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Effective Utilisation of E-Waste in Concrete by Partial Replacement of Coarse Aggregate

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Abstract

E-Waste is a electronic waste. India is developing country, so as the population growth rapidly and generation of E-Waste also increases. But in present scenario there is no proper implementation of E-Waste management rules and its impact on environment. After the limited life of electronic equipment they emerge radiation and are harmful for surrounding people. Nowadays the E-waste increases rapidly because of these modern living and thus creates a E-waste management problem. It is necessary to overcome such E-waste related problem in a meaningful manner. The purpose of this study is to find whether the E-Waste gives us that much Compressive strength as compared to conventional M20 grade concrete by partial replacing coarse aggregate with E-waste. So, this research examines the utilization of electronic waste in concrete with varying percentage like 0%,5%,10%,15%, 20%. Different test are carried out like the slump cone test, compaction factor test were conducted to investigate the fresh properties like workability and compression test were performed to find out the 7 days, 14 days and 28 days is determined with and without E-waste material compressive strength. Thus from present study it can be concluded that E-Waste material can be used as partial replacement of coarse aggregate up to 15% without compromising the compressive strength of the M20 grade concrete. The problem of disposal of E-waste disposal can be solved and hence helps the environmental pollution reduced by E-waste materials.

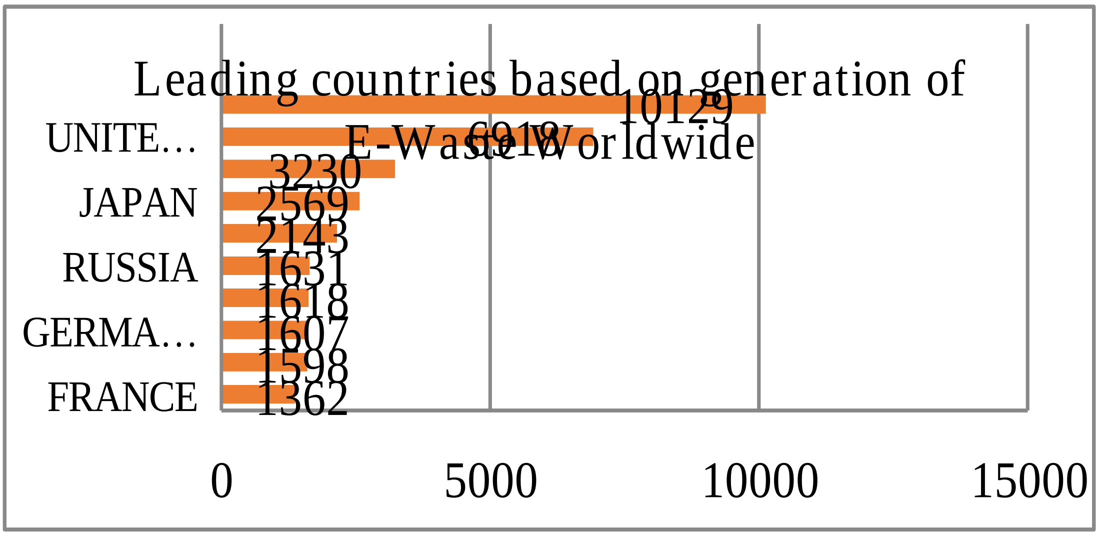
Keywords: E-Waste, Rapid Chloride permeability test, Fine aggregate, Compressive strength, Coarse aggregate

1. INTRODUCTION:

General:

Electronic waste describes discarded electrical or electronics devices. Used electronics which are destined for refurbishment, reuse, and resale, salvage, recycling through material recovery or disposal are also considered e-waste. On the other hand new electrical and electronic products have become an integral part of our daily lives providing us with more comfort, security, easy and faster acquisition. Due to technological growth, there is a high rate of obsolescence in the electronic equipment which leads to one of the fastest growing waste streams in the world. The E-waste that generated is usually disposed in the form of landfill, incineration, reuse, recycling. However, the cost of these disposal measures is high and hazardous effect on our environment. It is needful to come at a cost effective and environmental friendly recycling process. This study attempts to give a contribution to the effective use of domestic wastes in concrete to prevent the environmental strains caused by them, also to limit the consumption of high number of natural resources thus making the concrete more economical.

