THEORETICAL MODELING OF PRESTRESSED NANO-CONCRETE SLEEPER

RAHUL S MATE[1], C. B. POL[2]

[1]PG Student, Dept. of Civil Engineering, Walchand College of Engineering, Sangli, Maharashtra
[2]Assistant Professor, Walchand College of Engineering, Sangli, Maharashtra

---

Abstract - *In recent times nanotechnology has given rise to new wave of material science in construction industry. Railway sleepers are most crucial element of rail track system. Strength and durability of railway sleepers play major role in transporting higher loads which in turn can be improved by using Nano particles like Graphene and Nano-silica in concrete (Nano-concrete). In this paper an attempt is made for theoretical modeling of Prestressed Nano-concrete sleeper. Finite element analysis of sleeper is carried out to compare load deflection characteristics of ordinary sleeper and Nano- concrete sleeper. By interchanging properties of concrete to Nano concrete deformation of prestressed nano concrete sleeper is determined and compared with prestressed concrete sleeper. From analytical results it is evident that Prestressed Nano concrete sleeper has higher load carrying capacity compared to prestressed concrete sleeper specimen. Results of Finite Element Model showed performance of prestressed Nano concrete sleeper is better than conventional PSC sleeper.*

Key Words: Nano concrete; Industrial Graphene; Nano- silica; Prestressed Nano-Concrete sleeper; Finite Element Modeling.

1. INTRODUCTION

India is a land of different cultures, so in such railway play vital role in gathering the transportation need of the country also they are the backbone of the India's transportation facilities. In the world India has 4th number in railway network. India's most of railway network is older than 100 years. With the passing of time, ageing of railway network due to traffic increment, greater wheel loads and lack of maintenance. Not only the total number of trains plying on the network is rising, also the speed, the axle loads and the number of bogies attached to the trains is also increasing. All this calls for a through and fast modernization of the sprawling railway network through development of new design concepts and use of advanced materials.

Railway sleeper is most important element of railway track system. They transfer and distribute rail load to ballast and secures gauge displacement also maintains gauge-width. Failure to serve such roles can leads derailment which can be dangerous for both lives and property. For maintaining track quality to service level and to ensure safe track operation, replace damaged and degraded sleepers by new sleepers.

Sleepers are subjected to loads coming from axles and rails also sleepers are exposed to large temperature variations, excessive UV radiations, adverse weather conditions, and attack from microorganisms and insects. The premature declining of rail way sleeper is occurring by rail seat declination, cracks and damages under variable loading conditions and adverse environment conditions. To prevent the occurrence of accidents by failure of sleeper, the materials used for sleepers must be rigid, durable and unaffected by toUV light, temperature fluxes, and insect outbreak.

Prestressed concrete sleepers offer greater durability than timber and steel. The problem of cracking in concrete sleepers are principally by higher intensity load from wheel or rail irregularity like wheel burning, dipped jointing, rail corrugation, or defective track stiffness. The key to damage resilient concrete and longer life concrete structure lies in improving the tensile strength and fracture toughness of concrete material which can be achieved by using Nanoparticles in concrete i.e. by using Nano-concrete.

Nano Concrete is concrete produced by infilling pores in conventional concrete by Nano particles of less than 500 Nano meters. The innovation made in the revision of concrete at Nano scale has shown that addition of Nano-silica and Graphene leads to the densifying of the micro and Nano- structure ensuing in enriched mechanical properties, strength development.

2. OBJECTIVE OF WORK

The objective of this work is to develop theoretical modeling of prestressed Nano-concrete sleeper and compare the performance with conventional prestressed concrete sleeper using ANSYS workbench 19.2

2. LITERATURE REVIEW

Dimitar Dimov et al. (2020) studied the properties of Ultrahigh Performance Nano engineered Graphene Concrete. They used high shear liquid phase exfoliation method for addition of Graphene into concrete. Results of compression test and 3-point bending test show rise of 146% in compressive strength and 79.5% in flexural strength of concrete.

Guruswamy J. et al. (2019): This paper gives the behavior of prestressed concrete sleepers for static loading using Nano based Carbon Fiber Reinforced

Concrete. Authors used GGBS fibers, Silica Fume fibers, Carbon fibers, Polypropylene fibers and Carbon Nano tubes as Nano fibers with High Performance Concrete (M60). Energy absorption results shows that Energy absorption capacity has been increased by 49% in comparison to M60.

