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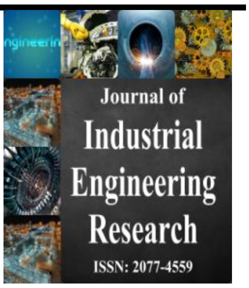

Development of Geopolymer Concrete on Railway Pre-Stressed Concrete Sleeper Under Static Loading

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ABSTRACT

Railway prestressed concrete sleeper is an imperative for component of ballasted railway tracks. Its main function is to help distributing axle loading to sub grade and formation. By nature, the concrete sleeper is subjected to sagging moment at the rail seat zone and to hogging moment at the middle section. Although behaviours of concrete sleepers under static loading have been enormously studied, their rotational characteristic and capacity under such loading have never been reported. The emphases of this paper are placed on the static behaviour and rotational capacity of a prestressed concrete sleeper under hogging moment. An Indian manufactured concrete sleeper was used in the experiment in accordance with Indian Standards, IS:2386-1963. LVDT was mounted at the middle span for measuring the deflection. The inclinometers were installed coincident with rail gauge in order to measure the rotations at those positions. Strains at bottom and top fibres under loading were recorded by strain gages. In this paper, the load-deflection curve of the static four-point loading test is presented. Relationship between hogging moment and gauge rotation is underlined. Criteria of the measure based on the loading capacity are also discussed for determining the failure of railway prestressed concrete sleeper. In this study the fly ash based geopolymer concrete mix design was obtained for M50 grade. The fluid to fly ash ratio was fixed as 0.45. The ratio of sodium silicate to sodium hydroxide was 2.5 and the concentration of the solution is 14 molar. The preliminary tests were carried out for the geopolymer concrete and conventional concrete and optimizing the mix design. Two numbers of sleepers were cast in each case one in conventional concrete and other one in geopolymer concrete. All the sleepers were tested under static monotonically loading and the results will be presented. Comparison will be made between conventional concrete and geopolymer concrete.

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INTRODUCTION

In recent years, there has been a growing challenge in railway engineering research. Railway tracks have been designed based on a consideration to overcome the heavier load-carrying capacity of the roads and trucks either at the moment or in the future. Usually, ballasted railway track – which consists of rails, sleepers, ballast formation, and fastening systems – is widely constructed for transportation especially in remote area [1]. The railway sleepers play an important role in: - Uniformly transferring and distributing loads from the rail foot to underlying ballast bed; - Sustaining and retaining the rails at the proper gauge by keeping anchorage for the rail fastening system; preserving rail inclination; and - providing supports for rails; restraining longitudinal, lateral and vertical rail movements by embedding itself into sub structures. Apparently, the main duty of railway concrete sleepers is to distribute the rolling stocks' axle loads to supporting formation and foundation finally. The axle loading could be considered static load when the train speeds are low to moderate [2]. However, indeed the axle loading tends to physically behave as the dynamic impact pulses. This is because of the continual moving ride over track irregularities and increased speeds. These dynamic effects would then deteriorate the engineering properties of railway tracks' components and undermine the load resistant performance of the railway concrete sleepers [3, 4]. Although the dynamic effects have evidently prevailed over the failures of railway concrete sleepers, most of design criteria are on the basis of the static sectional capacity of the concrete sleepers. Theoretical concepts of strength, ductility, stability, fracture mechanics, and so on,

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mostly refer to the static behaviours [5]. In addition, the numerical modelling of prestressed concrete sleepers requires the static testing results to validate against each other as can be seen in another work done by *Deivabalan* and *Tamilamuthan* [6]. The convergence of the model over static behaviours and modal analysis results will certainly strengthen the confidence of using the numerical model in accurately predicting the dynamic responses of concrete sleepers under various conditions. Indian Standards [7, 8] prescribes the conventional analysis and design of railway prestressed concrete sleepers and fastening assemblies. The maximum design flexural moments in sleepers can be statically calculated from the pressure or load distribution as illustrated in Figure 1. It is found that the maximum positive moment remains at the rail seat, whilst the maximum negative moment occurs at the middle of sleepers. The Standard also gives the consideration that need not to check sleeper section for stresses other than flexural stresses, e.g. shear, if the design is complied with all clauses in the Standard. For prestressed concrete sleepers, it is found that the influence of the dead load can be neglected and the design load can be expressed by the wheel load alone [11].