Fig. No.1. Leading countries based on E-waste generation worldwide (Source: Statista 2019)



Leading countries based on E-waste generation worldwide (Source: Statista 2019)

When we talk about electronic gadgets, first country that comes to is China because the technology that use in China for manufacturing of electronic gadget is very cheap so most of the countries uses products made by China. The electronic waste industry is booming at a very rapid pace. With increasing per capita income, changing lifestyles and revolutions in 2 Information and communication technology this number will increase exponentially.

2. OBJECTIVES OF STUDY:

1. To study the generation and management of E-waste and its use after disposal construction material.
2. To study and find out the probable percentage for replacement of coarse aggregate by E-waste in concrete.
3. To determine the workability of concrete for replacement of coarse aggregate by E-waste in concrete.
4. To determine the compressive strength of concrete for replacement of coarse aggregate by E-waste in concrete.
5. To analyse the property of Permeability in the E-waste concrete partially replaced by coarse aggregate.

3. LITERATURE REVIEW

Arora and Dave (2013) studied E-waste and plastic waste in concrete. The shreded E-waste and plastic waste were replaced by 0%, 2%, and 4% of the fine aggregates. The compressive strength and flexural strength were tested and compared with control concrete. They found that compressive strength of concrete has increased by 5% and reduce the cost of concrete production by 7% at optimum percentage of grinded waste. Prasanna et al. (2014) studied the E- waste materials and compared for M30 grade of concrete using E waste and without E waste. It found that the concrete produced with E waste was lighter in weight. compared to conventional concrete. He uses praportion of E waste as aggregate in 0%,5%,10%,15% and 20% replacement.

Manjunath (2015) studied the utilization of E-waste particle as a fine and coarse aggregate in concrete. He studied experimentally use of E waste particle as fine and coarse aggregate in concrete with 0% , 10%, 20% and 30% for M20 grade of concrete.

The strength observed like compressive, tensile and flexural strength of concrete with and without E-waste as aggregates which give better result in strength. Siddhique et al. (2015) It concluded that use of E-waste as fine aggregate increases durability of concrete and helps in reducing cost of E-waste disposal. Dawande et al. (2016) studied 25% of E waste material partially replaced with coarse aggregate and fly ash partially replacing with cement for M40 grade of concrete gives light weight concrete product. He also studied furnishings of concrete like workability, flexural strength and compressive strength. Kale et al. (2015) studied the replacement of fine aggregate with E waste in concrete. He established that compressive strength and split tensile strength of concrete concern to E-Waste aggregate is slightly lesser in comparison with control concrete mix. Donadkar et al. (2016) studied use of special E-waste like PCB as substitute for fine aggregate in concrete. It give better results than conventional concrete so use of E –waste (PCB) can reduced the use of natural fine aggregates in concrte.

Suchithra et al. (2015) presented use of E-waste as alternate material for coarse aggregate in M20 grade of concrete. The replacement done from 0% ,5%, 10 %, 15% to 20% of coarse aggregate shows increase in compressive strength compared with conventional concrete. Also the result shows increase in durability and it can be used effectively in concrete. Devi et al. (2017) studied utilization of E-waste material from scraped old refrigerators, radios, tvs, and computers.this E-waste replaces partially with coarse aggregate from 0% to 20 % in M20 grade concrete founds that attains increase in strength. Raut et al. (2018) observed change in mechanical properties of concrete like workability , compressive and flexural strength for M20 grade concrete. They replaced coarse aggregate with E plastic waste in 0%, 5%, 10% and 15%.

Saurav Dixit, Rishabh Arora (2021) have studied the possibilities of substituting recycled electronic trash for coarse aggregates in construction.P Muthupriya and B Vignesh Kumar (2021) have studied the reuse of E-waste plastics as aggregates in concrete mixture this helps in reducing unit weight of concrete. Kuldeep Rajput, Abhishek Gupta (2019) have studied ways to find out use of disposed E-waste as a construction material as coarse aggregate in concrete.Biradar Shilpa, Gayatri Deshpande (2019) have studied the properties of concrete by partial replacement of coarse aggregate by E-waste in combination with fly ash in the variation between 0-30%. Tried to understand how the strength of partially replaced coarse aggregate in concrete with e-waste decreases than conventional concrete block and how after addition of fly ash can help control the strength of concrete.

