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Utilization of PCB and cost-reduction of Concrete

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Abstract

This paper focuses on the study of experimental investigation on optimum level of printed circuit board (PCB) on the compressive strength of concrete. More than 20 million tons of e-waste is produced every year and the disposal of which is becoming a challenging problem. Due to increase in cost of conventional concrete, civil engineers has forced to find out the suitable alternatives to its ingredients. So considering economy and strength of concrete PCB, granulated blast-furnace slag (GBS) as partial replacement of fine aggregate were introduced and ground granulated blast-furnace slag (GGBS) as partial replacement of cement. The work was conducted on M20 grade mix and a total of 5 mixtures were prepared one for conventional mix and remaining contains PCB in the range of 5%, 7.5%, 10%, 12.5% and a constant percentage of GGBS & GBS. All specimens were moist cured for 7 & 28 days before testing. The test result shows that the compressive strength increased initially due to combined replacement and then starts decreases as increase in amount of PCB. The feasibility of utilizing PCB as partial replacement of fine aggregate has been presented. In present study we investigated that 10% is the optimum amount of PCB that can be replaced for opted replacement combination of GGBS & GBS.

Keyword: PCB, GGBS, GBS, Concrete, Compressive strength.

INTRODUCTION

In the present scenario, use of electronic gadgets increasing rapidly and hence large amount of e-waste is being produced every year. E-waste can be produced from many sources such as personal computers, DVD players, mp3 players, laptops, LCD, LED, television sets, mobile phones and so on. Many people think that e-wastes are only comprised of IT products, but electrical and other household appliances also form e-waste when they are discarded. Such items consist of washing machines, vacuum cleaners, toasters, drying machines, refrigerators, irons, air conditioners, coffee machines and related items. There are many components obtained from e-waste such as Cathode ray tubes (used in TVs, computer monitors, ATM, cameras etc.), Printed circuit board (PCB), Chips and other gold plated components, Plastic from printers, keyboards, monitors etc. and Computer wires.

An electronic circuit consisting of thin strips of a conducting material such as copper, which have been coated from a layer fixed to a flat insulating sheet called a printed circuit board, and to which integrated circuits and other components are attached. In the present scenario, the major issue of e-waste management is how to manage PCB waste. No construction activity can be imagined without using concrete. Concrete is the most widely used building material in construction industry. The main reason behind its popularity is its high strength and durability. 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 PCB. For solving the disposal of large amount of PCB waste material, reuse of PCB in concrete industry is considered as the most feasible application.

Figure 1: PCB Scrap obtained from motherboards

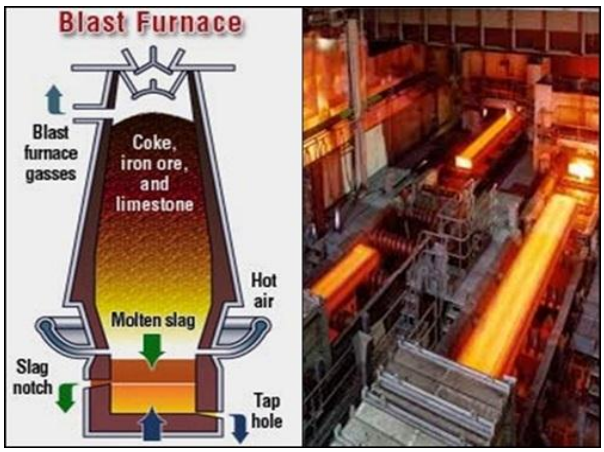


Figure 2: Sources of Ground Granulated Blast Slag

GGBS commonly known as blast furnace slag. GGBS is obtained by the heating of iron ore, limestone and coke at a temperature about 1500 to 1600 degree Celsius. This process is carried out in a blast furnace. The by-product of iron manufacturing is a molten slag and molten iron. The molten slag consist a composition of 30% to 50% silicon dioxide (SiO2) and about 28% to 40% calcium oxide (CaO), which is near to the composition of Portland cement. This slag is later granulated by cooling it at a certain temperature. For this, it is allowed to pass through a high-pressure water get system. This results in quenching of the particles of size less than 5mm in diameter. The particles are further dried and grind in a rotating ball mill to form a fine powder, known as ground granulated blast furnace slag.