Sadat Ali Khan et al. (2019): This paper describes the behavior of Railway PSC Sleeper for impact loading using Nano based Carbon Fibre Reinforced Concrete. Author studies the effect of repeated low energy horizontal impact loading on PSC sleepers integrated with next generation Nano Fiber along with FRC. Test results show that energy absorption capacity of sleepers and load carrying capacity increased by minimum 10%.

Mohan Raj and Sugila Devi (2019): They carried out experimental testing of Nano concrete using Nano-silica and micro sand. Cement is partially replaced with various percentages of Nano Silica and m sand. Percentage of Nano Silica used was 3%, 3.5%, and 10% for M20 mix. Test results shows that the flow ability of concrete declines with escalation in the amount of Nano-silica as Nano silica absorbs the waterfrom the mix.

Kishore Kumar and Sambasivrao established a typical finite element model of the concrete sleeper. A FEM of a conventional PSC sleeper is carried out for static load.

3. SLEEPERS

Sleeper is an important member of railway track system. Sleepers are the transverse connections that are placed to support the rails. They are also called as railroad ties or railway tie. Primary role of sleepers is to spread the wheel load from the rails to ballast.

Functions of Sleeper:

a) Hold the rails in exact gauge and alignment.

b) Give stable and uniform support to the rails.

c) Transfer the load uniformly from rail to broader area ofballast.

d) Act as elastic medium amongst the rails and the ballast absorbing the blows and vibrations produced by movingloads.

e) Provide longitudinal and lateral solidity to stable way.

f) Provide resources to enhance the track geometry during their service life.

Requirements of Ideal Sleeper:

a) The initial and maintenance cost should least.

b) The weight of the sleeper should be reasonable for convenient to handle.

c) The design of sleeper as well as fastenings should be such that conceivable to find and take out the rails simply.

d) The sleeper should have enough bearing area so that ballast under it is unlikely to be crushed.

e) The sleeper should be such that it likely to retain andalter the gauge properly.

f) The sleeper material and sleeper design should be suchthat it unlikely to break or get broken during packing.

g) The sleeper should be able to resist vibrations and shocks.

4. NANO-CONCRETE

Nano-concrete is a concrete produced by filling pores in conventional concrete by particles of size less than 500nm. When concrete is reduced to Nano level there properties aregreatly influenced.

Why Nano-concrete for sleeper?

1. To increase load carrying capacity of sleeper so that totransport higher loads.

2. To obtain thinner sections of concrete sleepers.

3. Reduce the cost of concrete sleeper.

4. To increase corrosion resistance of sleeper.

5. Nano-concrete increases effective length of Prestress.

In this research we are going to use Graphene and Nano silica as Nano additives. Previous studies show that addition of Addition of Graphene and Nano silica improves the compressive strength as well as tensile strength of concrete. It also increases the young's modulus of concrete. Nano concrete reduces the transmission length in Prestress concrete. Effective Prestress value is more for conventional concrete.

Nano Silica

Laboratory experiments show that Nano silica particles can be obtained by sol-gel process from the hydrolysis of tetra ethoxysilane in ethanol with use of ammonia as catalyst. Particle size of Nano silica can be governed by use of alcohol as solvent and changing reaction temperature.

Table1: Characteristics of Nano-silica

Characteristics	Value
1. Density	2.7

2. PH	3.7-4.7
3. SiO2 Content	>99.8% by wt.

Graphene

Graphene has had very thin layer of carbon, has a higher SSA, high Young's modulus of elasticity, higher thermal conductivity and greater electrical conductivity. These properties make graphene important nanomaterial in applications of reinforced concrete.

Graphene can be defined as single film of carbon atoms organized in a hexagonal lattice. Graphene is fundamental building block for graphite materials of all dimensions.

Graphene Nano particles are the extraction of carbon, which improves the strength of concrete, but graphene material does not mix properly with concrete directly, before adding it to concrete have to dissolve with water with the help of SDL.

Characteristics	Value
1.Specific Gravity	1.9
2. Test	Test less
3. Odor	Odor less
4. Color	Black

DESIGNING AND MODELING OF SLEEPER

Sleeper Section

The sleeper designed is of RDSO T-8527 type prestressed concrete wider sleeper. The cross section varies as trapezoidal in shape of sleeper and trapezoidal in size from the rail seat to centre of the sleeper. The sleeper is symmetrical in shape as well as in size from centre. The length of sleeper as per IRS T-39 is 2750 millimeter.