Sagar R Raut, Roshni S Dhapudkar (2018) have studied E-waste like non-metallic parts of Printed Circuit Boards (PCB) plates can be recovered and can be used as ingredient in concrete which helps in disposal of large amount of E-waste.R. Abinaya, G.U Nivethitha (2021) have studied how E-Waste concrete Strength, Durability and Resistance to Chemical Assault increases by addition of Fly

Ash.Iyappan G, Karthikeyan N (2020) have studied how strength properties of Concrete changes when powdered E-Waste is Substituted partially in place of Fine aggregate.

K. Alagusankareswari, S. Sandeep Kumar (2016) have studied PCB's are used as replacements for fine aggregates in concrete by 10,20,30%. Tests like Compressive Strength, Cube Weight Comparison, Split Tensile Strength, and Flexural Strength.

Zeeshan Ullaha, Muhammad Irshad Qureshi (2021) have studied aims to examine the influence of E-waste as a partial replacement of natural coarse aggregates (NCA) on both the fresh and hardened concrete properties.

Md. Masuduzzaman; Shishir Kumar Sikder Amit; Md. Alauddin (2018) have studied Utilization of E-waste materials is a partial solution to environmental and ecological problem. Due to large amount of concrete use as the construction material availability of raw material is being questioned.
In the present scenario, the problem disposing the E-waste can be reduced by utilizing it as replacement to construction materials. The objectives of the present study are, (i) to investigate the influence of the presence of E-waste as a partial replacement of coarse aggregate in concrete mixture, (ii) In the mix design of M20 grade of concrete for controlled concrete mix and a partially replaced of coarse aggregates with E-waste material in percentage from 0%, 5%, 10%, 15%, 20% gives good results for overall test.

4. MATERIALS AND METHODOLOGY

4.1 MATERIALS:

The materials used for M20 grade concrete are as follows:

i. Cement: The cement used for this study is Ultratech ordinary Portland cement (OPC) of 53-grade.
ii. Fine aggregates: Crushed sand is used as fine aggregates for preparing concrete. Aggregate most of which passes 2.36 mm IS sieve is used.
iii. Fly Ash: Fly ash (FA) is the principal industrial waste by product from the burning of solid fuels. Fly ash has been added to cement in a reduced Nano size form giving good durability and minimizing concrete pores size to resist adverse environment.
iv. Coarse aggregate: In this project we use coarse aggregates of size 20 mm and 10 mm in a proportion.
v. Water: The PH of water should not be less than 6. Hence potable water was used for the work.
vi. Electronic Waste: Computers, laptops, LED tv, scanner, and fax machines, mobile phones are common electronic products. Printed Circuit Board (PCB) is also used as an E-waste (as seen in fig 3.) in the form of long chips.
vii. Admixtures: Super plasticizers allow reduction in water content by 30% or more. These supplements are utilized at the level of a few weight present. Plasticizers and super plasticizers also slow down the setting and hardening of concrete.

