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An Experimental Study on Use of E-Waste Materials in Concrete for Rigid Pavements

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Abstract-***E-Waste can be defined as discarded computers, office electronic equipment, entertainment electronics device, mobile phones, television sets, and refrigerators contain potentially harmful components such as lead, cadmium, beryllium, or brominated flame retardants. Recycling and disposal of e-waste may involve significant risk to health of workers and communities in developing countries. These E-waste are easily used in concrete of rigid pavement because at this time in India construction of Rigid pavement at a larger Scale. Rigid pavements are generally used in constructing airports and major highways. They commonly serve as heavy-duty industrial floor slabs, port and harbor yard pavements, and heavy-vehicle park or terminal pavements. Offering high quality riding surfaces for safe vehicular travel, they function as structural layers to distribute vehicular wheel loads in such a manner that the induced stresses transmitted to the sub grade soil are of acceptable magnitudes. Portland cementconcrete (PCC) is the most common material used in the construction of rigid pavement slabs. Rigid pavements must be designed to endure frequently repeated traffic loadings. The typical designed service life of a rigid pavement is between 30 and 40 years, lasting about twice as long as a flexible pavement. From last few years, we have been discovered that by adding different E-waste replacing coarse aggregate by E-waste in a specific percentage increase or does not affects the mechanical properties of the PCC. During this experimental work the E-waste is used in 2%, 4%, 6%, 8% and 10% by weight replacing the coarse aggregate. Several specimens are tested of M40 grade for the analysis of compressive, flexural and tensile strength and result were compared with the controlled mix of concrete and by doing so we reduce the problem of environmental and human hazardous and solve the solid waste problems. The compressive strength at 0%, 2%, 4%, 6%, 8% and 10% were found to be increase 11.11%, 10.01%, 9%, 2.5% and decreased 2.75% and 12.5% .But we observed that up to 10% replacement of coarse aggregate with Electronic Waste (PCB) the compressive strength decreases, The flexural strength at 0%, 2%, 4%, 6%, 8% and 10% were found to be increase 3%, 2.68%, 0.9%, and decrease 1.65%, 3.07%, and 9.55 and The Split tensile strength at 0%, 2%, 4%, 6%, 8% and 10% were found to be increase 13.375%, 11.9%, 7.95%, 2.55% and decrease 2.575% and 11.675%. the Based on these experiment we concluded that the waste generated by the Electronic waste (PCB) can be used as an alternative for the natural crushed stone used in concrete cubes as the compressive strength, and the flexural strength of the testing blocks does not shown any major difference with its original standard mix concrete***

Keywords: E Waste, Rigid Pavements, M40, PCB, Alternate Coarse Aggregate**.**

1. Introduction

For any construction whether it is rigid pavement or building or any other structure, Concrete is a very most important element. It is well known homogeneous mix of cement, water and aggregates. These admixtures are of various types and are added as per the specific property required. Other important constitutes of concrete is fine aggregates. Fine aggregate provides body to the concrete, reduce shrinkage and give economy. The main properties for using natural aggregates is that its particle are cubical or rounded with smooth surface texture. Being cubical, rounded and textured they give good workability. Use of concrete is large so availability of natural sand are less and there is a no material which plays the role of this ideal material (concrete).Today, the world is advancing too fast and our environment is changing progressively. Attention is being focused on the environment and safeguarding of natural resources and recycling of wastes materials. One of the new waste materials used in the concrete industry is E-waste. For solving the disposal of large amount of E-waste material, reuse of E-waste in concrete industry is considered as the most feasible application-waste comprises of waste generated from used electronic devices and household appliances which are not fit for their original intended use and are destined for recovery, recycling or disposal. The disposal of these wastes is a very typical task found in many regions. When these wastes are directly disposed, they produces leaches which is irresponsible for the contamination of ground water. When E waste are wasted and then disposed, acid and sludge cause soil acidification. The utilization of E waste as a part of concrete is not a complete solution but use of E waste in concrete is considered to be most feasible application. Such wastes encompasses wide range of electrical and electronic devices such as computers, hand and cellular phones, personal stereos, including large household appliances such as refrigerator, air-conditioners etc. To explore the possibility of use such materials in construction industry and find the alternatives of natural resources (coarse aggregate).

