International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

E-WASTE (NMPCB) AS PARTIAL REPLACEMENT OF FINE AGGREGATE FOR SUSTAINABLE CONCRETE PRACTICE

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Abstract - *Waste from Electric and Electronic Equipment's (WEEEs) is currently considered to be one of the fastest growing streams in the world, with an estimated growth rate going from 3% up to 5% per year this rapid growth is due to continuous upgradation of technology and introduction of new technologies to the market. India is the 5th highest waste producer in the world. Disposal of E-waste is the typical task faced in many regions across the globe. Acids and sludge obtained from melting computer chips, if disposed in the ground causes acidification of soil. Utilization of E-waste is the partial solution to Environmental and Ecological problems. The rapid increase in the construction activity in India, has resulted huge demand for the aggregates to be used in the concrete. This has led to depletion of natural resources and adverse changes in environment. This rapid development in the infrastructure has led to the shortage of natural sand. This study illustrates the efforts to utilize E-plastic, Non-metallic Printed Circuit Board (NMPCB) as a filler material in concrete. In the research, to the present practical solution for the disposal of Waste Non-metallic Printed Circuit Board fractions (NMPCB) were casted by weight of the fine aggregate using Portland Composite Cement (PCC) for M20 grade of control concrete having 0.47 water cement ratio. Results showed by comparing with the conventional specimen that all the physical tests were conducted on materials. So, by notice to experimental results and environmental effects of (NMPCB), the best optimum replacing percentage of (NMPCB), with fine aggregate of control concrete is up to 8.5%. The main aim of this study recommends the recycling of E-waste as an aggregate in the production of new concrete.*

Key Words: **E-waste, Non-metallic printed circuit board, Portland Composite Cement, Concrete, Bulk Density, Compressive Strength, Fine aggregate replacement.**

1. INTRODUCTION

Every year, 20–50 Million tons of waste electrical and electronic equipment (WEEE) are generated worldwide. India is ranked 5th in the world among top e-waste producing countries-USA, China, Japan and Germany. 70% of e-waste is generated in ten states. Maharashtra ranks the first followed by Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab. Among the cities, Mumbai ranks first followed by Delhi, Bangalore, Chennai, and Hyderabad.

2. LITERATURE REVIEW

Ashutosh Bhaskar et al 2018 has represented the emerging issue posing serious pollution problems towards human & environment. For solving the disposal of large amount of E- waste like PCBs can be utilized and can be used as a partial replacement for fine aggregate ranging (0%,5%,10%,15%,20%) with ordinary Portland cement and water cement ratio 0.5 to achieve a desire concrete in terms of their properties.

Sagar R. Raut et at 2018 has discovered alternative to overcome the demand of natural materials such as aggregate and cement in construction work for solving large amount of E- waste material as a partial use of E-waste in concrete industry replacement 5% to 20% by coarse aggregate. And it is experimentally found that 15% replacement of aggregate gives the optimum results for compressive strength and also it provides a sustainable approach.

Ravindra N. Patil et al 2017 has studied processing of "Electronic waste" experimental study is aimed to utilize "E-waste" and corn cob which is used as partial replacement to coarse aggregate on strength criteria of M30 grade concrete to increase its mechanical properties and to make the concrete light weight ranging 5% 10%, 15%, 20% using Ordinary Portland cement 53 grade cement. Due to use of E-waste and corncob as partial replacement of coarse aggregate in construction, energy and cost of coarse aggregate is significantly saved. It has been concluded 10% E-waste and corn cob aggregate without any long term detrimental effects and with acceptable strength development properties useful for light weight concrete.

Balasubramanian B et al 2016 has discovered waste utilization as an attractive alternative for the disposal of fastest growing E-waste streams estimated growth rate is from 3% to 5% every year. Total replacement in concrete is not possible as it not plays role of concrete in terms of strength, durability and workability but can be used as partially replacement of coarse aggregate in concrete in a percentage of (5%, 10%, 15%, 20%,25%,30%) by weight using Ordinary Portland cement 43 grade water cement ratio 0.5 for M20 grade mix concrete. By comparing the results with the conventional it has been concluded as more than 15% of replacement for coarse aggregate is not considerably useful for construction field because of strength decease. But it solves a potential disposal problem and saves natural resources.

3. MATERIAL AND METHODOLOGY

(a) MATERIAL

- **CEMENT -** The Portland Composite cement (PCC) used in investigation confirming the specification as per IS 16415-2015**.**

Table 1: Physical Composition of PCC

Description	Result	Specification (IS 12269-1987)
Specific Gravity	2.97	-
Fineness modulus (%)	3.5	Not exceed 10%
Consistency (%)	27	-
Initial Setting time (min)	38	Minimum 30 min.
Final setting time (min)	480	Max 600 mins.
Compressive strength at (N/mm^2)		Target strength is achieved
7days	27.417	
14 days	41.321	
28 days	44.537	

- **FINE AGGREGATE -** The sand used in this research was natural sand conforming to grading zone II as per IS 383-1970.