Fig No.3.E-waste material

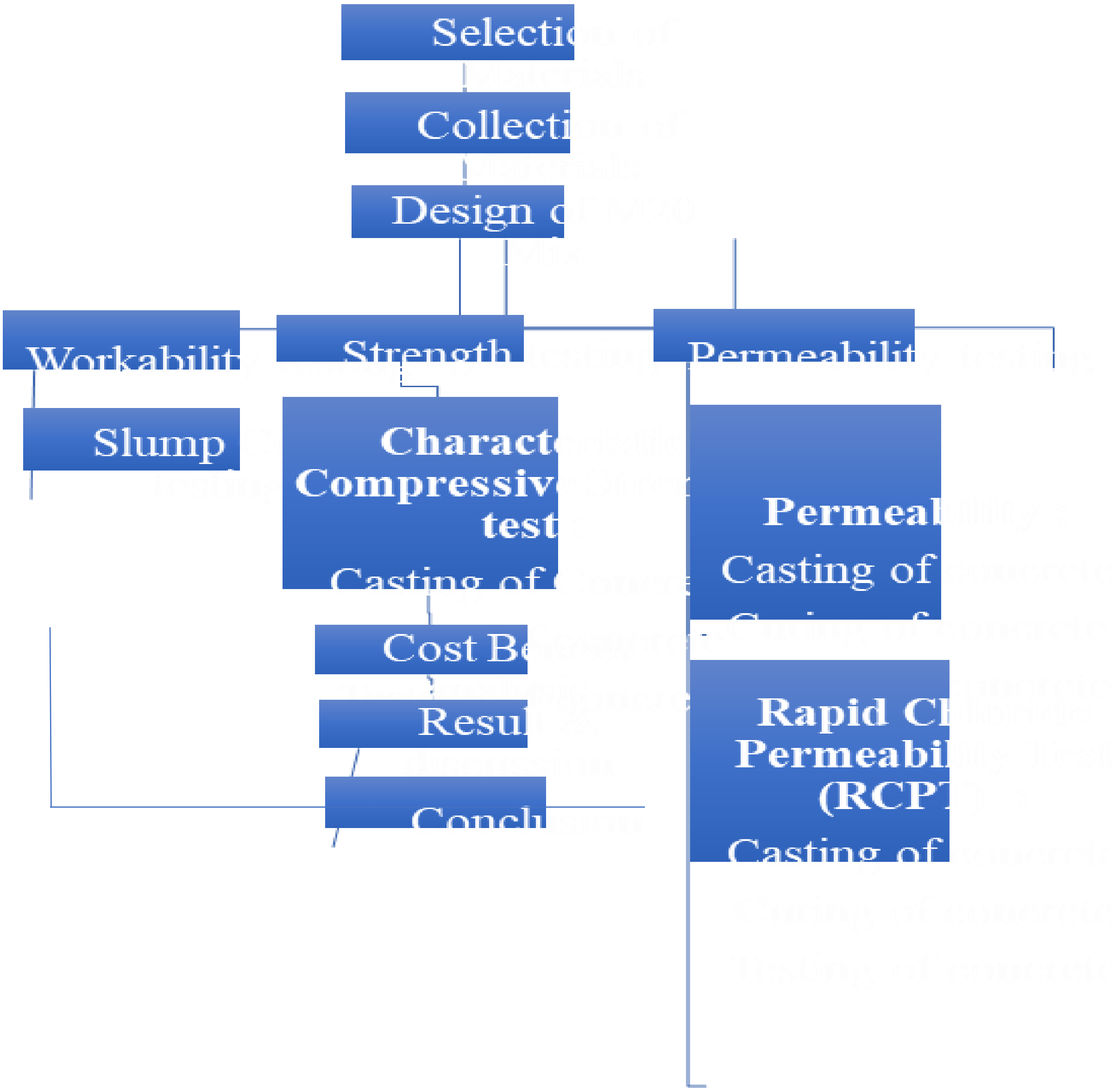


Fig. No. 4 Methodology

4.2 METHODOLOGY:

Following significant methodology was prepared to establish the objective of the project. This study is also focused on the effectiveness of E-Waste used in a construction project. In figure no.3.1 step by step methodology of work is explained.

4.3 NUMERICAL STUDY:

The mix design is carried out for the M20 grade of concrete as per IS 10262:2009 method. The mix proportion chosen for the present study base on mix design. Table 1 gives the properties of E waste materials.

Table1. Properties of E-waste materials

Type	**Crushed**
Maximum Size	20mm
Shape	Angular
Colour	Green and dark
Specific Gravity (20mm)	1.1
Water Absorption	0%

4.4 DATA ANALYSIS:

The data collected was analysed thoroughly. Vital aspects like the quantity of material used, aim, results, and conclusions were studied properly. Based on this context, the quantity of E-Waste to be used in concrete was decided. This overall collected data worked out to be our project topic.

Table No.2 Quantities of materials

Sr. No.	Percentage of E-waste to be used (%)	Quantity of E-waste (Kg)	Quantity of sand actually used (Kg)	Quantity of cement (Kg)	Quantity of Coarse Aggregates (10mm) (Kg)	Quantity of Coarse Aggregates (20mm) (Kg)	Quantity of Fly Ash actually used(Kg)	Quantity of Chemical Admixture actually used	Quantity of cementitious material (Kg)	Quantity of water required
1	0	0	31.78	10.27	11.54	23.33	2.12	109.74	10.974	7.27
2	5	2.62	30.47	8.85	12.08	23.65	2.124			7.5
3	10	5.27	30.47	8.85	14.92	17.2	2.124			7.43
4	15	7.89	30.47	8.85	12.77	15.78	2.124			7.35
5	20	10.55	30.47	8.85	7.82	17.2	2.124			7.27

4.5 MIXING AND TESTING:

After calculating all the materials quantity of all samples are mixed in tray (except water) and then water is added to it and again mixed thoroughly. The concrete mixture is then added in slump cone to perform slump cone test. After performing slump cone test, the same mixture is then used for compaction factor test. The same mixture was used to construct cube of size 150mm x150mm x 150mm. After performing all the tests the result were tabulated.