2. Literature Review

Salman et al (March 2015) [1] by using of E-waste in replacement of coarse aggregate give the different result. Till 12% replacement of aggregate with E-waste the compressive strength was better than reference concrete. At 20% replacement of E-waste the strength reduces in higher range E-waste in concrete replaced the coarse aggregate 0% - 20%. They also used 20% fly ash as a mineral admixture which gives the better result than reference concrete. *The replacement of coarse aggregate* by E-waste from 0% to 20% decreases the tensile strength of concrete than reference. They used also 10% fly ash as an admixture in concrete which give the better result in split tensile strength. Till 12% replacement of coarse aggregate by E-waste give better result than reference concrete. By the used of fly ash improved the split tensile strength up to 50%.Use of E-waste in concrete as coarse aggregate replacement from 0% to 24%.E-waste concrete exhibits slightly higher values than conventional concrete.

S Suchitrra et al (August-2015)[2] The work was conducted on M20 grade mix. Before checking and comparison of test find the some basic properties of material as Specific gravity for (fine aggregate 2.69%, coarse aggregate 2.74% and E-waste 1.9%), water absorption of (coarse aggregate 1.2%, fine aggregate 0.2% and E-waste 0.05%)The replacement of coarse aggregate with E-waste in the range of 0%, 5%, 10%, 15%, and 20%. Finally the mechanical properties as compressive strength (cube-150mm*150mm*150mm), flexural strength (beam 100mm*100mm8500mm) and Split tensile strength test (cylinder- 150mm*300mm). By the use of E waste up to 155 replacement of coarse aggregate all properties as compressive strength, flexural strength and split tensile strength are increases in 28 days but after % increment of E waste by replacement of coarse aggregate all properties are going to decreases. The results of compressive strength were presented the test was carried out to obtain compressive. Strength of concrete at the age of 7 and 28 days.

Sunil Airway et al (October 2016)[3] The main aim of this study is to investigate the change in mechanical properties of concrete with the addition of Electronic waste in concrete. It is found that the use of Electronic waste aggregates results in the formation of light weight concrete. In this research article Coarse aggregate is partially replaced by E- waste from 0% to 30% Then in these mix 10%, 20% and 30% of fly ash is also added by partial replacement of cement. It is thereby suggested that utilization of this Electronic waste in concrete will reduce the requirement for conventional coarse and fine aggregates thereby resulting in conservation of natural resources. Recent studies have shown that reuse of very finely grounded plastic e-waste in concrete has economical and technical advantage for solving the disposal of large amount of e-waste. An experimental study has been done on concrete using electronic waste as coarse aggregate and following points is observed from the present study. Workability of the concrete increases when percentage of the electronic waste increases. Workability of fly– ash with electronic waste concrete is even more than conventional and electronic waste concrete. Compressive strength of electronic waste concrete decreases with increase in the percentage of e-waste. Current study concluded that Electronic waste can replace coarse aggregate up to 10% or 20%.– Current study also concluded that electronic waste can replace coarse aggregate up to 30% in concrete when 30% fly ash is– replaced by cement.

3. Methodology

During this experimental study we are going to perform various test on fine aggregate, coarse aggregate, Electronic-waste (PCBs), and various compressive & flexural strength test on concrete designed by decided mixes of M40. We are going to perform following tests on materials:

a) **On Coarse Aggregate**
Specific Gravity, Water Absorption Test, Fineness Modulus, Crushing Value, Abrasion Value and, Impact Value

b) **On Electronic Waste (PCB)**
Specific Gravity, Water Absorption and, Impact Test of Electronic Waste (PCB).

c) **On Fine Aggregate**
Specific Gravity, Fineness Module, Bulk Density and,Water Absorption Test.

d) **On Cement**
Specific Gravity, Finesse Test, Consistency, Initial and Final Setting Time, Compressive Strength and Soundness Test.
We are going to perform following tests on modified mixed concrete cube:
a) Compressive Strength test
b) Splitting Tensile strength test

4. Result and Discussion

4.1 General

All the methodology and test adopted were discussed in the previous chapter. As per our experiment analysis, we used:
- Coarse aggregate of size 10-20 mm.
- Electronic waste chips of size 10-20 mm
- Fine Aggregate
- Ordinary Portland Cement of Grade 43

The process and experimental result analysis will be discussed further.

4.2 Preparation of Electronic Waste chips

The PCB brought from the market were varying in size, they are required to be broken further into smaller pieces and sieved as per the selection required for replacing the coarse aggregate. For breaking these we asked the worker of that market to break it into smaller pieces of about 10-20 mm. after that we sieved them from 10-20mm size sieve and the retained stoned were taken further for experiment.

