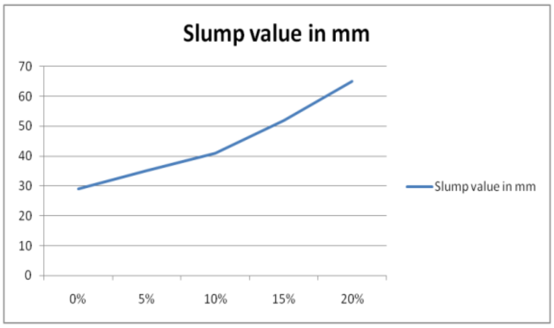
FRESH PROPERTIES

Slump cone results :

Following are the test result obtained from slump cone test for various grade and % replacement of E-waste for various grades of concrete.



Graph 1. Slump value in mm for M25 grade without metakaolin



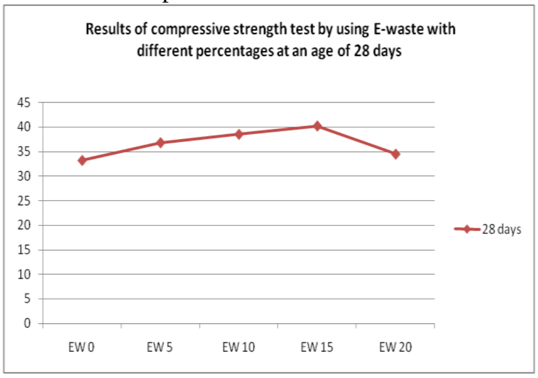
Graph 2. Slump value in mm for M25 grade with 10 % metakaolin

HARDENED PROPERTIES OF CONCRETE

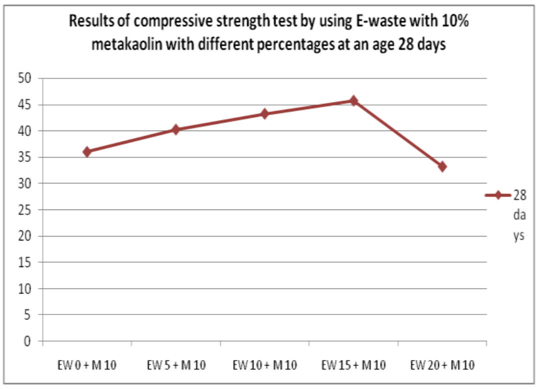
Compressive strength is the most important and useful property of concrete. In most structural applications, concretes are primarily used to resist compressive stresses. Concrete cube of size 150x150x150 mm were cast with various E-waste percentages and with 0 and 10% of cement replacement by metakaolin. The cubes were cured for a period of 28 days. The compressive, split tensile and flexural strength results are tabulated.

COMPRESSIVE STRENGTH RESULTS

The Compressive strength results for various replacement levels of E-waste by (0-20%) at an increment of 5% for 28 days with and without metakaolin are presented below.



Grpah 3. Average compressive strength for 28 days without metakaolin

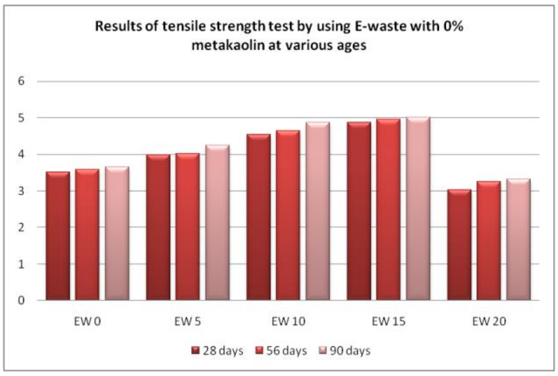


Grpah 4. Average compressive strength for 28 days with 10% metakaolin

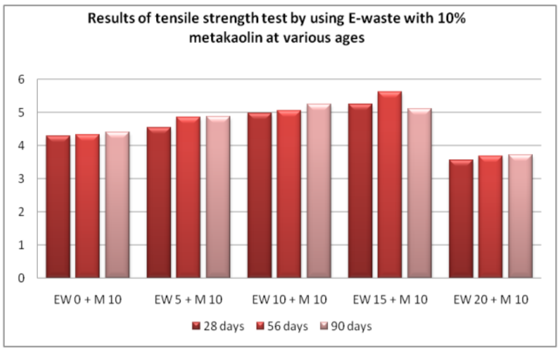
Combinations (%)	28 days (M 0%)	28 days (M 10%)
EW 0	33.25	36.03
EW 5	36.82	40.25
EW 10	38.51	43.22
EW 15	40.2	45.7
EW 20	34.52	33.26

Table 2. Results of compressive strength test by using E-waste with different percentages

SPLIT TENSILE RESULTS

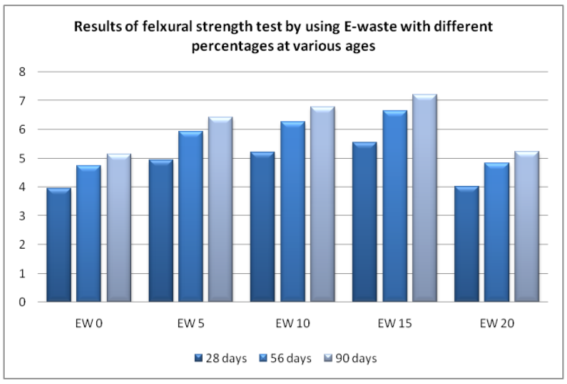


Graph 5. Average results of tensile strength test by using E-waste with 0% metakaolin at various ages