4.6 SLUMP CONE TEST:

Slump cone test is done to determine the consistency or workability of concrete. It is done at construction site or at laboratory to check the uniform quality of concrete during construction. It is helpful to confirm whether the correct water quantity has been added to the mix or not. Fig no shows the slump value of concrete as per mix. It is observed that workability of concrete decreases when the E-waste added in the mix. For the conventional mix, 150 mm slump value is observed and from sample 1 to sample 5 the slump value decreases with increase in percentage of E-waste.

4.7 COMPRESSIVE STRENGTH TEST:

Compressive strength is the mechanical test which determines the maximum amount of compressive load a block or cube can carry before breaking. The samples were tested in compression testing machine after specified curing period for different percentage of E-Waste replacement. The compressive strength is mentioned in table no. 4.

Fig. No.5. Slump cone test and compression test

Fig. No. 6. Compaction factor test

4.8 PERMEABILITY TEST OF CONCRETE:

The permeability of concrete refers to its ability to allow the passage of water or other fluids through its pores and capillaries. The permeability of concrete is a crucial property, especially when it is exposed to

water or aggressive environmental conditions. High permeability leads to durability issues, such as corrosion of reinforcing steel, freeze-thaw damage, and chemical attacks.
There are several methods to determine the permeability of concrete, including laboratory tests and field tests.

4.9 RAPID CHLORIDE PERMEABILITY TEST:

The rapid chloride permeability test is a widely used method for evaluating the durability and resistance to chloride ion penetration of concrete structures. This test is based on the principle that the rate of chloride ion migration through concrete is directly proportional to the electrical charge passed through the concrete specimen. It is important to note that the rapid chloride permeability test is just one method of evaluating the durability and resistance to chloride ion penetration of concrete structures.

