International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075, Volume-8 Issue-6, April 2019

Influence of Bottom Ash as Fine Aggregate in Ggbfs Geopolymer Concrete

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Abstract**: *The modern engineering has successfully involved in developing innovative, sustainable, green and recycled products in the manufacture of concrete. In India, the demand of natural sand is quite high due to the rapid infrastructural growth. The abundance availability of Fly ash and bottom ash that needed to be disposed of in a friendly way. Bottom ash has potential to be used as concrete material in place of fine aggregate. This paper elaborates the effect of bottom ash as fine aggregate in Geopolymer concrete. Bottom ash used as fine aggregate replaced partially in geopolymer concrete. GGBFS is used as Cement replacement in geopolymer concrete. NaOH and Na_2SiO_3 activator are used as binder in geopolymer concrete. The test involved designation of 20%, 40 % & 60% of bottom ash (BA) as a partial replacement of fine aggregate to study the engineering properties (compression test, split tensile strength) and the functional properties (test on sulphate resistance, salt water resistance, test on acid resistance, RCPT, sorptivity also quality assessment test (UPV test) and the test results indicate that there is decrease in compressive stress with increase of bottom ash, it is observed that 20%to 40% replacement of bottom ash has good strength and durability***

Index Terms**: *bottom ash, durability study, engineering properties, geopolymer concrete,***

I. INTRODUCTION

Concrete is most widely used material in construction and the ordinary Portland cement (OPC) is the major ingredient used in Portland cement concrete. Cement producing industry emits CO_2 gas which is dangerous greenhouse gas and also leads to environmental pollution. So, alternate binder should be used in concrete instead of cement but with chemical properties similar to cement. The industrial by-products such as fly ash, bottom ash, ggbfs has similar properties to cement. Bottom ash is the by-products of coal and they are disposed in large amount. There is a huge demand for sand (fine aggregate) in concrete, instead of disposing the bottom ash as land fill or waste material. Bottom ash can be used in fine aggregate as partial replacement. They are capable to be used in construction and road pavements.

GGBFS is used as an alternative of Portland cement binder in geopolymer concrete. The geopolymer concrete attains

Revised Manuscript Received on April 07. 2019.

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Various materials are replaced in geopolymer concrete to improve the strength of geopolymer concrete in such way that glass fines are used as replacement for fine aggregate which shows low density and high strength [1]. The other materials such as Fly ash, Nano silica and steel fiber incorporated 12M geopolymer concrete produced high compressive strength [2]. Spent garnet also used as fine aggregate in self-compacting which shows good workability in geopolymer concrete [3] Light weight geopolymer concrete with fly ash as binder and bottom ash fine aggregate used as thermal insulator and modern strength [4].Fly ash was replaced in geopolymer binder and they showed density of 1500kg/m^3 and compressive strength of 17.5 MPa [5].There are some re-cycled materials such as Electronic waste was used as fine aggregate at different proportion which shows moderate increase in the compressive strength [6]. Recycled coarse aggregate also used as fine aggregate in geopolymer concrete [7]. Bottom ash is used fine aggregate in fly ash and fly ash-bottom ash based geopolymer concrete in which bottom ash is significantly low.[8]. Granite slurry was also used in geopolymer concrete as fine aggregate in fly ash and GGBFS as binder [9]. Lime stone and oil palm shell OPS used as fine aggregate in geopolymer concrete [10] Bottom ash is partially replaced with fine aggregate at different proportion and 20% replacement is found to be optimum replacement [11]. Bottom ash used at partial and full replacement of fine aggregate in fly ash based geopolymer concrete [12].

In this investigation the bottom ash is used as fine aggregate in geopolymer concrete at replacement level of 0%,20%,40% and 60% to evaluate the engineering properties (compressive strength test, split tensile test) for 3,7 and 28 days and durability tests (salt water resistance, acid attack tests, sulphate attack test, RCPT, sorptivity) for 28,56 and 90 days and quality assessment test.