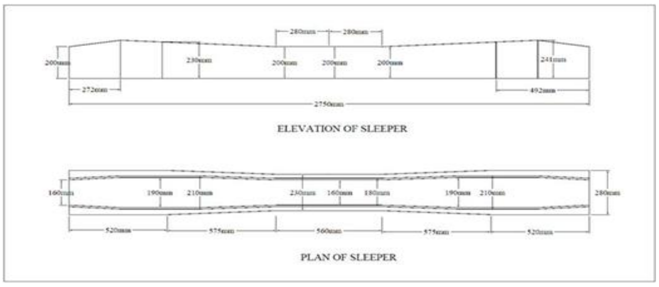

Fig. 1 – Plan and elevation of sleeper

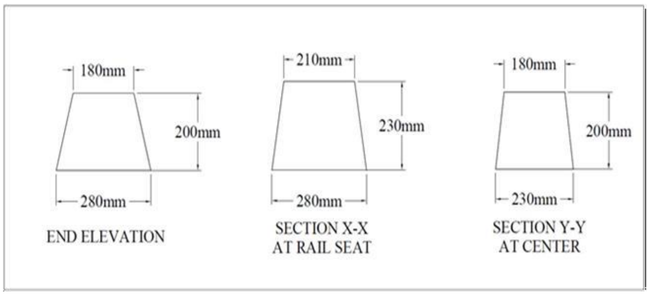

Fig. 2 – Sections of sleeper

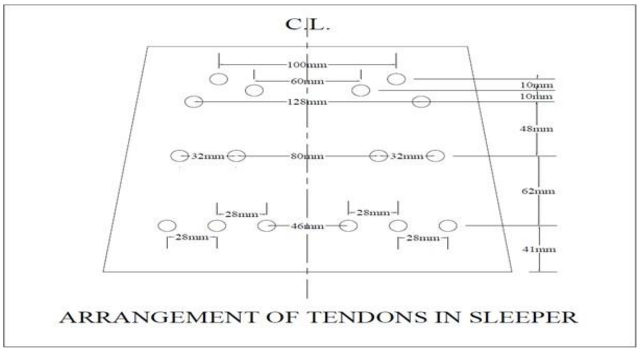

Fig.3 - Arrangement of tendons in sleeper

Material Properties

1. Concrete:

Table -1: Material Properties

Properties	Conventional Sleeper	Nano-concrete Sleeper
Young's Modulus Of Elasticity	38729.83 MPa	43457 MPa
Poisson's Ratio	0.18	0.17
Coefficient Of Thermal Expansion	$1.2x10^{-5}$	$1.2x10^{-5}$
Ultimate Compressive Strength	60 N/mm^2	82 N/mm^2
Ultimate Tensile Strength	5.2 N/mm^2	6.3 N/mm^2
Density	24 kN/m^3	24 kN/m^3

2. Prestressing Tendons:

Young's Modulus	195000 MPa
Poisson's Ratio	0.3
Tensile Yield Strength	1640 MPa
Ultimate Tensile Strength	1865 MPa
Density	78.5 kN/m^3

Modeling the sleeper:

For modeling of sleeper first solid model of sleeper is required to build and then meshing and loading conditions is required to be applied. Firstly 3D solid model is drawn in AutoCAD and then it is imported in ANSYS. In this type we canbuild full sleeper volumetric model in ANSYS 19.2. The sleeper volumetric model built is shown in Fig.4.

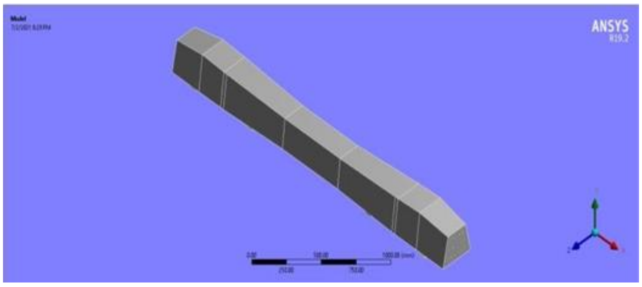

Fig.4 – Geometric model of sleeper

FEM of Sleeper:

The volumetric model of the mono block sleeper built in ANSYS is then discretized with sweep method of meshing. A total of 156267 elements and 655454 nodes have been used in the FE mesh of the sleeper model. The FE model has been utilized for studies of influential parameters and thereby a better knowledge concerning the structural behavior of a concrete sleeper is gained. The obtained FE meshed model ofthe sleeper is shown in Fig.5.

