International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 05 | May 2017 www.irjet.net p-ISSN: 2395-0072

PERFORMANCE AND CHARACTERIZATION OF PRESTRESSED GEOPOLYMER CONCRETE SLEEPERS

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Abstract - *In the recent years, geopolymer concrete are reporting as the greener construction technology compared to conventional concrete that made up of ordinary Portland cement. Geopolymer concrete is an innovative construction material that utilized fly ash as one of waste material in coal combustion industry as a replacement for ordinary Portland cement in concrete. The uses of fly ash could reduce the carbon dioxide emission to the atmosphere, redundant of fly ash waste and costs compared to ordinary Portland cement concrete. However, the plain geopolymer concrete suffers from numerous drawbacks such as brittleness and low durability. Out of this two geopolymer sleepers ,one sleeper with normal cement concrete (one normal concrete and four geopolymer concrete sleepers) with Alkali–Activator Solution / Fly ash ratio 0.40, 0.45,0.5 and 0.55 and comparable compressive strength. The load-deflection and moment curvature behaviors obtained from the experimental results are compared with analytical solutions. A special railway sleeper of 2750 x 2700 x 2350mm (Broad Gauge) using 3 ply 3 mm HTS strands in geopolymer concrete with pre tensioning was considered in this study.*

Key words: *environment, geopolymer binders, post-tensioned beams, presterssed Concrete sleepers, load-deflection and moment curvature.*

1. INTRODUCTION

Railways as a mode of transportation have played a pivotal role in the development of all economies providing means for the transport of goods and passengers. Railways play a significant role in ensuring connectivity to different parts of a country at affordable costs to the common man. With the development of technology, there has been dramatic face-lift from where it all started to the present. In India, the railway track system components have undergone gradual evolution from the timber sleepers of pre-independence days to the presterssed concrete sleepers of the modern era being the most noticeable feature of a railway track. There are number of sleeper manufacturing units in our country. The demand of sleepers will go on much higher side in time to come. In near future the railways are likely to develop at least 5000 to 8000 kilometer of rail network per year, which is almost 30 to 40% more than in past assuming that kilometer of rail would need 1600 sleepers these plans are likely to results in an annual demand of about 1.3 crore of sleeper. Present manufacturing cost of mono block broad gauge pre-stressed concrete sleeper is in the range of 2200 – 2500/-. The cement which is utilized for manufacture of sleeper is main raw material. In order to make cost effective sleeper the fly ash can be used as supplementary raw material which will result in improving the quality of environment as well.

2. EXPERIMENTAL INVESTIGATION ON RAILWAY SLEEPERS

For development of high strength geopolymer concrete with strength above 50 MPa, it was also decided to use geopolymer concrete for pretensioned railway sleepers. The positions of HTS wires in geopolymer concrete sleepers are arranged as shown in Fig. 1.

A special railway sleeper of 2750 x 2700 x 2350mm (Broad Gauge) size using 3 ply 3mm HTS strands in geopolymer concrete with pre tensioning was considered in this study. In geopolymer concrete sleepers 18 numbers of strands were used in one sleeper. The compressive stress of geopolymer concrete sleeper is 60.85 N/mm². The pre-stressing strands are stressed to 350.3 N/mm².

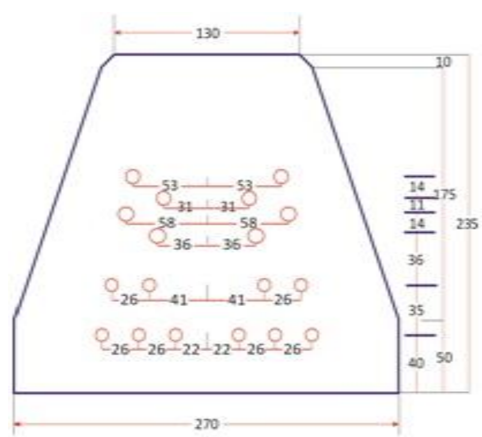

Fig.1. Position of HTS wires

A special sleeper mould with Pretensioning bed has been fabricated as shown in Fig. 2. The mould is similar to that of country sleeper mould used in the railways. But in railways, many sleepers are cast using long line method of Pretensioning.