4.3 Test on Coarse Aggregate:

4.3.1 Results of various test
The summarized results are shown in table 4.1 and plotted in graph no 4.1 for better and easy understanding.

4.3.2 Discussion
The results of our test various test shows that the specific values which we are calculated are within the limits as per ISO 9001:2008 with approximately. The minor deviations may be results of temperature and human errors. Specification for the coarse aggregate required for concrete is followed by IS383:1970.Method of testing of coarse aggregate are done as per IS2386:1963 (PART III & PART IV)

Table 4.1: Properties of Coarse Aggregates

Sr. No.	*Properties*	*Observed Value*
1	Avg. Specific Gravity	2.6567
2	Water Absorption Test	0.70%
3	Impact value	24%S
4	Abrasion value	27%
5	Crushing Value	24.66%
6	Fineness Modulus	6.86

4.4 Test on Electronic waste (PCB) used as Coarse Aggregate

4.4.1 Results of various test

The summarized results are shown in table 4.2 and plotted in graph no 4.2 for better and easy understanding.

Table 4.2: Properties of PCB

Sr. No.	*Properties*	*Observed Value*
1	Average Specific Gravity	2
2	Water Absorption Test	0.3%
3	Impact test	17%

4.4.2 Discussion

By performance of above mention test in chapter three. We founded that the certain values which are necessary to obtain before test so as to replace the coarse aggregate, we notice that the E-waste which we are using possess similar values as that of coarse aggregate. This type of situation E-waste having similar value to coarse aggregate has been observed in various literature in chapter 2 **Salman et al (March 2015) [1]** and may other similar cases . So we can say that we can use E-waste effectively and efficiently to replace natural coarse aggregate.

4.5 Test on fine Aggregate

4.5.1. Result

The summarized results are shown in table 4.3 and plotted in graph no 4.2 for better and easy understanding.

Table 4.3: Properties of Fine Aggregates.

Sr. No.	Properties	Observed Value
1	Average Specific Gravity	2.67
2	Water Absorption Test	1.21%
3	Fineness Modulus	3.16
4	Bulk Density	1577 m^3

4.5.2 Discussion

The test result shows a good physical properties of fine aggregates. The sand used in our experiment seems to a natural river sand as its properties are similar to those used in experiment counted by PanneerSelvam S. et al (2015)

4.6 Test for Cement

4.6.1. Discussion

The test results shows a properties of Cement as per ISO 9001:2008 standards. The minor deviations may be results of temperature and human errors. Results of our experiment are shown in following table 4.4.

Table 4.4: Properties of Cement

Sr. No.	*Properties*	*Observed Value*
1	Average Specific Gravity	3.15
2	Fineness	3%
3	Normal Consistency	31.5%
4	Initial Setting Time	29mins
5	Final Setting Time	625 minute
6	Compressive Strength	
	At 3 days N/mm2	19.33
	At 7 days N/mm2	27.3
	At 28 days N/mm2	43.33
7	Soundness Test	3.33 mm

4.7 Preparation of concrete

4.7.1. Quantity estimation by IS10262:2009

- Target Mean Strength = 48.25n/mm^2
- Water Cement Ratio = 0.4 (from IS 456:2000 table no 5)
- Water Content = 180 kg (from IS 10262:1982 table3)
- Estimated Air Entrapped = 2% (from IS 10262:1982 table3)
- Cement Content = 450 kg (OPC43) (from IS 10262:1982 table3)
- Fine Aggregate = 623.63 kg/m^3(from IS 10262:1982 table3)
- Coarse Aggregate = 1084.95 kg/m^3(from IS 10262:1982 table3)

4.7.2. Quantity after replacement with Electronic Waste (PCB)

The concrete is prepared by mixing in the mix proportion of M40 and 0%, 2%, 4%, 6%, 8%, and 10% of the coarse aggregate proportion and quantities of each components are given in following table 4.6

Table 4.5: Quantity of Components.