II. MATERIALS

A. GGBFS

Ground granulated blast furnace slag was used as binder in this study. This geopolymer concrete consist of 100% ggbfs. The chief chemical components of ggbfs are similar to cement. The alkaline solution is used in this instead of water

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B. Alkaline solution

Sodium hydroxide and sodium silicate was used as alkaline solution in this geopolymer concrete. The $NaOH/Na_2SiO_3$ ratio is 2.5. NaOH is available in pellets form. It is dissolved in water a day prior to use to make required molarity / concentration .10M = (10 x 40 = 400gm). Na_2SiO_3 is available in brownish colored.

C. Bottom ash

Bottom ash was collected from nearby Thermal power plant. The chemical composition found to be more similar to sand. Thus, the bottom ash is partially replaced in sand at different mix proportion. The properties of bottom ash are listed in Table 1

Table I. Properties of bottom ash

Physical properties of bottom ash		
S.no	Property	Value
1	Specific gravity	1.7
2	Water absorption by mass (%)	30.2
3	Fineness modulus	1.37

D. Superplasticizer

To achieve the workability for concrete, superplasticizers are used. In this, 5% of polycarboxylic ether is used as superplasticizer

E. Water

Generally, water is used to achieve workability for concrete. In this geopolymer concrete 12% water is used.

III. MIX PROPORTION AND EXPERIMENTAL PLAN

All ingredients such as GGBS, fine aggregates and coarse aggregates were mixed in dry condition for 3-4 minutes then alkaline activator solution was added Sodium hydroxide pellets was mixed in water 24 hours before mixing with sodium silicate solution. Alkaline activator solution was prepared 3-4 hours before mixing. Bottom ash is partially replaced at 0,20,40,60% in sand their mix proportion is shown in table II.

Table II. Mix proportion

Materials		0% (Kg/m^3)	20% (Kg/m^3)	40% (Kg/m^3)	60% (Kg/m^3)
GGBFS		330.66	330.66	330.66	330.66
Fine aggregate	sand	749.4	608.74	456.56	304.37
	Bottom ash	0	97.98	196	294
Coarse aggregate		1344.7	1344.7	1344.7	1344.7

The mix proportion has been done based on the specific gravity of the bottom ash and sand. The mix proportion where given specimen ID. The properties of fresh concrete have been tested and then the specimen is tested for engineering and durability properties. The various percentage of replacement are done only for fine aggregate as follows

a) GPB0 – Control GPC, with M sand
b) GPB20- 20% replacement of M-sand with BA
c) GPB40- 40% replacement of M-sand with BA.
d) GPB60- 60% replacement of M-sand with BA.

Table III. Mix proportion with MIX-ID

Specimen ID	GGBFS (Kg/m^3)	Fine aggregate (Kg/m^3)		Coarse aggregate (Kg/m^3)
		Sand	Bottom ash	
GPB0	330	749	0	1344.
GPB20	330	608	97	1344
GPB40	330.	456	196	1344
GPB60	330	304	294	1344

IV. EXPERIMENTAL RESULTS AND DISCUSSION

A.COMPRESSIVE STRENGTH

The specimen was tested as per IS: 516-59. Compressive strength of geopolymer concrete specimen was tested for 3,7 and 28 days. The results are shown in Fig 1.

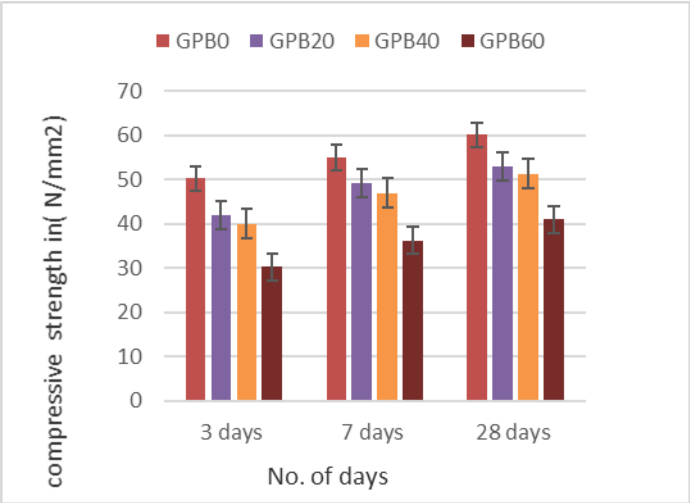

Fig 1. Variation in compression strength

The geopolymer concrete attains high early strength because of geopolymerisation process the results show that there is no increase in compressive strength with increase of bottom ash percentage. The percentage of change in GPB20 compared to GPB0 is 12%. GPB20 AND GPB40 is almost in the same range and they are good in compressive strength compared to GPB60.