Fig. No.7. RCPT (Rapid Chloride Permeability Test)- ASTM C 1202

5. RESULTS AND DISCUSSIONS:

5. RESULTS AND DISCUSSIONS: The results obtained after performing the various tests on concrete are as follows:

5.1 FOR SLUMP CONE TEST: The values of the slump are mentioned for all samples in the tables given below.

Workability Testing Result Slump Cone Test

Replacement Percentage	Slump Values
0 %	150
5 %	135
10 %	80
15 %	50
20 %	35

Table No. 3 Comparison of Slump Value

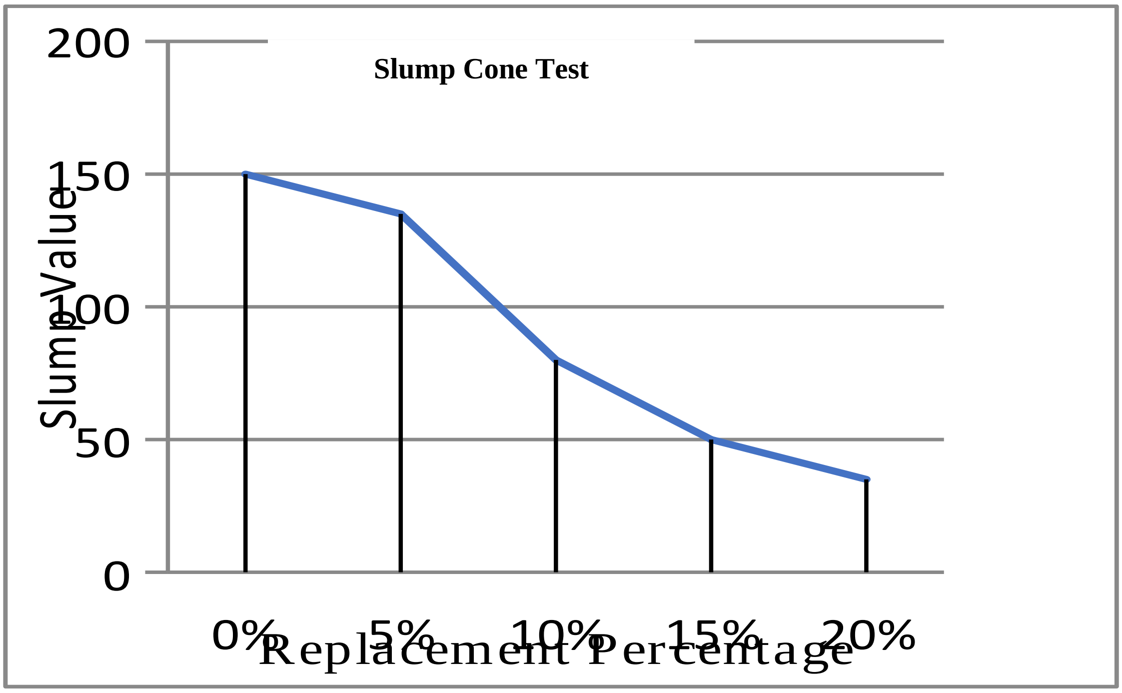


Fig. No. 8. Workability Testing Result Slump Cone Test

5.2 FOR COMPRESSION STRENGTH TEST :

Compressive strength = load / cross-sectional Area Compressive strength in N/mm2

COMPRESSIVE STRENGTH TEST							
7 DAYS				**28 DAYS**			
PERCENT %	**WEIGHT (KG)**	**COMPRESSIVE STRENGTH (KN)**	**AVG**	**PERCENT %**	**WEIGHT (KG)**	**COMPRESSIVE STRENGTH (KN)**	**AVG**
0%	8.560	493.4	**22.06**	**0 %**	8.513	793	**36.4**
	8.470	492.7			8.548	843	
	8.580	511			8.470	840	
5%	8.466	271.8	**11.81**	**5 %**	8.408	440	**20.02**
	8.484	261.8			8.401	471.1	
	8.404	268			8.469	448	
10%	8.424	280.2	**12.24**	**10 %**	8.333	506	**21.36**
	8.314	279.5			8.338	452	
	8.360	270.7			8.300	489	
15%	8.290	342	**15.12**	**15%**	8.280	543	**24.76**
	8.210	348			8.206	581	
	8.175	335			8.238	553	

20%	8.140	302.4	**13.71**	**20%**	8.170	480	**22.09**
	8.140	315.7			8.180	501	
	8.110	311.8			8.192	516	

Table No. 4. Observations for compression test of 7 & 28 days

The below figure shows the comparison of Compressive strength test of all samples of concrete used in the experiment.