Designated Mix	*Weight kg/m3*				
	Cement	*Water*	*Fine Aggregate*	*Coarse Aggregate*	*PCB*
CA100E0	450	180	623.63	1084.95	0
CA98E02	450	180	623.63	1063.251	21.699
CA96E04	450	180	623.63	1040.64	43.398
CA94E06	450	1800	623.63	1019.853	65.097
CA92E08	450	180	623.63	998.154	86.796
CA90E10	450	180	623.63	976.455	108.495

4.8. Test on Concrete

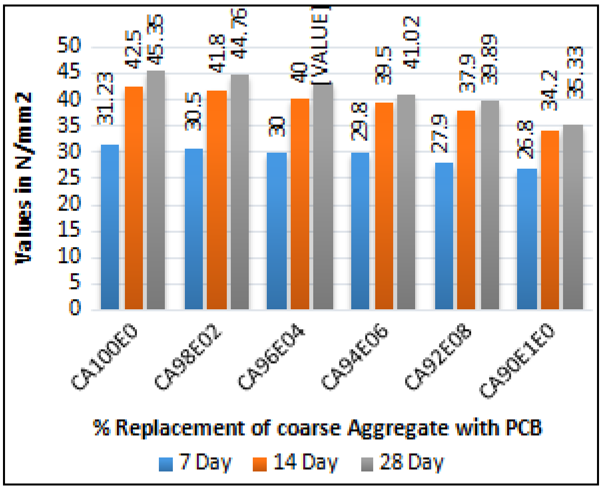
4.8.1 Test of Compressive strength:

As discussed above we prepared the concrete cubes and designated them as CA100E0, CA98E02, CA96E04, CA94E06, CA92E08, and CA90E10 each have 3 no. of cubes. Hence total no. of cubes are 18 for the test of compressive strength. The test for compressive strength is conducted as discussed in chapter 3. The maximum compressive strength found out of three concrete cubes of each mix is plotted on graph. The maximum value observed is 45.35 N/mm^2 for CA100E0 mix. The lowest value is observed at CA90E10 is 35.33 N/mm^2. The different value observed during the experiment is given in the following given table 4.7 and the plotted graph in graph no 4.5.

As we increase the content of then we observed that up to 10% replacement the decrease in compressive strength changes from 45.35 N/mm^2 to 35.33 N/mm^2. As we increase the PCB (Electronic waste) above 10% the compressive strength of the concrete cubes starts decreasing but with larger rate as compared to up to 6% replacement. The lowest value observed is at 10% replacement of Electronic Wastes (PCB) with coarse aggregate is 35.33 N/mm^2

Table 4.6: Test result of compressive strength of concrete cubes

Designated Mix	*Weight kg/m3*					*Compressive Strength (N/mm²)*		
	Cement	*Water*	*Fine Aggregate*	*Coarse Aggregate*	*PCB*	*7 Days*	*14 Day*	*28 days*
CA100E0	450	180	623.63	1084.95	0	**31.23**	**42.50**	**45.35**
CA98E02	450	180	623.63	1063.251	21.699	**30.50**	**41.80**	**44.76**
CA96E04	450	180	623.63	1040.64	43.398	**30.00**	**40.00**	**43.18**
CA94E06	450	180	623.63	1019.853	65.097	**29.8**	**39.5**	**41.02**
CA92E08	450	180	623.63	998.154	86.796	**27.9**	**37.9**	**39.89**
CA90E1E0	450	180	623.63	976.455	108.495	**26.80**	**34.2**	**35.33**



Graph No. 4.1: Compressive strength observed during experiment.

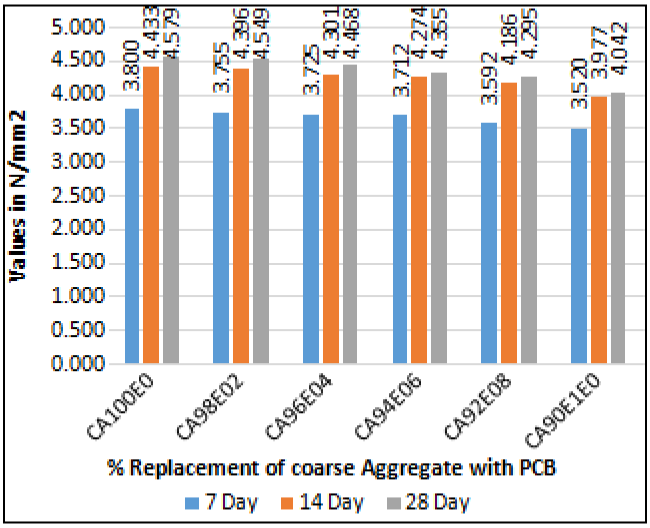
4.8.2 Test of Flexural strength

As discussed above we prepared the concrete beam and designated them as CA100E0, CA98E02, CA96E04, CA94E06, CA92E08, and CA90E10 each have 3 no. of beams. Hence total no. of beams are 18 for the test of flexural strength. The test for flexural strength is conducted as discussed in chapter 3. The maximum flexural strength found out of three concrete beam of each mix is plotted on graph. The maximum value observed is 4.579 N/mm^2 for CA100E0 mix. The lowest value is observed at CA90E10 is 4.042 N/mm^2. The different value observed during the experiment is given in the table 4.7 and the plotted graph in graph no. 4.5