EXPERIMENTAL PROGRAMME

MATERIALS

Cement

Most commonly available Portland Pozzolana Cement of 43 grade confirming to IS:8112-1987 was used for investigation and its properties were tested as per Indian Standard IS:4031. The cement used was dry, powdery, free from lumps and all possible contact with moisture was avoided while storing cement. Specific gravity of cement used was 3.15.

Aggregate

Locally available river sand confirming to grading Zone-2 of IS:383-1970 was taken into account. Specific gravity of fine aggregate was 2.60 and the shape was angular. Type of fine aggregate used was uncrushed (natural) and having dark colour. Locally available ordinary crushed stone with size 10mm and 20mm were used in the proportion of 40% and 60% as per IS:383-1970. Superplasticizer used was Polycarboxylate Ether.

PCB

Recent study have shown that use of finely grounded PCB waste gives better result and technical advantages than used as coarse aggregate, for solving disposal problem of PCB. By doing sieve analysis of PCB we found it as fine aggregate confirming to grading Zone-4, which means that passing percentage on 600µ sieve more than 80%. So during replacement we have replaced that sand only which was passing through 600µ by PCB for better results and accuracy.

TABLE 1
PROPERTIES OF MATERIAL

S.N.	Characteristics	PCB	GBS	GGBS	Fine Aggregate	Coarse Aggregate
1.	Type	Fine Aggregate	Fine Aggregate	Binding Material	Uncrushed (Natural)	Crushed
2.	Maximum Size	< 4.75	4.75	-	4.75	20
3.	Specific Gravity	1.20	2.58	2.85	2.60	2.64
4.	Colour	Light Grey	White-Grey	Near-White	Dark	Brown to Black
5.	Shape	Round & Angular	Round & Angular	Nearly Spherical	Angular	Angular
6.	Fineness Modulus	1.64	2.32	-	2.46	7.12
7.	Grading Zone	Zone-4	Zone-2	-	Zone-2	-

GGBS & GBS

A good quality GGBS of specific gravity 2.85 was provided by a cement manufacturer in Delhi NCR. Pozzolanic materials such as ground granulated blast-furnace slag (GGBS), fly ash and silica fume are commonly used in concrete because they improve the durability and reduce porosity; improve the interface with the aggregate. GBS used was collected from local supplier in Delhi confirming to Zone-2 as per IS:1383-1970. A fixed percentage of GGBS & GBS were 20% & 15% used respectively on the basic of previous studies. Physical requirements of GGBS are presented in Table-1 and Chemical requirements of GGBS provided by distributor are presented in Table-2.

TABLE 2
CHEMICAL PROPERTIES OF GGBS

S.N.	Chemical Compositions	Test Results	S.N.	Chemical Compositions	Test Results
1.	Loss on Ignition	0.10	7.	MgO	8.52
2.	Insoluble Residue	0.56	8.	SO_3	0.22
3.	SiO_2	37.28	9.	Na_2O	1.14
4.	Al_2O_3	10.18	10.	K_2O	0.30
5.	Fe_2O_3	2.02	11.	Cl^-	0.00
6.	CaO	34.47	12.	Glass Content*	94.00

SPECIMEN PREPARATION AND CURING

M20 concrete was designed as per IS:10262-1982. Water-cement ratio used for this mix design was 0.40 and weigh batching was taken into account. A total number of 5 mixes were prepared:

- S1: Conventional Mix
- S2: 20% GGBS; 15% GBS + 5% PCB
- S3: 20% GGBS; 15% GBS + 7.5% PC
- S4: 20% GGBS; 15% GBS + 10% PCB
- S5: 20% GGBS; 15% GBS + 12.5% PCB

For each mixture six 150mm cubes were cast for determining the compressive strength for 7 & 28 days. Casting of cubes was conducted in three layers. Each layer was compacted by external vibrator and then top surface was levelled and smoothed using a trowel. After 24 hours concrete cubes were demoulded and cured until the time of compressive strength test according to IS:516-1959.

Testing of the Specimens

The mixtures of concrete S1,S2,S3,S4 and S5 were tested for compressive strength development. The workability of fresh concrete including slump was measured for each mixture. The slump of fresh concrete was determined following IS 456:2000. Compression test was performed on a 200 tonne compression testing machine available in the laboratory as per IS:516-1959. Load applied by the compression testing machine was uniform until the failure of specimen. Specimens were placed horizontally between the loading surfaces of compression testing machine and maximum load at failure was noted to calculate compressive strength of specimen.

