Geopolymer Concrete for Railway Sleepers

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Abstract

Application of geopolymer concrete is in precast industry therefore the main objective of this paper is to develop the geopolymer concrete for the preparation of pre-cast railway sleepers. The other objective is to reduce the consumption of energy in curing by adopting ambient(sunlight) curing. In the present study, alkaline liquid to fly ash ratios of 0.35 and 0.4 with 16Molarity and 18Molarity of NaOH solution were used. To determine the compressive strength for geopolymer concrete, specimens of size 15cm X 15cm X 15 cm cubes were prepared. The curing regimes adopted were steam curing at average temperature of 650C for 24 hours and ambient curing at average temperature of 400C for 7days. The compressive strength attained for alkaline liquid to fly ash ratio 0.4 and 0.35 for 18Molarity were in the range of 36.44N/mm2 to 60.35N/mm2 for ambient curing and 41.9N/mm2 to 72.09N/mm2 for steam curing. The compressive strength attained for alkaline liquid to fly ash ratio 0.35for 16Molarity were in the range of 58.88N/mm2 to 61.33N/mm2 for steam curing and ambient curing.

Keywords: Geoplymer Concrete, Fly Ash, GGBFS

I. INTRODUCTION

Global warming has developed rapidly in recent years, and the reduction of carbon dioxide emission has become a serious consideration in all the sectors of industry. In particular, the amount of carbon dioxide discharged as a result of cement manufacture is huge, standing at almost a ton per ton of cement output. Fly ash is adopted for its strong reactivity as an amorphous material containing large quantities of sio2 and al2O3,similar to metakaolin. Geopolymer concrete is made by using 100% of fly ash instead of cement. In Geopolymer concrete fly ash is activated using alkaline solution to form binders. In 1988, Davidovits[1] proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminium in source materials of geological origin or by-product materials such as fly ash and rice husk ash. Palomo et al [2] suggested that pozzolans such as blast furnace slag might be activated using alkaline liquids to form a binder and hence totally replace the use of OPC in concrete. The chemical composition of Geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous instead of crystalline [3]. The chemical compositions of various fly ash show a wide range, indicating that there is a wide variations in the coal used in power plants all over the world. The colour of fly ash can be taken to dark grey, depending upon the chemical and mineral constituents [4]. Palomo et al [2] concluded that the type of alkaline liquid plays an important role in the polymerization process. Reactions occur at a high rate when the alkaline liquid contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides. Xu and van Deventer [3] confirmed that the addition of sodium silicate solution to the sodium hydroxide solution as the alkaline liquid enhanced the reaction between the source material and the solution. Davidovit;s J[5] suggested that it is preferable to mix the sodium silicate solution and the sodium hydroxide solution together at least one day before adding the liquid to the solid constituents. When this suggestion was followed, it was found that the occurrence of bleeding and segregation ceased. In this work we studied the application of this geopolymer concrete to railways by manufacturing pre-stressed geopolymer concrete sleepers and conducting a performance test on them as per Indian railway code for sleepers (T39-85). The main Objectives of this paper is

- To determine the parameters of Geopolymer concrete, such as Alkaline liquid to fly ash ratio, Alkaline liquid to GGBS ratio, molarity of NaoH and ratio of water to Geopolymer solids required for preparation of railway sleeper.

II. EXPERIMENTAL PROGRAMME

A. Materials

In this experimental work, low calcium fly ash from the silos of Raichur thermal power station of Karnataka state was used. The chemical composition of fly ash as supplied by the supplier are presented in Table.1. GGBFS(Ground Granulated Blast Furnace slag) was used. The chemical composition of GGBFS as supplied by the supplier are presented in Table.2. The aggregates shall have 30% abrasion and 30% impact value suitable for wearing surfaces when tested in accordance withIS:2386 (Part-IV). The flakiness index and elongation index shall not exceed 30% when tested in accordance with IS: 2386 (Part-I). The specific gravity of coarse aggregate was 2.71 and of fine aggregate was 2.65 Coarse and fine aggregates shall pass sodium or magnesium sulphate accelerated soundness test specified in IS: 2386 (part V)-1963.

Table – 1
Chemical Composition of Fly Ash

Sl. No	*Characteristics*	*Fly ash (%wt)*
1	*Silica*	*55-65*
2	*Aluminium oxide*	*22-25*
3	*Iron oxide*	*5-7*
4	*Calcium oxide*	*5-7*
5	*Magnesium oxide*	*<1*
6	*Titanium oxide*	*<1*
7	*Phosphorous*	*<1*
8	*Sulphates*	*0.1*
9	*Alkali oxide*	*<1*
10	*Loss of ignition*	*1-1.5*

Table – 2
Chemical Composition of GGBFS

Sl.No	*Characteristics*	*GGBFS(%wt)*
1	*Silica*	*35*
2	*Alumina*	*13*
3	*magnesia*	*8*

B. Mix Proportions

The below Table 3 shows the mix proportions of Geopolymer concrete as per the research papers and literature.For mix proportions assumed combined mass of aggregate = 77%.