As we increase the content of then we observed that up to 10% replacement the decrease in Flexural strength very slightly from 4.579 N/mm^2 to 4.042 N/mm^2. As we increase the PCB (Electronic waste) above 10% the flexural strength of the concrete beam does not show any major difference but starts falling below 4.00 N/mm^2. The lowest value observed is at 10% replacement of Electronic Wastes (PCB) with coarse aggregate is 4.042 N/mm^2.

Table 4.7: Test result of flexural strength of concrete beam

Designated Mix	*Weight kg/m³*					*Flexural Strength (N/mm²)*		
	Cement	*Water*	*Fine Aggregate*	*Coarse Aggregate*	*PCB*	*7 Days*	*14 Day*	*28 days*
CA100E0	450	180	623.63	1084.95	0	**3.800**	**4.433**	**4.579**
CA98E02	450	180	623.63	1063.251	21.699	**3.755**	**4.396**	**4.549**
CA96E04	450	180	623.63	1040.64	43.398	**3.725**	**4.301**	**4.468**
CA94E06	450	180	623.63	1019.853	65.097	**3.712**	**4.274**	**4.355**
CA92E08	450	180	623.63	998.154	86.796	**3.592**	**4.186**	**4.295**
CA90E1E0	450	180	623.63	976.455	108.495	**3.520**	**3.977**	**4.042**



Graph No. 4.2: Flexural strength observed during experiment

This type of testing is observed in the experiment performed by S.S. Singh and ArunPatel in concrete beam using Plane Circuit Board. The maximum value observed by them was 4.582 N/mm^2. The reason from the deviation of their result was due to atmospheric conditions and also due to different types and quality of electronic waste (PCB) which we used for replacing the coarse aggregate.

These result shown in table No.7 can be shown graphically as for 7 Day, 14 Day and for 28 Days individuallly

4.8.3 Test of Tensile strength

As discussed above we prepared the cylinder and designated them as CA100E0, CA98E02, CA96E04, CA94E06, CA92E08, and CA90E10 each have 3 no. of cylinders. Hence total no. of cylinders is 18 for the test of Tensile strength. The test for Tensile strength is conducted as discussed in chapter 3. The maximum Tensile strength found out of three concrete cylinder of each mix is plotted on graph. The maximum value observed is 4.534N/mm2 for

CA100E0 mix. The lowest value is observed at CA90E10 is 3.150 N/mm2. The different value observed during the experiment is given in the following given table 4. 8 and the plotted graph in graph no 4.6.

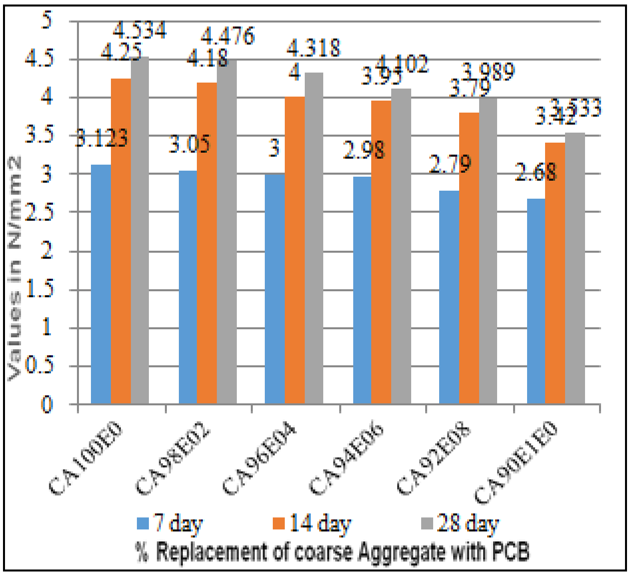
As we increase the content of then we observed that up to 10% replacement the decrease in Tensile strength very slightly from 4.534 N/mm2 to 1.751 N/mm2. As we increase the PCB (Electronic waste) above 10% the Tensile strength of the concrete cylinder shows major difference but starts falling below 4.00 N/mm2. The lowest value observed is at 06% replacement of Electronic Wastes (PCB) with coarse aggregate is 3.33 N/mm2.