RESULTS AND DISCUSSION

A concrete mix grade of M20 is aimed; the design mix proportion is obtained by Indian standard method of mix design as per IS:10262-2009. For obtained proportion water-cement ratio was 0.40. PCB was added in amount of 0%, 5%, 7.5%, 10% and 12.5% by the weight of fine aggregate of mix.

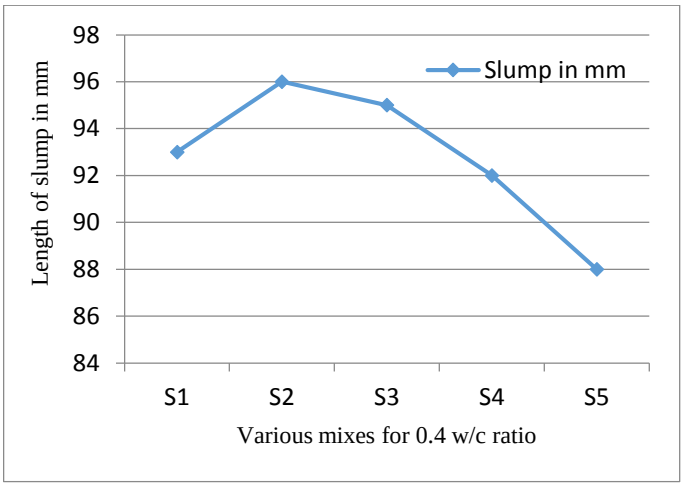
WORKABILITY TEST RESULTS

Slump cone test was conducted on fresh concrete with varying percentage of PCB waste increases. The effect of PCB, GGBS & GBS on the workability of concrete can be seen in the Table 3 and Graph 1 shows the graphical representation of slump values of S1, S2, S3, S4 and S5. Test results shows that value of slump on combined replacement as in mix S2 came more than conventional mix and as the PCB content increased the value of slump decreased.

TABLE 3

RESULT OF SLUMP OF CONCRETE FOR VARIOUS MIXES

Type of Concrete	Slump in mm	Workability
S-1	93	Medium
S-2	96	Medium
S-3	95	Medium
S-4	92	Medium
S-5	88	Medium



Graph 1: Variation of slump for different mixtures.

