FEASIBILITY STUDIES ON TERNARY BLENDS IN GEOPOLYMER CONCRETE

[1]R ARUN, [2]S.SHAJAHAN.

[1]Assistant professor, [2] Assistant professor.
[1]Civil Department,
[1]SVTM Group of Institutions, Madanapalle, India.

Abstract : *The major problem the world is facing today is the environmental pollution. The production of cement contributes about 7% of the global carbon dioxide emission and cement is the second most consumed product in the world. Several efforts are underway throughout the world to develop a eco-friendly construction materials, which will minimize the utility of natural resources and also reducing the emission of greenhouse gases. The industrial wastes from Thermal plant – Bottom Ash and Iron manufacturing industry – GGBS is used as a complete replacement for cement in this project. The Alkaline Activators (sodium hydroxide and sodium silicate) facilitate the polymerization process and act as a bonding agent. The Geopolymer concrete properties are studied in this project by casting Paver blocks as per codal provisions of IS 15658:2006 and the corresponding Geopolymer mix is identified to satisfy the appropriate Grade of Paver blocks as per its specifications. The mechanical and durability properties of Geopolymer paver blocks are studied and also the effects of density and Molarity on these properties are also examined. The potential use of these industrial by products as efficient building materials would minimize their harmful effects if they were dumped in landfills.*

Keywords: *Ground Granulated Blast Slag, Geopolymer.*

I. INTRODUCTION

Several efforts are in progress to reduce the use of Portland cement in concrete in order to address the global warming issues. These include the utilization of metakaolin, fly ash, silica fume, granulated blast furnace slag, rice husk ash, and bottom ash etc as supplementary cementing materials. Rather than using supplementary cementing materials in concrete, need for the development of alternative binders to Portland cement is also warranted to overcome various issues associated with cement production. One such attempt made in the recent decades is the development of Geopolymers which has emerged as a new environmentally friendly construction material for sustainable development.

MATREIALS AND METHODOLOGY

3.1 GENERAL

The materials used in the manufacture of Geopolymer Paver blocks are described in this chapter. The physical and chemical properties of bottom ash GGBS are reported. Also the physical properties of fine aggregate (river sand), coarse aggregate (6mm chips).The chemical composition of alkaline activators is also presented.

3.2 METHODOLOGY

The step by step progress is shown below

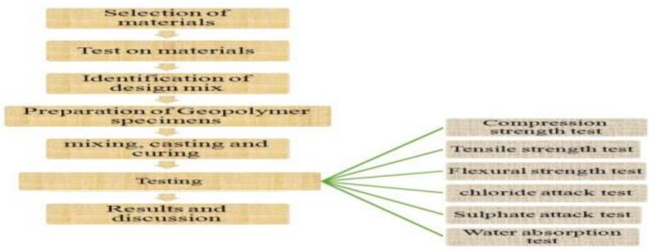


FIGURE 3.1 FLOW CHART OF METHODOLOGY

3.3 SELECTION OF MATERIALS

The materials are chosen based on the specifications of Indian standards. The materials used in the Geopolymer concrete are listed below

- Bottom ash
- Ground Granulated Blast furnace Slag (GGBS)
- Alkaline activators (NaOH pellets, Na_2SiO_3)
- Fine aggregates
- Coarse aggregates

TABLE :3.1 PROPORTIONS OF MATERIAL

% OF BOTTOM ASH	% OF GGBS	PARAMETER IDENTITY
100	0	BG0
75	25	BG25
50	50	BG50
25	75	BG75
0	100	BG100

MIX DESIGN

4.1 MIX PROPORTION

This chapter defines the mix design for Geopolymer paver block. As the Geopolymer concrete are new construction materials they don't have any standard mix design. To identify the mix ratios for different grades of Geopolymer Concrete the trial and error method is followed. To identify the best mix or optimum mix for the Geopolymer paver block the various parameters and ingredients are varied. The parameters changed in the mix proportions are Density, Molarity and percentage ratio between the Bottom ash and GGBS. The density is varied from 1800 – 2400 kg/m^3. The Molarity or the concentration of sodium hydroxide pellets solution is varied around 4-8M. And the major parameter is the ratio between the bottom ash and GGBS which is fully replaced for ordinary cement and the percentage is varied in range of 0,25,50,75,100.

4.2 PARAMETERS VARIED

- Percentage between bottom ash and GGBS
- Density

DENSITY	PARAMETER IDENTITY
1800 kg/m^3	A
2000 kg/m^3	B
2200 kg/m^3	C
2400 kg/m^3	D

- Molarity
  - 4M
  - 6M
  - 8M

RESULTS AND DISCUSSION

5.1 GENERAL

Various tests are conducted on the Geopolymer paver blocks after 1day and 3 days at ambient curing and their results are calculated and compared. To determine the mechanical properties, compressive strength test, split tensile test and flexural strength test are performed on the geopolymer paver blocks. In case of durability analysis it is studied for sulphate attack, chloride attack and water absorption.