Table 4.8: Test result of Tensile strength of concrete cylinder

Designated Mix	Weight kg/m^3					Split Tensile Strength (N/mm^2)		
	Cement	Water	Fine Aggregate	Coarse Aggregate	PCB	7 Days	14 Day	28 days
CA100E0	450	180	623.63	1084.95	0	3.123	4.25	4.534
CA98E02	450	180	623.63	1063.251	21.699	3.05	4.18	4.476
CA96E04	450	180	623.63	1040.64	43.398	3	4	4.318
CA94E06	450	180	623.63	1019.853	65.097	2.98	3.95	4.102
CA92E08	450	180	623.63	998.154	86.796	2.79	3.79	3.989
CA90E1E0	450	180	623.63	976.455	108.495	2.68	3.42	3.533

This type of testing is observed in the experiment performed by P Krishna in concrete cylinder using Plane Circuit Board. The maximum value observed by them was 7.41 N/mm2 at 0% use of PCBs and at 20 % of E-waste tensile strength has been reduced at 2.91N/mm2. The reason from the deviation of their result was due to atmospheric conditions and also due to different types and quality of electronic waste (PCB) which we used for replacing the coarse aggregate.

These result shown in table No.8 can be shown graphically as for 7 Day, 14 Day and for 28 Days individuallly.



Graph 4.3: Test result of Tensile strength of concrete cylinder

5. Conclusion

The final conclusion of our detailed analysis is as follow:

[1] Average specific gravity of the stone used as coarse aggregate is 2.66, water absorption noted is not more that 0.70% by its own weight. Also the fineness modulus for the fine aggregate is 6.86.The average Impact Value coarse Aggregate is 24%. The average Crushing Value coarse Aggregate is 24.6%. The average Abrasion Value coarse Aggregate is 27%. These results shows that the fine aggregates which we buyer or used is up to standard grade.

[2] For Electronic Waste (PCB) used to replace Coarse Aggregate following point can be concluded from our detailed dissertation: The Average specific gravity of the PCB used is 2, the water absorption noted is not more that 0.3% by its own weight, the average Impact Value of the PCBs is 17%

[3] For Fine Aggregate following point can be concluded from our detailed dissertation: The Average specific gravity of fine aggregate is 2.67, the water absorption noted is not more that 1.21% by its own weight, Also the fineness modulus for the fine aggregate is 3.16.

[4] The bulk density note is 1577 N/mm^3.These results shows that the fine aggregates which we used is up to standard grade.

[5] For Cement grade 43 testing used the following point are drawn: The Average specific gravity is 3.15, The fineness is 3%.The Normal consistency found is 31.5%.The Initial time and final setting time for the cement which we used are 19 min And 625 min. The compressive strength for cement cube after 28 days found to be 43.33 N/mm^2.The expansion in the cement mixture is noted to be 3.33 mm.

[6] The compressive strength found to be in between 45.35 $N/mm^2$to 35.33 N/mm^2. But we observed that up to 10% replacement of coarse aggregate with Electronic Waste (PCB) generally does not shows any major difference in the compressive strength and after that the strength decreases but up to 5%.

[7] As we increase the content of then we observed that up to 10% replacement the decrease in Flexural strength very slightly from 4.579 N/mm^2 to 4.042 N/mm^2. As we increase the PCB (Electronic waste) above 10% the flexural strength of the concrete beam does not show any major difference but starts falling below 4.00 N/mm^2. The lowest value observed is at 10% replacement of Electronic Wastes (PCB) with coarse aggregate is 4.042 N/mm2.

[8] As we increase the content of then we observed that up to 10% replacement the decrease in Tensile strength very slightly from 4.534N/mm2 to 3.533 N/mm^2. As we increase the PCB (Electronic waste) above 10% the tensile strength of the concrete cylinder does not show any major difference but starts falling below 4.00

N/mm^2. The lowest value observed is at 10% replacement of Electronic Wastes (PCB) with coarse aggregate is 3.533 N/mm^2.

[9] Based on these experiment we concluded that the waste generated by the Electronic waste (PCB) can be used as an alternative for the natural crushed stone used in concrete cubes as the compressive strength, and the flexural tensile strength of the testing blocks does not shown any major difference with its original standard mix concrete.

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