Fig. 2 Pretensioning of GPC Sleepers

In this study, Pretensioning has been done for individual sleepers. The railway sleepers are cast with Country Portland concrete and Geopolymer concrete. Pretensioning adopted for prestressing the railway sleeper is shown in Fig.3. The locations of the cables are maintained exactly the same as that for country sleepers.

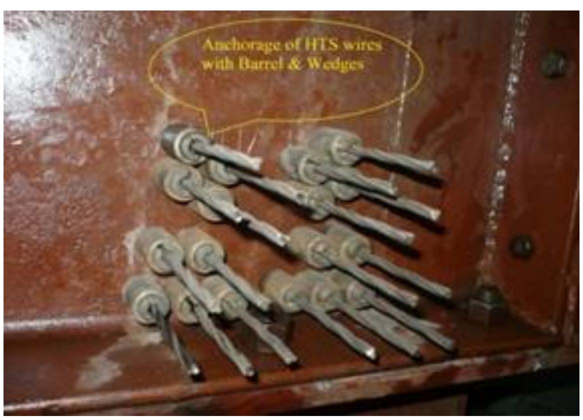

Fig.3. Anchored in HTS Tendons with Barrel and Wedges

2.1 Material properties

The material properties used for modeling, concrete and reinforcement are given in Table 1.

Table 1.Material properties Normal Concrete

Parameters	Values
Elastic modulus (Ec)	38020.00MPa
Compressive strength (f ck)	45.5 MPa
Poisson's ratio (µ)	0.2

Geopolymer Concrete

Parameters	AAS/FA Ratio	Values
Elastic modulus (Ec)	0.4	42142.90 MPa
Elastic modulus (Ec)	0.45	41092.21 MPa
Elastic modulus (Ec)	0.5	41085.54 MPa
Elastic modulus (Ec)	0.55	39951.29 MPa
Compressive strength (f ck)	0.4	46.4 MPa
Compressive strength (f ck)	0.45	46.6 MPa
Compressive strength (f ck)	0.5	45.8 MPa
Compressive strength (f ck)	0.55	44.2 MPa
Poisson's ratio (µ)		0.2

Reinforcement

Parameters	Values
Elastic modulus (Ec)	2x105MPa
Yield stress (fy)	451MPa
Poisson's ratio (µ)	0.3

2.2 Casting of Railway Sleepers

For preparing geopolymer concrete, the fly ash and the aggregates were first mixed in the Pan mixer for about 3 minutes. Then the alkaline liquid mixed with super plasticizer (Conplast SP 430) was added with the dry mixers in the pan mixer itself. Two numbers of sleepers were cast with normal concrete and two sleepers were cast with geopolymer concrete (Fig.4). Companion cubes and cylinders of both geopolymer concrete and normal concrete were cast.

Fig.4. Casting of Railway Sleepers

2.3 Steam Curing of railway sleepers

All the specimens were kept in steam curing chamber for 24 hours. The specimens were covered with polythene sheet during steam curing. The constant temperature was maintained at 60˚ C.

The geopolymer concrete Pretensioning bar tendons are usually threaded and anchor by means of barrel and wedge that bear against a square or rectangular bearing plate cast into the concrete. After stream curing, protruding strands or bars of permanent tendons are cut off using an abrasive disc saw. Flame cutting should not be used as it negatively affects the characteristics of the prestressing steel.

2.3.1 Test on geopolymer concrete sleepers

All the sleepers were tested under two point loading (four point bending).The sleepers were placed in the 50 Ton frame for testing. The displacements were measured using the LVDT placed at the bottom of the sleeper at center, left 1155 mm and right 1155 mm from the support. The schematic diagram of experimental diagram of the sleeper is shown in Fig. 5 and the actual setup is shown in Fig. 6.