The above tests are carried to identify the properties of M30, M35 and M40 grade Geopolymer concrete paver blocks.

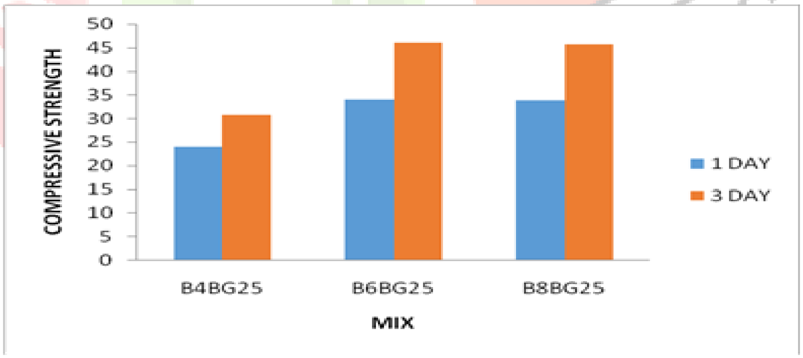
GEOPOLYMER PAVER BLOCKS OF BG25 FOR VARYING DENSITY AND MOLARITY

The compressive strength results of Geopolymer paver blocks for full replacement of cement by 75 % Bottom ash and GGBS 25 % with varying densities and Molarity is shown in table 5.2 and corresponding comparison graphs are drawn below. From the results it is noted that,

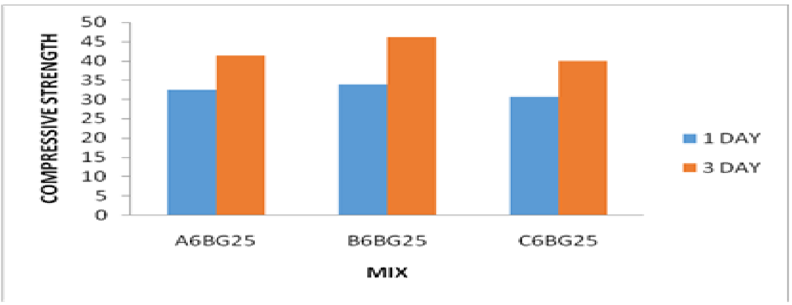
- ✓ When bottom ash and GGBS combined the strength achieved is similar to the conventional concrete.
- ✓ Increase in density from 1800 kg/m^3 to 2400 kg/m^3 correspondingly increases the compressive strength.
- ✓ Similarly the increase in Molarity content of a sodium hydroxide pellets from 4M to 8M does not affects the strength of concrete paver block respectively.
- ✓ The maximum strength is achieved in the optimum Molarity i.e. 6M because it provides both workability and higher reactivity.
- ✓ With combined increase in Molarity and Density the compressive strength is achieved.
- ✓ In both 1 day and 3 day ambient curing the above results are achieved

TABLE 5.1 COMPRESSIVE STRENGTH RESULTS FOR BG25

MIX PROPORTION	COMPRESSIVE STRENGTH OF PAVER BLOCKS	
	AFTER 1 DAY CURING	AFTER 3 DAY CURING
UNIT	N/mm^2	N/mm^2
A4BG25	23.251	41.21
A6BG25	32.54	41.399
A8BG25	30.813	34.78
B4BG25	25.008	30.813
B6BG25	34.026	46.125
B8BG25	33.837	45.125
C4BG25	27.221	35.35
C6BG25	30.624	39.89
C8BG25	29.868	36.862



COMPARISION OF COMPRESSIVE STRENGTH IN N/mm^2 FOR VARYING MOLARITY AT CONSTANT DENSITY



COMPARISION OF COMPRESSIVE STRENGTH IN N/mm^2 FOR VARYING DENSITY AT OPTIMUM MOLARITY 6M

SPLIT TENSILE STRENGTH TEST RESULTS

The split tensile strength is carried out at 3 day since the Geopolymers are used it implies early strength achievement. The results of split tensile test are shown in table 5.8.

TABLE 5.8 SPLIT TENSILE STRENGTH RESULTS

GRADE	MIX	PAVER BLOCK SIZE	STRENGTH
M30	A6BG25	230*115*50	2.55
M35	A4BG50	230*115*60	2.76
M40	B6BG25	230*115*80	2.97

5.4 FLEXURAL STRENGTH TEST RESULTS

The flexural strength is carried out at 3 day since the Geopolymers are used it implies early strength achievement. The results of flexural strength test are shown in table 5.9.