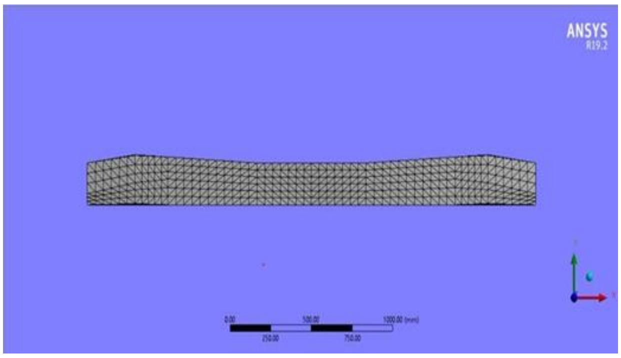

Fig.5 – Mesh model of sleeper

Loading Conditions:

Loading & support conditions are adopted as per RDSO. Sleeper is applied with 2 loads as shown in Fig.6. Each sleeper should carry 286kN load. Hence load of 286 KN applied on each rail seat as shown in Fig.6

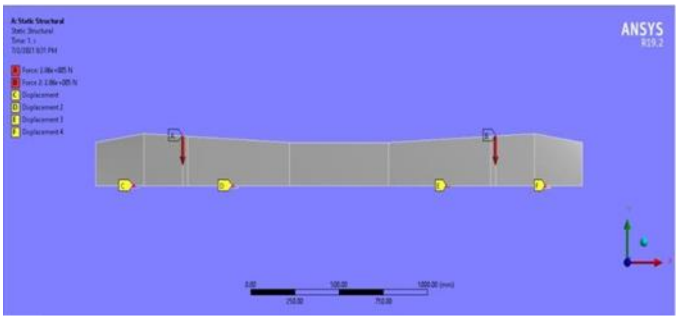

Fig.6 – Loading and supports conditions

Static Stress Analysis results:

For carrying out the static analysis of sleeper, deflection is obtained for the sleeper model. From FEM analysis we can see that the vertical deformation is larger at the rail seat. Fig.7 and Fig.8 shows results of total deformation in conventional sleeper and Nano-concrete sleeper respectively.

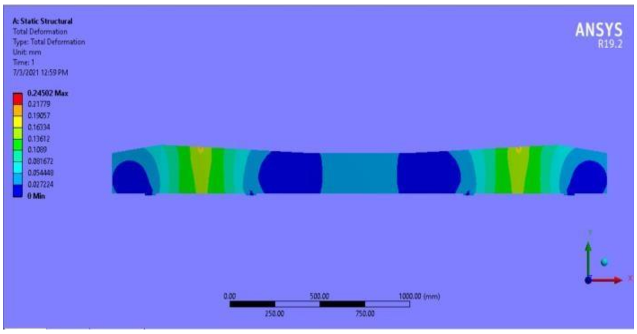

Fig.7 - Total deformation in conventional sleeper

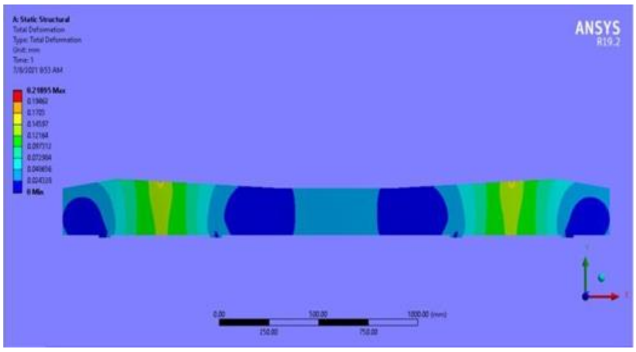

Fig.8 - Total deformation in Nano-concrete sleeper

In fig. 7 we can see that max deformation come out to be 0.24mm for conventional sleeper at seat.

In fig. 8 we can see that max deformation was 0.21 mm for Nano-concrete sleeper.

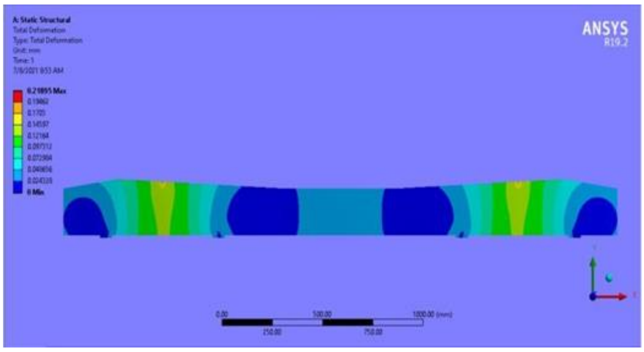

Fig.8 - Total deformation in Nano-concrete sleeper

From fig 7, and 8 we can conclude that total deformation in Nano-concrete sleeper is less than total deformation in conventional sleeper.