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B. SPLIT TENSILE STRENGTH TEST

The tensile test was conducted as per IS 5816. The split tensile test is conducted for 3,7 and 28 days and their results are shown in Fig 2.

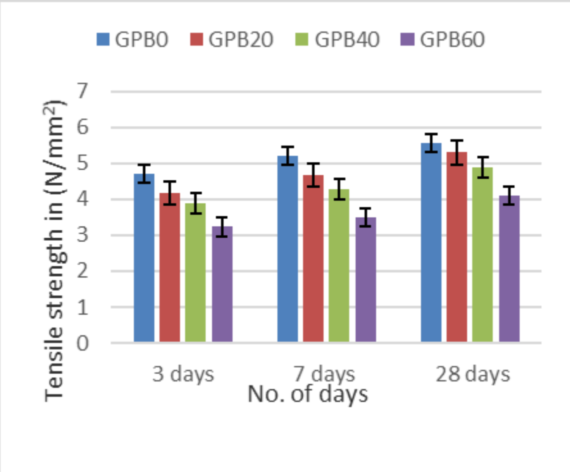

Fig 2. Variation in tensile strength

The split tensile results show that the GPB0 remains to have high tensile strength compared to all other mix proportion. The 28 days result for GPB20 shows that their tensile value is similar to GPB0 and GPB40 shows good tensile value compared to GPB60.

C. SALT WATER RESISTANCE

The sample kept in 10% of sodium chloride (NaCl) solution and the pH value were maintained and checked for weight and compressive strength. The compressive strength and weight of chloride attack specimen is compared to initial strength and weight.

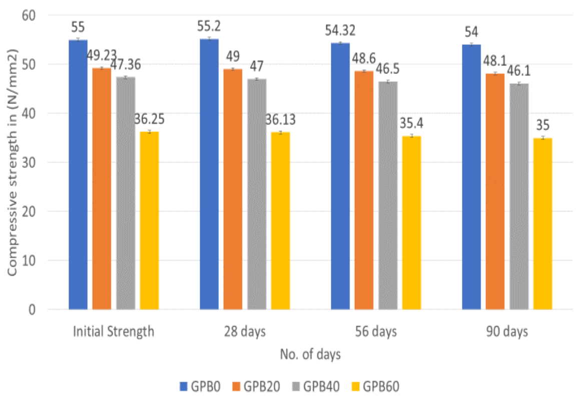

Fig 3. Variation of Compressive strength in salt water

The compressive strength of all mix proportion for salt water resistance at 28,56 and 90 days shown in Fig 3. The percentage of change for all mix proportion with their mix ID is shown in fig 4.

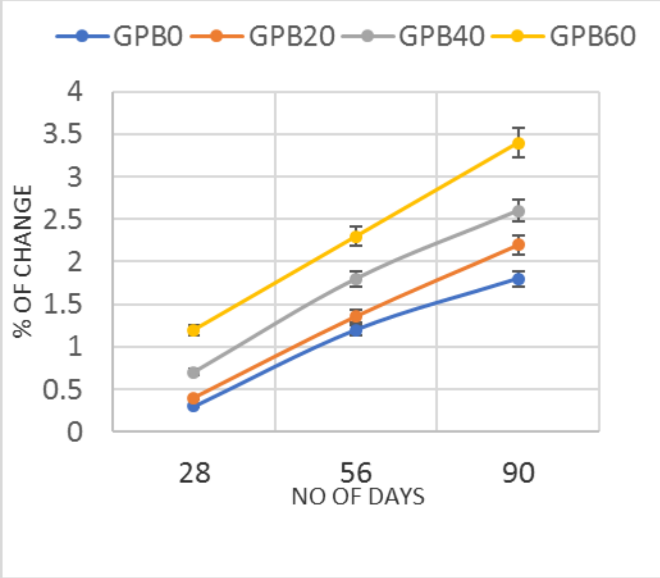

Fig 4. Percentage of change in strength against chloride

Table IV. % of change in strength against chloride

Mix proportion	% of change		
	28 days	56 days	90 days
GPB0	0.3	1.2	1.8
GPB20	0.4	1.36	2.2
GPB40	0.7	1.8	2.6
GPB60	1.2	2.3	3.4

The results show that the maximum percentage of change for GPB60 is 3.4% and GPB20 and GPB40 are similar and significantly less compared to the GPB0.