Table - 3
Mix proportions of Geopolymer concrete

Sl.No.	Fly Ash kg/m^3	San D kg/m^3	Aggregates kg/m^3		NaOH kg/m^3	Sodium silicate kg/m^3	Alka Line liquid to Fly Ash
			20 mm	10 mm			
1	409	554	776	517	41	102	0.35
2	394	554	776	517	45	113	0.4
3	380	554	776	517	49	123	0.45

1) Mixing, Casting of Geopolymer concrete cubes and Curing.

Prepare the sodium hydroxide solution of 16molarity and 18molarity by mixing the pallets in water. Mix the above prepared sodium hydroxide solution and sodium silicate solution at least one day prior to adding the liquid to the dry materials. Take dry materials as mentioned in Table no.3 and mix all dry materials properly, add the liquid component of the mixture at the end of dry mixing, and continue the wet mixing for another 10-15 minutes. The fresh geopolymer concrete was cast in mould of size 15cm x 15cm x 15cm cubes immediately after mixing. It was compacted using 9000 RPM vibrator. In this work two types of curing regime were adopted that is steam curing and ambient curing. Steam curing was done at an average temperature of 65^{0}C for 24hours and ambient curing was done at an average temperature of 40^{0}C for 7days.

Fig 1: Geopolymer concrete cubes.

III. RESULTS AND DISCUSSION

Table – 4
Compressive strength of Geopolymer concrete for 18M

Sl. No.	*Molarity*	*AlkaLine Liguid to Fly Ash*	*Percentage of GGBFS*	*Steam curing 24 Hrs*	*Ambient Curing 7 Days*	*Compressive Strength N/mm^2*	
						Steam curing	*Ambient Curing*

1	*18*	*0.4*	*0%*	*65^{0}C*	*39^{0}C*	*56.4*	*36.4*
2	*18*	*0.4*	*0%*	*65^{0}C*	*41^{0}C*	*56.9*	*37.1*
3	*18*	*0.4*	*0%*	*65^{0}C*	*39^{0}C*	*57.3*	*36.8*

It is observed from the Table 4 that for alkaline liquid to fly ash ratio = 0.4 and molarity of NaOH 18, steam curing has attained the required strength as per the Indian railway code for sleepers T39-85 (M55-55N/mm^2) but ambient curing has failed to attain the required strength as mentioned by the Indian railway code.

Table – 5
Compressive strength of Geopolymer concrete for 18M

Sl. No.	*Molarity*	*AlkaLine Liguid to Fly Ash*	*Percentage of GGBFS*	*Steam curing 24 Hrs*	*Ambient Curing 7 Days*	*Compressive Strength N/mm^2*	
						Steam curing	*Ambient Curing*
1	*18*	*0.35*	*0%*	*65^{0}C*	*39^{0}C*	*60.1*	*42.6*
2	*18*	*0.35*	*0%*	*65^{0}C*	*41^{0}C*	*58.7*	*43.5*
3	*18*	*0.35*	*0%*	*65^{0}C*	*39^{0}C*	*59.5*	*41.9*

In order to improve the compressive strength of geopolymer concrete for ambient curing alkaline liquid to fly ash ratio is changed to 0.35 and the results of trial casting are given in the Table 5. It is observed from the Table 12 that for alkaline liquid to fly ash ratio = 0.35 and molarity of NaOH 18 again steam curing has attained the required strength but ambient curing has failed to attain the required strength as per the Indian railway code for sleepers T39-85 (M55-55N/mm^2).

Table – 6
Compressive strength of Geopolymer concrete for 18M

Sl. No.	*Molarity*	*AlkaLine Liguid to Fly Ash*	*Percentage of GGBFS*	*Steam curing 24 Hrs*	*Ambient Curing 7 Days*	*Compressive Strength N/mm^2*	
						Steam curing	*Ambient Curing*
1	*18*	*0.4*	*30%*	*65^{0}C*	*39^{0}C*	*60.0*	*56.8*
2	*18*	*0.4*	*30%*	*65^{0}C*	*41^{0}C*	*59.7*	*57.6*
3	*18*	*0.4*	*30%*	*65^{0}C*	*39^{0}C*	*60.4*	*56.5*

Further casting is continued for molarity of NaOH 18 and alkaline liquid to fly ash ratio =0.4 with addition of 30% GGBFS as per the literature. The results of trial casting are presented in Table 6. It is clear from the results that improvement in compressive strength is obtained for both curing regimes. Percentage increase in compressive strength for steam curing and ambient curing are 3% and 25% respectively. Steam curing and ambient curing has attained the required strength as per the Indian railway code for sleepers. For sleepers in the normal track the grade and strength of the concrete required is M55 and 55N/mm^2 (T39-85 (M55-55N/mm^2). This mix can be used for preparation of sleepers in normal track (straight path).