Load v/s Total Deformation:

Following figure shows load v/s total deformation graph for conventional prestressed concrete sleeper and Prestressed Nano-concrete sleeper.

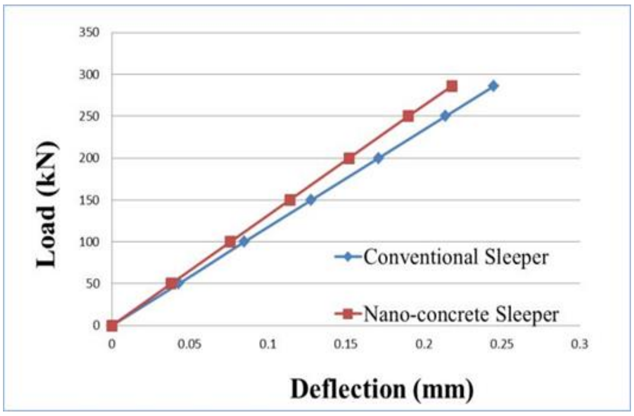

Fig.8 - Total deformation in Nano-concrete sleeper

From load deflection curve we can see that, total deflection in conventional sleeper is 12-13% less than that of sleeper with concrete containing Nano-silica and graphene.

When Nano-silica added in concrete the pores in concrete gets filled, thus reduces shrinkage hence increases strength, corrosion resistance and durability.

When graphene is added into concrete, it results into higher C-S-H gel forming which increases strength, durability characteristics of concrete.

Hence, the sleeper with Nano-concrete has higher load carrying capacity and lesser yield deflection than that of conventional concrete sleeper.

CONCLUSION

1. By using Nano-concrete in sleeper, load carrying capacity of sleeper increased by 26.19%.
2. Prestressed Nano-concrete sleeper can results in lesser deflection for same load than conventional sleeper.
3. Prestressed Nano-concrete sleeper has higher Yield deflection than conventional sleeper.
4. By using Nano-concrete Yield deflection of sleeper increased by 12-13%.
5. By using Nano-concrete we can reduce the section of sleeper for same load. Also we can use same section for higher load and high speed than present load and speed.

ACKNOWLEDGEMENT:

We would like to acknowledge our Institute Walchand College of Engineering, Sangli, Maharashtra, India for providing us supportive environment for completion of research.

REFERENCES:

1. Zengshun Chen, Yemeng Xu, Jianmin Hua, Xu Wang, Lepeng Huang, Xiao Zhou, “Mechanical Properties and Shrinkage Behaviour of Concrete-Containing Graphene- Oxide Nano sheets”, Materials, 13, 2-15, 2020
2. Vasanthi P., Senthilselvan, D. Benita Hexton, Mohamed Salman Farooq, P. Suresh , “Durability Study on Nano Concrete”, International Journal of Chem. Tech Research,10(3), 693-698, 2017.
3. Guruswamy J., Ashwini Joish, Sadath Ali Khan and Shashi Shankar, “A static behaviour of railway PSC sleepers using Nano based carbon Fibre reinforced concrete”, International Journal Of Current Research, 11(02), 1285-1290, 2019.
4. Dimitar Dimov, Iddo Amit, Olivier Gorrie, Matthew D. Barnes, Nicola J. Townsend, “Ultrahigh Performance Nano engineered Graphene–Concrete Composites for Multifunctional Applications”, Adv. Funct. Mater., 28, 1705183, 2018.
5. Guruswamy J, Akash Babu, L, Sadath Ali Khan, Zai Shashishankar., A. N. Jayaramappa, “A Impact Behaviour of Railway PSC Sleeper using Nano based Carbon with Fibre Reinforced Concrete”, International Journal of Science Technology & Engineering, 5(9), 32-42, 2019.
6. Mohan Raj, Sugila Devi., “Experimental Investigation on Nano Concrete with Nano Silica And M-Sand”, International Research Journal of Engineering and

Technology (IRJET), Vol. 6(03), 6860-6871, 2019

7. Suresh Kumar A, Muthukannan M, "An Examination on Performance of Railway Sleepers", International Journal of Recent Technology and Engineering (IJRTE), Volume-8 (4S2), 37-44, 2019

8. Sadeghi, "Investigation on the accuracy of current practices in analysis of railway track sleeper", International Journal of Civil Engineering, 3(1), 34-51, 2005.

9. IRS:T-39 fifth feb2016 Revision Indian railway Standard specification for Pretensioned PSC sleepers for Broad- gauge and Meter gauge.

10. IS: 1343 -1980 Practice for PSC.