Table 2: Properties of Fine Aggregate

Test	Values Obtained	Specification (IS 383-1970)
Specific Gravity	2.585	2.50-2.90
Water Absorption %	0.2	Less than 2%
Fineness Modulus %	2.726	Medium Sand (2.60-2.90)
Bulk density Kg/m^3	1464	1450-1650

- **COURSE AGGREGATE -** Locally available crushed angular coarse aggregate was used. The properties of coarse aggregate were tested according to IS 383-1970.

Table 3: Properties of Coarse Aggregate

S.No	Test	20mm	10mm	Specification (IS 383-1970)
1	Specific Gravity	2.782	2.745	2.50- 2.90
2	Water Absorption %	0.4	0.6	Less than 2%
3	Fineness Modulus %	3.995	3.321	3.25 -5.70
4	Bulk Density kg/m^3	1590	1534	1500 -1700

- **E-WASTE NON-METALLIC PRINTED CIRCUIT BOARD(NMPCB) -** The divided particle size of waste E-plastic (WNMPCB) particles is determined to be between 1.18mm – 2.36mm. The usage of waste E-plastic particles was considered as filler material in cement concrete in various percentages.

Table 4: Properties of E-Waste NMPCB

S No.	Test	Values obtained
1	Specific Gravity	1.4
2	Water Absorption %	<0.2
3	Fineness modulus %	2.932
4	Rodded Bulk Density g/cc	0.738
5	Color	Dark
6	Shape	Angular

(b) CONCRETE NOMINAL MIX DESIGN - All the calculations are done per meter cubic. M20 Nominal mix design is done using Portland Composite Cement (PCC) with w/c 0.47 as per the standards of IS 456-2000 under BIS norms. As the mix prepared contains combination of E-Waste NMPCB and fine aggregate the corresponding weights per meter cubic of concrete for different proportions using Portland Composite Cement (PCC). Various tests have been performed taking different percentage of E-waste (NMPCB) specimen have been casted and evaluated compared with control mix. This chapter presents the details of materials used, concrete Nominal mix design under BIS standard, properties of materials and specimens used, test setup and testing procedure for cubes. On the basis of the result from testing of specimen conclusion will be obtained by adopting optimum percentage of E-waste (NMPCB).

Table 5: Mix Proportions

Mix	Cement	Fine Aggregate	E-waste (NMPCB)	Coarse Aggregate
Mix 1	PCC	100%	0%	CA
Mix 2	PCC	95%	5%	CA
Mix 3	PCC	92.5%	7.5%	CA
Mix 4	PCC	91.5%	8.5%	CA
Mix 5	PCC	91%	9%	CA
Mix 6	PCC	90.5%	9.5%	CA
Mix 7	PCC	90%	10%	CA
Mix 8	PCC	87.5%	12.5%	CA
Mix 9	PCC	85%	15%	CA

Table 6: Nominal Mix Design M20 for kg/m^3

Mix Code	Cement	Water w/c=0.47	Coarse aggregate		Fine Aggregate	WNMPCB
			20mm.	10mm		
Mix 1	403.2	189.50	725.76	483.84	604.8	0
Mix 2	403.2	189.50	725.76	483.84	574.56	30.24
Mix 3	403.2	189.50	725.76	483.84	559.44	45.36
Mix 4	403.2	189.50	725.76	483.84	553.39	51.408
Mix 5	403.2	189.50	725.76	483.84	550.37	54.43
Mix 6	403.2	189.50	725.76	483.84	547.34	57.456
Mix 7	403.2	189.50	725.76	483.84	544.32	60.48
Mix 8	403.2	189.50	725.76	483.84	529.2	75.6
Mix 9	403.2	189.50	725.76	483.84	514.08	90.72

(c) CONCRETE PREPARATION AND CASTING –

- The present study is an attempt to investigate experimentally the effect of E-waste NMPCB (i.e. Non-metallic Printed Circuit Board) in M20 grade mix concrete with IS 456-2000 standard under BIS norms.
- The Portland Composite cement (PCC), fine aggregate and coarse aggregate and E-waste NMPCB are mixed in dry state and then the calculated water quantity is added and the whole concrete is mixed for 5 minutes, then fresh concrete is tested for Workability (Slump Cone) and Bulk Density after that concrete is poured in the moulds which are screwed tightly.
- The concrete is poured into the moulds in 3 layers by poking with tamping rod for cubes of 150×150×150 mm Size.
- The cast specimens are removed after 24 hours and these are immersed in a water tank.
- After a curing period of 7, 14 and 28 days the specimens are removed and these are tested was tested for Compression Strength.
- The results are compared with conventional concrete Mix1 obtained in (100%FA+0%EWNMPCB).
- Six sets of mixture proportions were cast. For every set 9 cubes were prepared, Out of 9cubes, 3cubes are tested for compressive strength testing at 7days another 3 cubes are tested for compressive strength testing at 14days and for 28 days.
- First was control mix (without E-Waste NMPCB) of M20 (1:1.5:3) and other 5 sets contained E-Waste (NMPCB) in the difference of 2.5% i.e. (5%, 7.5%, 10%,12.5%, 15%) but after results are performed it has been observed that Mix3 having the composition of 92.5% FA+7.5% EWNMPCB gave higher result but value obtained in Mix7 having the composition of 90%FA+10%EWNMPCB was not up to the certain limit of strength, therefore the mid percentages in between the 7.5% and 10% is also observed i.e. (8.5%, 9%, 9.5%)to get the optimum value of E-waste NMPCB % which is then compared with the standard obtained in Mix1 having the composition of 100% FA+ 0% EWNMPCB ranging such as (5%, 7.5%, 8.5%, 9%, 9.5% 10%,12.5%,15%) using Portland Composite Cement (PCC) and other general material used for this project were tested to get their properties.