D. ACID ATTACK TEST

As per standards of ASTM C- 267 the acid tests was conducted**.** The sample kept in 10% of sulfuric acid solution and the pH value were maintained and checked for weight and compressive strength. The compressive strength and weight of acid attack specimen is compared to initial strength and weight of specimen. and the results, percentage of change in compressive strength is listed below.

Table V. % of change in strength against acid

Mix proportion	% of change		
	28 days	56 days	90 days
GPB0	2.18	3.07	5.4
GPB20	2.49	3.19	6.1
GPB40	2.87	4.02	6.7
GPB60	3.01	5.57	7.06

The results show that the percentage of change in compressive strength found to be high. The maximum percentage of change is found to be 7.06 for GPB60. In this the maximum percentage of change for GPB0 and GPB20 found to be similar and less compared to GPB40 and GPB60.

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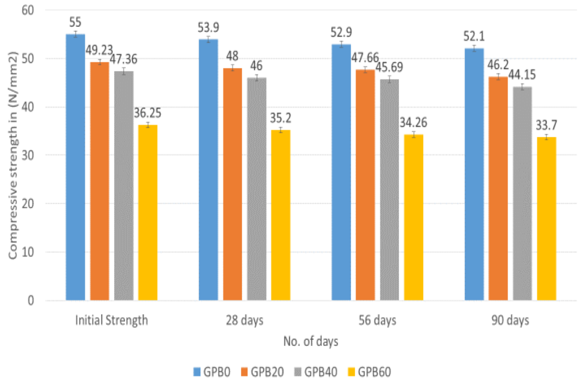

Fig 5. Variation of Compressive strength in acid attack

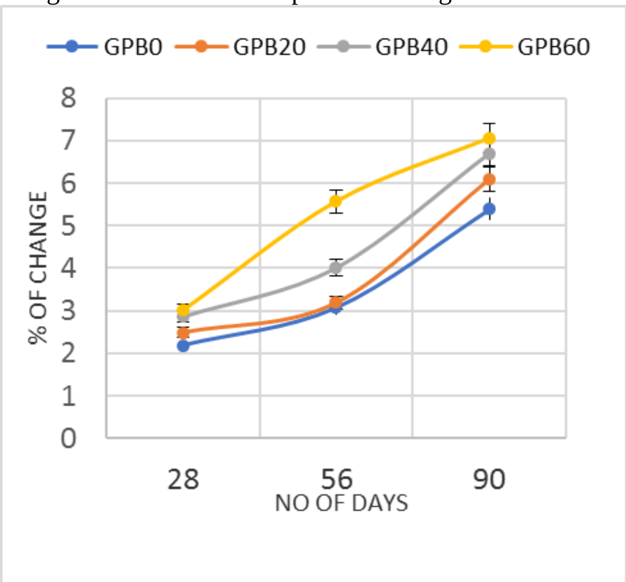

Fig 6. Percentage of change in strength in acid attack

E. SULPHATE ATTACK TEST

As per ASTM C 1012-10 the test procedure is followed. Samples were immersed in 10% sulphate solution and the test is conducted and the percentage of change in compressive strength is shown in Table VI.