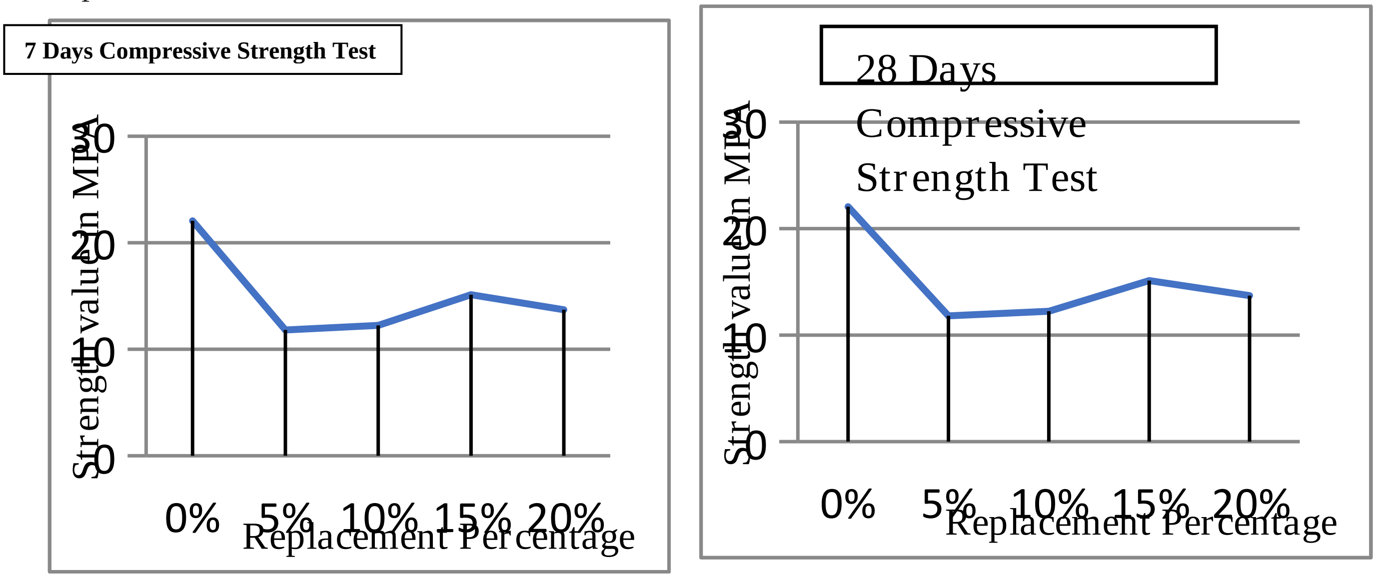


Fig. No. 9. 7 & 28 Days Comparison of Compressive Strength Test

4.3 FOR PERMEABILITY TEST OF CONCRETE:

The test permits measurement of the water entering the specimen as well as that leaving it.

PERCENTAGE %	**WATER PENETRATED (mm)**
0	20
5	30
10	40
15	60
20	100

Table No. 5. Permeability Test of Concrete

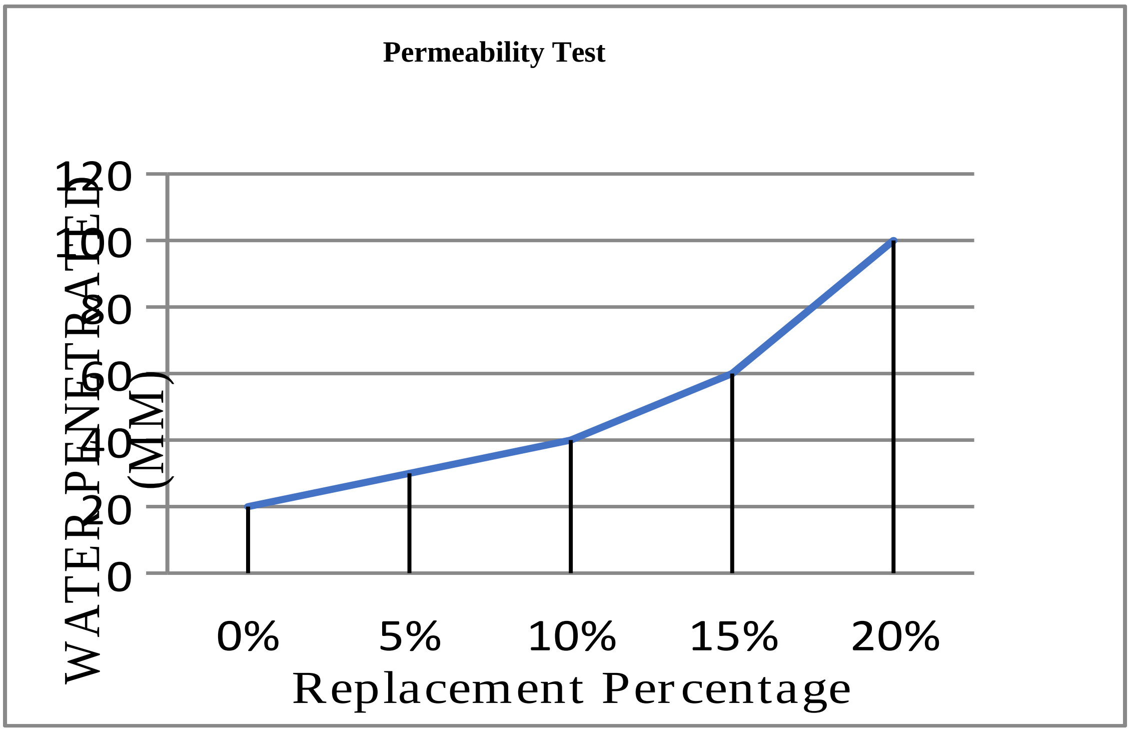


Fig. No. 10. Permeability Test of Concrete

4.4 RAPID CHLORIDE PERMEABILITY TEST:

It is important to note that the rapid chloride permeability test is just one method of evaluating the durability and resistance to chloride ion penetration of concrete structures.