Table – 7
Compressive strength of Geopolymer concrete for 18M

Sl. No.	*Molarity*	*AlkaLine Liguid to Fly Ash*	*Percentage of GGBFS*	*Steam curing 24 Hrs*	*Ambient Curing 7 Days*	*Compressive Strength N/mm^2*	
						Steam curing	*Ambient Curing*
1	*18*	*0.35*	*30%*	*65^{0}C*	*39^{0}C*	*72.0*	*66.5*
2	*18*	*0.35*	*30%*	*65^{0}C*	*41^{0}C*	*66.2*	*67.8*
3	*18*	*0.35*	*30%*	*65^{0}C*	*39^{0}C*	*71.1*	*67.1*

In order to reach the compressive strength required for sleepers at curved portion, points and crossings the alkaline liquid to fly ash ratio is changed to 0.35 with addition of 30% GGBFS. The results of trial casting are given in Table 7. The results indicate that improvement in compressive strength is obtained for both curing regimes. Percentage increase in compressive strength for steam curing and ambient curing are 11% and 16% respectively.

Steam curing and ambient curing has attained the required strength as per the Indian railway code for railway sleepers. For sleepers in the curved portion, points and crossings portion of the track the grade and strength of the concrete required is M60 and 60N/mm2.

(T39-85 (M60-60N/mm2)). This mix can be used for preparation of sleepers in the curved portion, points and crossing portion of the track.

Table – 8
Compressive strength of Geopolymer concrete for 16M

Sl. No.	*Molarity*	*AlkaLine Liguid to Fly Ash*	*Percentage of GGBFS*	*Steam curing 24 Hrs*	*Ambient Curing 7 Days*	*Compressive Strength N/mm^2*	
						Steam curing	*Ambient Curing*
1	*16*	*0.35*	*30%*	*65^{0}C*	*39^{0}C*	*59.7*	*59.2*
2	*16*	*0.35*	*30%*	*65^{0}C*	*41^{0}C*	*61.3*	*60.0*
3	*16*	*0.35*	*30%*	*65^{0}C*	*39^{0}C*	*58.8*	*59.2*

In order to improve the workability and reduce the quantity of NaOH considering the economy, Further casting is continued for 16molarity of NaOH and alkaline liquid to fly ash ratio=0.35 with addition of 30% GGBFS,. The results of casting are presented in Table 8. It is clear from the results that steam curing and ambient curing has attained the required strength as per the Indian railway code for sleepers T39-85 (M 55-55N/mm^2).

From the above results, mix given in Table 6 alkaline liquid to fly ash ratio =0.35, percentage of GGBFS 30% and molarity of NaOH 18 can be used for further casting of railway sleepers at any location of the track as this mix satisfies the codal requirement for railway sleepers.

Fig 2: Testing of geopolymer concrete cubes.

IV. CONCLUSIONS

Based on the experimental work reported in this study, the following conclusions are drawn for Geopolymer concrete.

1) Compressive strength of Geopolymer concrete cubes satisfies the strength requirement of Indian railway code for sleepers (T39-85).
2) In short period of 24hours, Geopolymer concrete prepared using steam curing regime satisfies the strength requirement of Indian railway code for sleepers (T39-85).
3) Required strength for railway sleepers cannot be attained without addition of GGBFS under ambient curing.
4) By using Ambient curing only the Geopolymer concrete can be used for preparation of sleepers in all portion of track. That is straight, curved portion, points and crossing portion of the track.
5) Ambient curing method will save the energy required in steam curing.
6) Geopolymer concrete of 16molarity for alkaline liquid to fly ash ratio 0.35 with steam curing and with addition of 30% GGBFS under ambient curing can be used for preparation of railway sleepers in normal location of tack (straight path).
7) Geopolymer concrete of 18molarity for alkaline liquid to fly ash ratio 0.35 and 0.4 with steam curing and with addition of 30% GGBFS under ambient curing can be used for preparation railway sleepers in all locations of track.

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