Table VI. % of change in strength in acid attack

Mix proportion	% of change		
	28 days	56 days	90 days
GPB0	0.5	1.2	1.8
GPB20	0.9	1.4	1.9
GPB40	1.2	1.6	2.2
GPB60	1.9	2.2	2.5

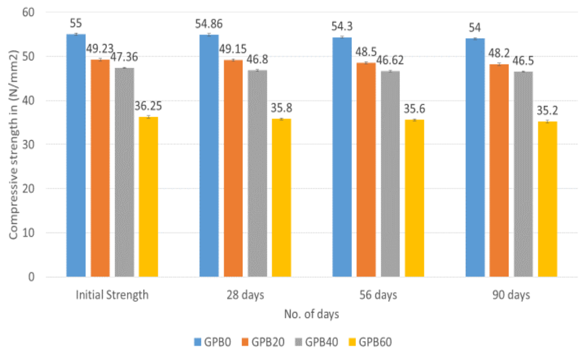

Fig 7. Variation of Compressive strength in sulphate attack

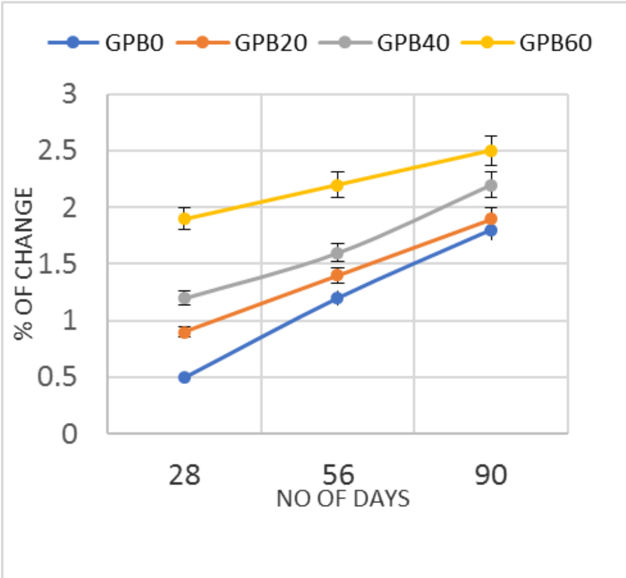

Fig 8. Percentage of change in strength against sulphate

The percentage of change was found to be low compared to all other chemical attack and the maximum percentage of change in GPB60 is found to be 2.5%. this shows that the GPC concrete is resistant against sulphate.

F. RAPID CHLORIDE PENETRATION TEST

. The RCPT test procedure is followed as per ASTM C 1202. The potential of 60V is passed through the specimen of 50mm thick and 100 mm diameter for about 6 hours and the reading was noted for every 15min. One side of the specimen is filled with sodium chloride and the other side with sodium hydroxide. The total charge in coulombs passed is tabulated.

Table VII. Chloride penetration

RAPID CHLORIDE PENETRATION TEST (coulombs)				
No of days	GPB0	GPB20	GPB40	GPB60
28	864	983.5	1485	1800
56	923	1200	1653	1963
90	989	1256	1980	2064

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The chloride permeability of concrete specimen based on the coulomb passed is listed in table VIII.

Table VIII. Chloride permeability based on charges passed

Charges passed (Coulombs)	Chloride permeability
>4000	High
2000 – 4000	Moderate
1000 - 2000	Low
100 – 1000	Very low
<100	negligible

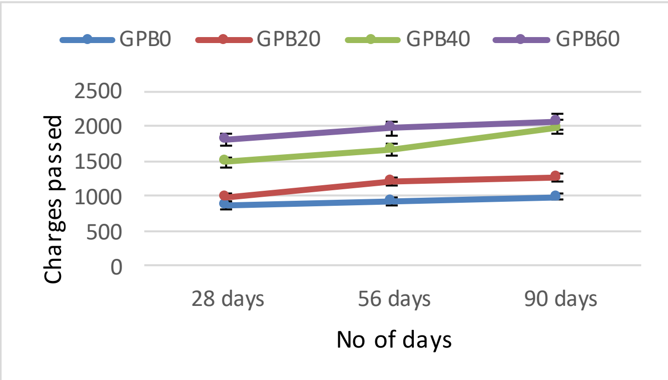

Fig 9. Chloride penetration in GPC

From the charges passed the chloride permeability of GPC specimen for GPB0 is found to be very low. The chloride permeability is found to be low for GPB20 and GPB40. Penetration of chloride ion is found to be moderate for GPB60.