Replacement Percentage	Charge Passed in Coulombs	Chloride Ion Permeability
0	798	Very Low
5	821.23	Very Low
10	1322.66	Low
15	2842.88	Moderate

Table No. 6. Rapid Chloride Permeability Test

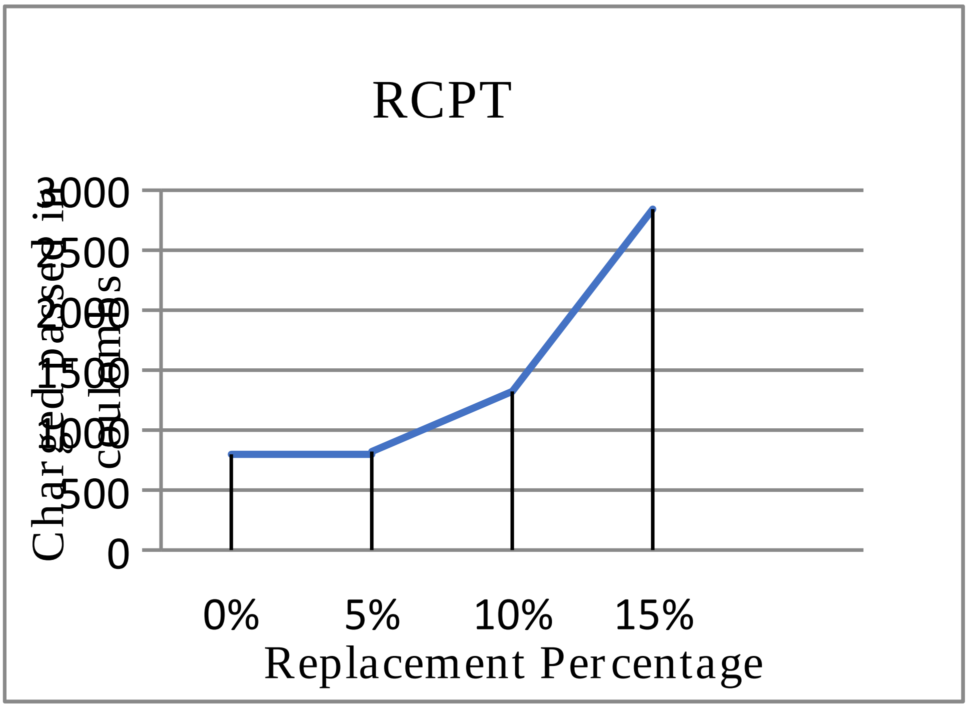


Fig. No. 11. Rapid Chloride Permeability Test T of Concrete

CONCLUSION:

The following conclusions can be drawn from the experimental investigation carried out

1. This project has found the optimum limit of replacement of coarse aggregate by E-waste up to 15% shows increase in compressive strength of concrete for compressive test. This project has studied that with the increase in the replacement percentage of E-waste with coarse aggregate, slump value of concrete is increased.
2. This project has studied that the compressive strength of E-waste concrete increase up to 15% and after that there is decrease in the compressive strength so it is found that 15% replacement is the optimum point.
3. According to ACI (American Concrete Institute) 40 mm permeability is allowed. But in our project, it is found that 40 mm permeability is achieved at 10% E-waste replacement but by compressive strength point of view 15% replacement has achieved optimum strength which has 60 mm permeability value hence the results do not recommend 15% replacement for structures which are in close vicinity of water or moisture.
4. This project has studied that in RCPT test chloride ion penetrability of 0% and 5% replacement batch is very low, 10% replacement batch is low, 15% replacement batch is moderate and 20% replacement batch is high.
5. E-waste concrete can be an environmentally friendly solution for the construction industry. The use of e-waste in concrete can reduce the need for traditional aggregates and reduce the carbon footprint of construction activities.

6. Overall incorporating E-waste into concrete has the potential to be a sustainable solution for both the construction industry and E-waste management. However, further research and development are needed to optimize the use of E-waste in concrete and ensure the safety of the resulting material.

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