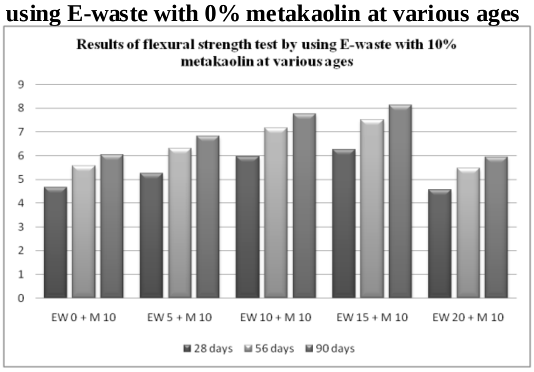


Graph 6. Average results of tensile strength test by using E-waste with 10% metakaolin at various ages

BEAM-FLEXURE RESULTS



Graph 7. Average results of flexural strength testby using E-waste with 0% metakaolin at various ages



Graph 8. Average results of flexural strength testby using E-waste with 10% metakaolin at various ages

VI. CONCLUSIONS

This study highlights the current situation of global e-waste generation and its effect on the environment. The scope of utilizing e-waste in the construction industry to prepare concrete is also reviewed. Moreover, techniques to produce e-waste aggregates and their effects on the properties of concrete are investigated in this study. The following conclusions and recommendations can be deduced from the above discussed topics :

- The disposal of toxic e-waste in landfill sites causes irreplaceable health and environmental hazards. Therefore, reusing raw materials obtained from e-waste recycling is the most viable solution to reduce the substantial growth in e-waste.
- The mechanical properties (e.g., compressive strength, flexural strength, and splitting tensile strength) of concrete containing e-waste aggregate decrease at higher e-waste aggregate replacement levels owing to the lower density of e-waste aggregates and increased porosity of the concrete matrix. Increasing the amount of e-waste plastic aggregates leads to high reduction in mechanical properties of concrete. However, using low w/c ratio to prepare concrete with e-waste aggregates can decrease the reduction in mechanical properties (particularly compressive strength).
- The fresh and dry properties of concrete with e-waste aggregates can be enhanced with admixtures (like metakaolin and steel slag), superplasticizer, and biomineralization. However, more data is necessary to estimate the long-term performance potential of e-waste incorporated concrete.
- The availability of limited data on the impact of e-waste on the engineering properties of concrete suggests in-depth analysis of e-waste modified concrete should be investigated comprehensively by incorporating various factors, i.e., w/c ratio, concrete type, cement type, curing and environmental conditions. This will enable concrete technologists to conclude whether e-waste aggregates are suitable replacements for coarse aggregates in the preparation of concrete.
- E-waste modified concrete has the potential to decrease the thermal conductivity due to its lower density, which makes it a suitable material for energy conservation in buildings. However, limited literature is available on the mentioned topics, which makes it difficult to predict whether it would

satisfy the conditions of designing lightweight or fireproof concrete.

- Manufactured e-waste modified concrete performs better than using unmanufactured e-waste aggregate. However, an evaluation of the cost and environmental impact of preparing manufactured aggregates is missing. Therefore, a life cycle assessment of e-waste modified concrete should be conducted to see how its manufacturing affects social, economic, and environmental conditions. Such evaluation will enable concrete technologists to see if the environmental impact of e-waste may be diminished by using it as a supplement to coarse aggregates in concrete.
- Most of the studies suggest that e-waste aggregates can be used to prepare non-structural members of a concrete structure. However, some researchers suggest that incorporation of e-waste increases durability and mechanical properties of concrete, which indicates that it has the potential to be used in preparing structural concrete. Moreover, a few studies also suggest that e-waste aggregate enhances the ductility of concrete as compared to conventional concrete, which indicates its ability to resist seismic loads. This should be studied more extensively to make the most of increasing e-waste worldwide.
- As mentioned earlier, e-waste causes environmental pollution both by disposing e-waste on landfill sites and via combustion. Although incorporation of e-waste aggregates gives a glimmer of hope to concrete technologist and environmental protection organizations to recycle and manage e-waste, processing of e-waste or/and enhancing the properties of e-waste modified concrete may increase the cost of the project. Therefore, LCA studies are recommended to better understand the potentials of e-waste modified concrete leading to acceptance of e-waste in the construction industry.
- Compressive strength of concrete decreases through increase in substitution of normal coarse aggregate with E-waste aggregate.
- The decrease in compressive strength is marginal up to 15% substitution of normal coarse aggregate by E-waste aggregate.
- Chloride ion permeability of concrete increases with increase in replacement of normal coarse aggregate by E-waste aggregate.
- Addition of 10% metakaolin has increased the compressive strength and decreased the chloride permeability.
- Hence, it is recommended that Printed Circuit Board E-waste aggregate be able to be use as partial substitution of normal coarse aggregate up to 15% by combining cement with 10% metakaolin.
- The addition of E-waste shows increase in compressive strength up to 15% replacement.
- Increase in split tensile strength is almost insignificant whereas gain in flexural tensile strength have occurred even up to 15 % replacements. E-waste seems to have a more pronounced effect on the flexural strength than the split tensile strength.

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