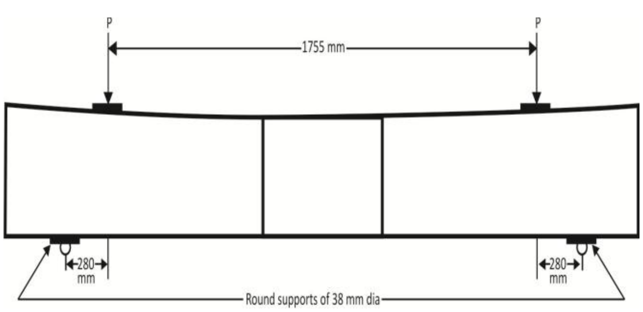

Fig.5. Schematic diagram of PSC sleeper with Railway Standards

Fig.6. Experimental Setup of the Sleeper (OPC)

From the experimental work the load and deflection curve was obtained for GPC and OPC sleepers as shown in Fig.7. The GPC sleeper behaves in the same way as that of OPC sleeper.

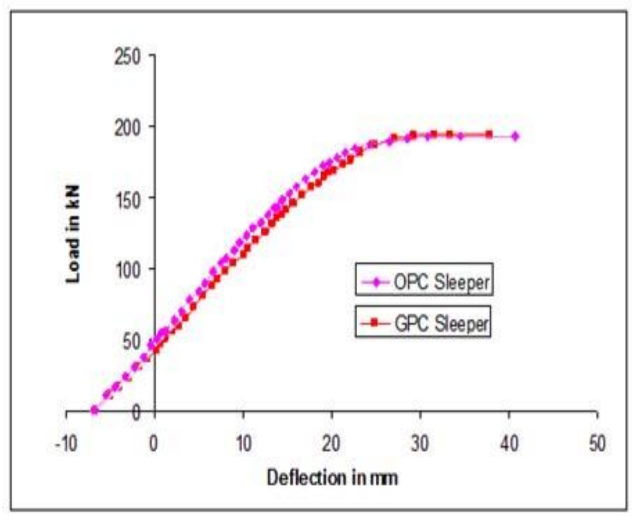

Fig.7. Load - Deflection of GPC and OPC sleeper

The load and deflection details of both sleepers at salient load stages are given in Table 2. The ultimate load carrying capacity of GPC sleeper is slightly higher than that of OPC sleeper.

Table 2 Experimental Results of OPC and GPC sleepers

Sleeper code	First crack stage		Yield stage		Ultimate stage		Average crack width at service load (mm)
	Load (kN)	Central deflection (mm)	Load (kN)	Central deflection (mm)	Load (kN)	Central deflection (mm)	
GPC	**110**	**25**	**175**	**35**	**260**	**48**	**0.15**
GPC	**115**	**22**	**178**	**37**	**265**	**50**	**0.20**
GPC	**118**	**25**	**180**	**40**	**270**	**52**	**0.25**
GPC	**120**	**27**	**182**	**42**	**272**	**54**	**0.30**
OPC	**102**	**21**	**155**	**32**	**230**	**42**	**0.80**

The crack pattern of railway sleepers made of GPC is shown in Fig.8.

Fig.8. Crack Pattern of GPC Sleeper

3. RESULT AND DISCUSSIONS

The geopolymer concrete beams were cast and tested, based on the results the moment -curvature and load-deflection relationships were obtained using deflection measurements from LVDTs and strain data collected for the normal concrete sleeper and geopolymer concrete sleepers under static monotonic loading.

From the load-deflection, it is noted that the geopolymer concrete sleepers exhibit decreased deflection and appreciable flexural strength when compared to normal sleeper. Experimental work was conducted on GPC and OPC sleepers and load deflection behavior was obtained.

The GPC and OPC sleepers behave in the same way as that of OPC sleeper. The ultimate load carrying capacity of GPC sleeper is moderately higher than the OPC sleeper.

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