G. SORPTIVITY

As per ASTM C158-13, Sorptivity determines the absorption of water in concrete specimen

Table IX. Chloride permeability based on charges passed

Sorptivity S (*10^-4) mm/min $^{(1/2)}$				
No of days	GPB0	GPB20	GPB40	GPB60
28	4.32	4.96	5.07	5.41
56	4.67	5.22	5.87	6.13
90	5.05	5.96	6.76	6.9

The results show that for GPB0 and GPB20 mix proportion the value is below 6. The quality of control geopolymer concrete and GPB40 and GPB60 are found to be greater than 6 in sorptivity value. Thus, GPB0 and GPB60 is good compared to other mix proportions.

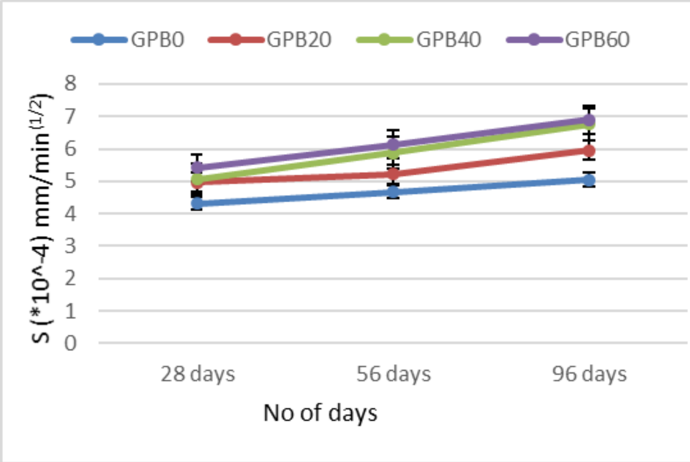

Fig 10. Sorptivity results

I. ULTRASONIC PULSE VELOCITY TEST

The UPV is carried out according to IS 13311-1992(part 1). Higher the pulse velocity readings higher is the quality of concrete.

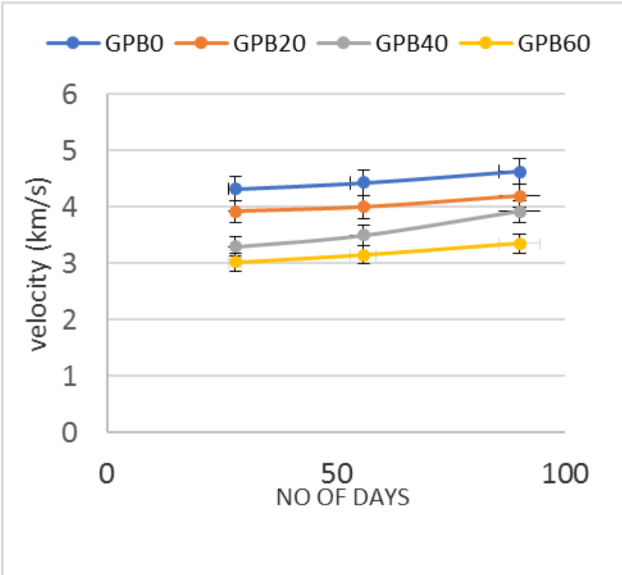

Fig 11. UPV results

Table X. Pulse velocity

UPV (km/s)				
No of days	GPB0	GPB20	GPB40	GPB60
28	4.32	3.92	3.3	3.02
56	4.43	4.3	3.5	3.15
90	4.6	4.2	3.92	3.35

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Table XI. Charges based concrete quality

Pulse velocity (Km/s)	Concrete quality
Above 4.5	Excellent
3.5 – 4.5	Good
3.0 -3.5	Medium
Below 3	Poor

GPB0 and GPB20 shows good quality of concrete based on the velocity passed and GPB40 and GPB60 shows medium quality of concrete. Thus, the GPB mix proportion lies in the average range of good to medium

V. CONCLUSION

Based on the results obtained from the experiments the subsequent conclusions can be derived regarding the performance of the concrete

1. It is observed that as the percentage of increase in bottom ash there is subsequent decrease in compressive and tensile strength of concrete. Mix GPB20 and GPB40 have high potential to meet the strength and workability properties.
2. Durability properties of concrete by various test show that the chemical resistance of GPB20 and GPB40 are almost similar and significantly less compared to GPB0.
3. Based on the NDT test it is observed that on various percentage of concrete mix they produced good results
4. The optimum mix of GPB20 and GPB40 has been evaluated based on the strength and durability

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