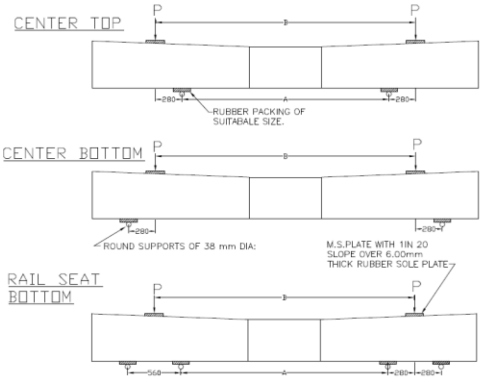


Fig.1: Pressure (or) Load distribution for maximum positive rail seat and centre moments.

Based on Figure 1,Centre bottom at the loading level of centre negative moment (*Mc_*) at centre is maximum for track gauge of 1,600 mm and greater and can be read [5]
Mc_0.5<Rg-4Rg –L-g-/3L-2g – R-2g-l-2°/6L-4g

For track gauge of 1,435mm, the values of the maximum centre negative moment is based on a uniform distribution of ballast pressure on the sleeper soffit and can be read
Mc-R 2g-L/4

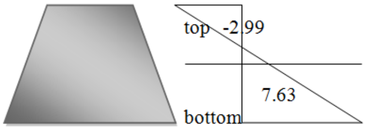
Failure behaviours of prestressed concrete structures under static loading have been enormously investigated [5]. However, most of static investigations on prestressed concrete sleepers have focused on the peak or collapse loads and the related displacements [12]. Understanding rotational mechanism at rail gauge allows to improve the design criteria of such components. In this paper, the static testing results are presented, aiming at providing experimental results for the nonlinear finite element modelling [6]. Due to the standardized quality control and a limited number of concrete sleepers, a detailed test covers only results on the failure behaviour, rotational and load-carrying capacities of a railway concrete sleeper at the centre of the sleeper. [13]. The sleeper specimen was unused and lasted about two years. At the centre section, the negative moment was applied through the four-point-load bending test. Those tests were arranged in accordance with IS:516-1959 Prestressed concrete sleepers and IS:656-1991 Resilient fastening assemblies [7,8]. Static performance and failure mode are discussed in addition to the rotational behaviour at the residue capacity of concrete sleepers.

2. Ultimate moment capacity:

Cross section of the test concrete sleeper is presented in Figure 2. Ultimate moment capacity was predicted by sectional analysis of prestressed concrete section, which in calculated from a computer package, Response-2000. This package relied upon the modified compression field theory for concrete structures [14]. The input data include: the measured initial strain of wires due to prestressing is about 6.70 mm/m, and each prestressing wire has a proof stress of 1860 MPa. The tested compressive strength of concrete is 88.5MPa. Sectional analysis of the specimen for ultimate negative moment of middle section is shown in Figure 2b. It is found that the ultimate negative moment is 53 kNm, while the decompression moment is about 19 kNm Cross section of the specimen Longitudinal Strain

3. *Experiments:*

The test set ups were carried out in accordance with Indian Standards: IS 2386-1963 Prestressed concrete sleepers are Resilient fastening assemblies [7, 8]. IS 2386-1963, IS 656-1991 indicates the boundary conditions, location of supports, and characteristics of loading. The strain measurements on top and bottom fibres at the surface of concrete sleepers are followed from IS 2386-1963, IRS T-40. The concrete sleeper specimen used in the ultimate test has been kindly supplied by an Australian manufacturer with the collaboration of the Indian Railway Specification Centre for Railway Engineering and Technologies). The total length is about 2,750 mm and the rail gauge is approximately 1,600 mm. The schematic diagram for the experimental setup of centre negative moment test is shown in Figure 3. The strain gages were installed 10 mm away from the top and bottom surface at the centre of sleeper. LDVT was used to measure deflection at the load point. The rotations support which that represent the gauge rotations were measured using the inclinometers. The test had been implemented at small rate displacement control that provides loading rate at approximately 2.5 kN/min, as prescribed in IS 2386-1963 that the loading rate should not be greater than 40 kN/min. After performing the ultimate static test, the concrete sleeper has been drilled for materials testing specimens, in order to investigate the mechanical properties of concrete materials at that condition. The specimens were subjected to uni-directional axial loading tests. The LDVT was used to measure the displacement under loading. Nonlinear stress-strain curves were adopted for the numerical analysis, ref: [6]. It is found that the average strength of concrete is 68.5 MPa. The sleepers shall be loaded gradually (30-40 KN/min) up to the specified load, which will be retained at this level for one minute for observing cracks, if any. For the purpose, a crack is defined as one which is barely visible to the naked eye and is at least 15mm long from the tension edge of the sleeper. However, if crack appears at a load smaller than the specified load, that value shall be recorded. In case of ‘Moment of Resistance’ (MR) test, the sleeper shall be deemed to have passed the test if it sustains the loads without cracking. Sleepers shall be subjected to loading till the appearance of first cracks. In case of ‘Moment of failure’ (MF) test, the sleeper shall be deemed to have passed the test if it is able to take load beyond the specified test load Figure 4.