TABLE 5.9 FLEXURAL STRENGTH RESULTS

GRADE	MIX	PAVER BLOCK SIZE	STRENGTH
M30	A6BG25	230*115*50	6.50
M35	A4BG50	230*115*60	6.97
M40	B6BG25	230*115*80	6.60

5.5 WATER ABSORPTION TEST RESULTS

The water absorption of the mixes was carried out and it is presented in chapter 3.6.4.The water absorption of the mix A6BG25 (M30W) was obtained as 2.61%. The water absorption of mix A4BG50 (M35W) was 2.23% and water absorption of B6BG25 (M40W) mix was obtained as 1.82 %. According to IS: 15658:2006 The water absorption, Annex C, Shall not be more than 6 percent by mass and in individual samples, the water absorption should be restricted to 7 percent.

TABLE 5.10 WATER ABSORPTION IN PERCENTAGE

GRADE	MIX	PAVER BLOCK WEIGHT AFTER 24 hr SOAKED IN WATER	PAVER BLOCK WEIGHT AFTER 24 hr HEATED IN AIR OVEN	WATER ABSORPTION IN %
NOTATIONS		W_w	W_d	$(w_w-w_d)100/w_d$
UNIT		Kg	Kg	%
M30	A6BG25	3.254	3.171	2.617
M35	A4BG50	4.063	3.971	2.230
M40	B6BG25	5.237	5.139	2.617

5.6 SULPHATE ATTACK

After the Geopolymer paver blocks are placed in 7 days curing at ambient curing the weight in loss of the paver blocks are calculated as mentioned in 3.6.6.Loss in weight percentage should be minimum at range around 1% for better resistance to the surroundings.The initial weight of the paver block specimen is notified as (w1), The weight of the paver block after 7 days immersed in sulphuric acid solution is notified as (w2).

The percentage loss in weight is calculated using below formula.

$$\% \text{ loss in weight} = \frac{(w2-w1)}{w1} * 100$$

The results are shown in table 5.11 describes the higher percentage of weight loss is seen in M30 and M35 than M40 is due to reason that M40 grade has higher cross section than the corresponding M30 and M35 grades and it is shown in graph below.

TABLE 5.11 PERCENTAGE WEIGTH LOSS FOR SULPHATE ATTACK

GRADE	MIX	PAVER BLOCK WEIGHT BEFORE SOAKING	PAVER BLOCK WEIGHT AFTER SOAKED IN H_2SO_4 SOLUTION FOR 7 DAYS	PERCENTAGE WEIGHT LOSS
NOTATIONS		W_w	W_d	$(w_2-w_1)100/w_1$
UNIT		Kg	Kg	%
M30	A6BG25	3.14	3.189	1.58
M35	A4BG50	3.72	3.768	1.295
M40	B6BG25	5.076	5.109	0.652

CONCLUSION

The Paver Blocks are mainly used in ultra duty areas like industrial units, yards, airport pavements etc., they should offer higher strength, durability and resistance to chemicals. The Geopolymer paver blocks mix designed in this project are able to produce strength; durability and resistance to chemical attack from environment similar to that of normal concrete mix. In this project the cement is fully replaced by industrial by-products Bottom Ash and GGBS and they produce higher strength than the conventional concrete. The 28 day strength compressive strength of conventional concrete is achieved in the 3 day of the Geopolymer concrete.

The 3 day compressive strength of Geopolymers paver blocks of M30, M35 and M40 are 39.38, 49.15 and 40.86 respectively, which satisfies the required grade strength. flexural strength calculated at 3 Day for M30, M35 and M40 grades are 6.5, 6.97 and 6.60 correspondingly; these values are similar to the flexural strength of ordinary cement concrete.The Split tensile strength of M30, M35 and M40 grades calculated after 3 days ambient curing are 2.55, 2.76 and 2.97.

The water absorption percentage of M30, M35 and M40 grades are 2.617, 2.230 and 2.617which are less than 7% as per codal provisions specified. The sulphate attack results of M30, M35 and M40 grades are 1.58, 1.295 and 0.652 and in chloride attack results of M30, M35 and M40 grades are 1.168, 1.032 and 0.7138, which are around value 1 for conventional concrete. These values clearly show that increase in cross section of paver block reduces the percentage of weight loss.

The M50 and M55 grade Geopolymer paver blocks can be obtained by increasing the Molarity to next level i.e. 10M or 12M and correspondingly increasing the GGBS content to higher proportions than bottom ash. From these reports it is clearly stated that the Geopolymers concrete are effective to be replaced for the conventional cement concrete. This reduces the emission of carbon dioxide from cement production and reducing industrial wastes to utilize it innovatively.

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