4. TEST RESULT & DISCUSSION

(a) SLUMP TEST -

Table 7: Slump value for different mixes

Type of Mix	Slump(mm)
Mix 1(100%FA+0.00%EWNMPCB)	75
Mix 2(95%FA+5%EWNMPCB)	68
Mix 3(92.5%FA+7.5%EWNMPCB)	57
Mix 4(91.5%FA+8.5%EWNMPCB)	55
Mix 5(91%FA+9%EWNMPCB)	55
Mix 6(90.5%FA+9.5%EWNMPCB)	53
Mix 7(90%FA+10%EWNMPCB)	51
Mix 8(87.5%FA+12.5%EWNMPCB)	47
Mix 9(85%FA+15%EWNMPCB)	40

(b) BULK DENSITY -

Table 8: Bulk Density for different mixes

Type of Mix	Bulk Density kg/m^3
Mix 1(100%FA+0.00%EWNMPCB)	2433

Mix 2(95%FA+5%EWNMPCB)	2405
Mix 3(92.5%FA+7.5%EWNMPCB)	2383
Mix 4(91.5%FA+8.5%EWNMPCB)	2371
Mix 5(91%FA+9%EWNMPCB)	2367
Mix 6(90.5%FA+9.5%EWNMPCB)	2355
Mix 7(90%FA+10%EWNMPCB)	2348
Mix 8(87.5%FA+12.5%EWNMPCB)	**2321**
Mix 9(85%FA+15%EWNMPCB)	**2294**

(c) COMPRESSIVE STRENGTH –

Table 9: Compressive Strength test result for varying E-Waste NMPCB waste replacement levels in concrete in N/mm^2

Type of Mix	Compressive Strength (N/mm^2)		
	7days	14 days	28days
Mix 1(100%FA+0.00%EWNMPCB)	14.962	19.881	22.281
Mix 2(95%FA+5%EWNMPCB)	14.311	20.755	22.814
Mix 3(92.5%FA+7.5%EWNMPCB)	15.510	21.081	23.910
Mix 4(91.5%FA+8.5%EWNMPCB)	15.348	21.940	24.073
Mix 5(91%FA+9%EWNMPCB)	14.296	20.355	21.866
Mix 6(90.5%FA+9.5%EWNMPCB)	13.821	20.192	21.584
Mix 7(90%FA+10%EWNMPCB)	13.525	19.318	21.007
Mix 8(87.5%FA+12.5%EWNMPCB)	12.785	17.407	19.511
Mix 9(85%FA+15%EWNMPCB)	12.207	16.222	17.436

5. CONCLUSIONS

(a) M20 grade concrete can be adopted of mix (1:1.5:3)using Portland composite cement with water cement ratio 0.47
(b) The different range of E-waste NMPCB (5%, 7.5%,8.5%, 9%, 9.5%, 10%, 12.5%, 15%) are taken whose slump value, Bulk density, Compressive strength is conducted which is compared with the conventional mix grade of concrete.
(c) .The Workability of fresh concrete is decreased by increase of substitute percentage of E-waste NMPCB. Decrease in consistency is due to angularity of E-waste (NMPCB).
(d) The Density of the concrete was found to be reducing with the increase in the e-waste quantity. Self-weight of concrete reduces when there is rise in E-waste percentage. Hence it can be consumed as a light weight concrete.
(e) Compressive strength of E waste concrete having 5% E- waste as a partial replacement to fine aggregates shows a significant increase in comparison to conventional concrete and gave a increased 8.042% result with 8.5% partial replacement of E-waste NMPCB after that the strength started decreasing with the increase of E-Waste (NMPCB).
(f) Cost of the EC can be reduced and made further economical if proper support, and legal amendments are made through government organizations to process it on a large scale.
(g) Utilization of E-Waste NMPCB in concrete may be the efficient gave a optimum value of 8.5% in terms of Strength as a partial replacement of E-WNMPCB using Portland Composite Cement (PCC) and shows economical and best way of disposing the e-waste which is now the fastest growing solid waste in the world.

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