a) Sectional analysis results

Fig. 2: Ultimate Moment Capacity.

Fig. 3: Static testing setup.

Fig. 4: Static testing with Crack pattern.

4. Static Performance:

The load-deflection and moment-deflection relationships are presented in Figure 4, while the rotational capacity against loading can be seen from Figure 5. The crack initiation load was detected visually during each test as well as determined by the use of the load-deflection relation. Crack initiation was defined as the intersection between the load-deflection relations in stages I and II [12, 13]. This method provides a slightly higher cracking load that from the first deviation point from the linear elastic part of load-deflection relationship. It should be noted that the first cracks are in flexure. The visualized crack initiation load is about 65 kN while the measured one is about 69 kN. The maximum load experimentally found is 73 kN, equivalent to bending moment about 45kNm. Comparisons of measured and predicted collapse loads showed good for Geopolymer concrete.

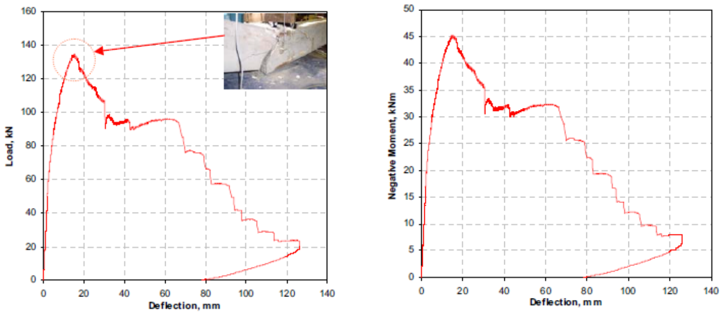


Fig. 5: Load and Moment – Deflection Curve.

5. Conclusions:

5.1 Under Static Loading:

In general, rotational capacity of a railway prestressed concrete sleeper plays vital role in its analysis and design because its excessive movement could let to devastating events. To have an understanding into its rotational behaviour, this paper firstly presents the rotational capacity of a type of railway concrete sleepers carried out from the ultimate hogging moment test, which simulates the normal loading on tracks. The additional aim of this paper is to supply experimental results to the nonlinear finite element analysis of the concrete sleeper. From the results, it can be seen that the prestressed concrete sleeper has relatively low rotational capacity. This would not allow the rail gauges misbehaving and not lead to the derailment. Also, it is found that the modified compression field theory can be used to predict the static responses of prestressed concrete sleepers. The predicted result is about 15% higher than the experimental one.

5.2 Under Performance Of Geopolymer:

Under flexure test, the conventional concrete M50 grade prestressed sleeper is it in noticed that the ultimate load of 230 kN. The same setup M50 grade geopolymer concrete sleeper to reach the ultimate load of 250 kN The load carrying capacity increased nearly 10%. At any given load level, 20% increased deflection obtained in geopolymer pretensioned concrete sleeper at any load level with respect to conventional pretensioned concrete sleeper. The crack distribution and width are increased geopolymer pretension concrete sleepers with respect to conventional pretensioned concrete sleepers. Adequate high curing temperature (60 ° - 70 °) and adequate curing time at minimum 24 hours will give better results for geopolymer concrete. From the studies carried out on low calcium fly ash based geopolymer concrete, it is concluded that the geopolymer with 14M gives considerable results in strength point of view. From the experimental results, it is understand that geopolymer perform well in all are aspects when compared with conventional concrete.

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