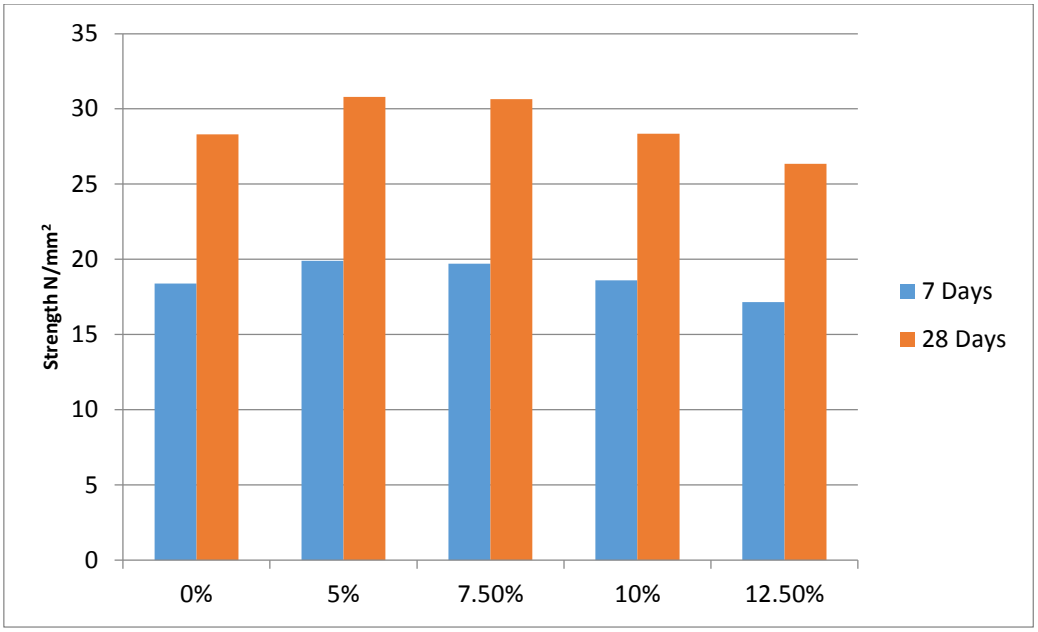
COMPRESSIVE STRENGTH TEST RESULT

The test result of compressive strength is represented in Table 4. The test was carried out to obtained compressive strength of concrete at the curing period of 7 & 28 days. Graphical representation of variation in compressive strength for various mixtures is shown in Graph 2. It is obtained that compressive strength increased initially for mix S2 and then decreases as the value of PCB increased in concrete. Mixtures S2, S3 & S4 gives more compressive strength value than conventional mixture. Compression strength value lower than conventional mixture came from mixture S5.

TABLE 4

COMPRESSIVE STRENGTH TEST RESULTS

Mix Specification	Conventional Mix S1	S2	S3	S4	S5
Proportion of PCB Scrap	**0%**	**5%**	**7.5%**	**10%**	**12.5%**
7 Days	18.40	19.90	19.70	18.60	17.15
28 Days	28.30	30.80	30.65	28.35	26.35



Graph 2: Compressive strength gained in number of days.

COST ANALYSIS

From Table 5 we noted that for S2, S3, S4 & S5 percentage saving in material cost were 10.28%, 10.58%, 10.88% & 11.18 respectively over the conventional concrete for 1 m^3 volume. This is a significant saving of material cost. Replacement of cement with GGBS, fine aggregate with PCB & GBS can save huge cost where mass concreting has to be done.

TABLE 5
COST OF MATERIALS PER CUBIC METRE OF CONCRETE FOR M20

Material	Rate (Rs.)	Conventional Concrete		S2		S3		S4		S5	
		Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Cement	400 per bag	8.22	3288	6.576	2630.4	6.576	2630.4	6.576	2630.4	6.576	2630.4
Fine Aggregate	45 per cubic ft^3	16.63	748.4	13.304	598.68	12.888	579.96	12.471	561.2	12.061	542.75
Coarse Aggregate	68 per cubic ft^3	30.55	2077	30.55	2077.4	30.55	2077.4	30.55	2077.4	30.55	2077.4
GGBS	100 per bag	0	0	1.644	164.4	1.644	164.4	1.644	164.4	1.644	164.4
GBS	0 per cubic ft^3	0	0	2.495	0	2.495	0	2.495	0	2.495	0
PCB	0 per cubic ft^3	0	0	0.831	0	1.247	0	1.664	0	2.074	0
Super Plasticizer	40 per lt	3.5	140	3.5	140	3.5	140	3.5	140	3.5	140
Total Cost			6254		5610.9		5592.2		5573.4		5554.9
Percentage saving (%)			**0**		**10.28**		**10.579**		**10.879**		**11.174**

CONCLUSIONS

Following conclusions can be made based upon this experimental study:

A. When the water-cement ratio of mixes is taken into account, it can be concluded that as the GGBS & GBS content increases, the value of slump also increases for same water-cement ratio and as PCB content increases, the value of slump decreases for the same water-cement ratio, and thus, the GGBS & GBS has positive effects on the workability while PCB has negative.

B. The compressive strength of PCB, GGBS & GBS concrete increased up to an optimum point and start decreases as the PCB content increased to a optimum percentage even though remains more than compressive strength of conventional concrete.

C. It is observed that PCB can be used to replace some of the fine aggregate in a concrete mixture. The optimum level of PCB content for maximizing strength is about 10% of the total fine aggregate content for opted GGBS & GBS content in this experimental study.

D. It is observed that the use of PCB, GGBS & GBS in concrete has saved a good quantity of binding material and fine aggregate by replacing it by weight. Replacement of PCB up to 10% shows a good behaviour as the strength of concrete slightly equal to the strength of conventional concrete and saves material cost up to 10.88% over the conventional concrete.

E. From above experimental results and discussions, it is proved that the replacements we have done are the good alternative materials for reducing cement & fine aggregate consumption, reducing the cost of materials. Use of electronic waste product can be one of the economic way for their disposal in environment friendly manner which contributes to save environment and conserve natural resources.

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