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RESEARCH ARTICLE

STATIC BEHAVIOR OF RAILWAY PSC SLEEPERS USING NANO BASED CARBON FIBER REINFORCED CONCRETE

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ABSTRACT

This paper presents the experimental study on static behavior of Railway Prestressed concrete (PSC) sleepers Using Next Generation Nano Based Carbon Fiber Reinforced Concrete. The next generation nano based carbon fiber reinforced concrete is prepared using advance concrete materials such as GGBS, Silica Fumes, Carbon fibers, Polypropylene fibers and Carbon Nanotubes, (CNTs) integrated with High Performance Concrete having its compressive strength of 60 N/mm^2. Five different PSC test specimens were casted viz. S1(M60), S2(M60+CNT), S3(M60+CNT+PF), S4(M60+CNT+CF) and S5 (M60+CNT+PF+CF). Carbon Nanotubes were first dispersed in deionized water and surfactant using an ultrasonic mixer as per state-of-the-art techniques, then the CNTs, Carbon fibers, Polypropylene fibers were combined with concrete. The PSC sleepers are casted at Sri Maruthi Builders and manufacturers of PSC railway sleepers, Yeshwanthpur, Bangalore, Karnataka and static tests were carried out at Department of Civil Engineering, UVCE, Bangalore University, Bangalore, Karnataka, India. Load deflection curve was established. Ductility index, energy absorption and toughness index characteristics are determined and also the crack pattern, first crack load and ultimate load were studied. It is experimentally observed that sleeper specimen S5, first crack load and the ultimate load has been significantly enhanced as compared to other PSC railway sleeper test specimens.

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INTRODUCTION

A major portion of the railway network in India is more than a century old. Indian Railways is the backbone of the country's transport infrastructure integrating market and connects communities all over the country. It is the fourth largest railway networks in the world (after USA, China and Russia). With the passage of time, this network is showing signs of ageing due to increased traffic, heavier wheel loads and improper maintenance. The premature deterioration of railway sleepers is due to rail-seat deterioration, cracking and damaging under different loading conditions and adverse environment conditions.

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The problem of cracking in concrete sleepers and corollary damage are largely due to the high intensity loads from wheel or rail irregularities such as wheel burns, dipped joints, rail corrugation, or defective track stiffness. All this calls for a development of an economically competitive material or structure of suitable strength which will satisfy the needs of the industry and all the requirements for serviceability, durability, maintenance and ease of construction. The key to damage-resistant concrete and long-life concrete structures, which has been known for a long time, lies in enhancing the tensile strength and fracture toughness of concrete material which is achieved by reinforcing fibers in concrete.

LITERATURE REVIEW

An Australian manufactured concrete sleeper (B.G) was used in the experiment in accordance with Australian Standards, AS1085.14.

Concrete with strength of above 40 N/mm^2 is generally termed as high strength concrete, studied on High strength Prestressed Concrete sleepers. The materials used are Special grade cement conforming to IRS No, T-40, Portland Slag Cement, River sand, coarse aggregate, potable water, HTS wires (18nos of 3x3mm) and Super Plasticizer (Glenium ACE-30). They carried out Compression test, Flexural test, Static Bending test and Electrical Resistance test (Chaitra, 2007; Agarwal, 2012). The cross section dimension of sleeper at rail seat 250x210x150 mm and at centre 220*180*150mm, the length of sleeper is 2750mm for broad gauge track. They carried out Compression test, Flexural test, Static Bending test, Electrical Resistance test, rail seat bottom & center top and center bottom respectively. The results of PSC sleepers satisfy all requirement of Railway specification and load values within the specified limit. The sleepers passed the electrical resistance test (Gonzalez-Corominas1, 2012; Ramamani, 2007; Chaturvedi, 2011). Investigated experimentally and numerically, the behavior of prestressed concrete railway sleepers with M60 grade concrete modified with SBR latex and polypropylene fibres, The load deflection curves and failure modes was found to be in good agreement with the experimental results for all the sleepers (Harish, 2016; Sakdirat Kaewunruen and Alex M. Remennikov, 2007). The concrete structures rely largely on deformation and yielding of tensile reinforcement to satisfy the ductility demand. Although nano carbon fiber reinforced concrete modified with High Performance concrete is still a concern for practical application under seismic loading or severe service conditions. A few experimental results have shown the use of polypropylene and carbon fibers in improvement of strength capacity in concrete but this is still to be quantified with more experimental test which will change the design parameters with enhanced strength capability of structural members. Progress in the area of Next Generation Nano Based Carbon Fiber Reinforced Concrete has been fairly low, partly due to the high material cost which may discourage the industrial application and partly due to the lack of experimental data on new composite materials. The potential of Next Generation Nano Based Carbon Fiber Reinforced Concrete has been fairly low in the research activities. Hence, the present experimental investigation aims at full understanding of the influence of Cement, GGBS, Silica Fumes, Carbon fibers, polypropylene fibers, Carbon Nanotubes when integrated with High Performance Concrete by casting PSC railway sleeper test specimens tested under static bending test.

EXPERIMENTAL PROGRAM

The present experimental program was designed to investigate the static behavior of railway PSC sleepers.In PSC test sleeper specimens, the concrete mix ingredients consists of Cement, GGBS, Silica Fumes, Carbon fibers, polypropylene fibers and CNTs on five different mixes with the following PSC railway sleeper test specimens as shown in Table 1. The materials, mix proportions, test specimens, experimental procedure and test setup used in the present investigation to study the static behavior of railway PSC sleepers are illustrated in the following subsections

MATERIALS AND METHODS

In this experiment, Special Grade Portland cement (53-S) conforming to IRS/T-40-1985 was used, to ascertain the physical characteristics of the cement, tests were conducted in accordance with the Indian standards confirming to IS-12269:1987. Locally available crushed sand was used. The tests on the fine aggregate were conducted in accordance with IS 2386 Part 1 to Part 4-1964 (Reaffirmed-2002) for requirement as per IRS T-39 Specifications to determine Specific gravity, Bulk density and Fineness modulus. The results conform to IS: 2383 (Reaffirmed 1990). Crushed angular of 20 mm and 10mm maximum size has been used as coarse aggregate. The sieve ana1ysis of combined aggregates confirms to the specifications of IS 383: 1970 for well graded aggregates. The tests on the coarse aggregate were conducted in accordance with IS 2386 Part 1 to Part 4-1963 (Reaffirmed-2002) to determine Specific gravity, Bulk density and Fineness modulus. Auracast 270M as Super Plasticizer (chemical admixture) was used. Silica fumes supplied by Elkem India Pvt. Ltd, Navi Mumbai and Ground Granulated Blast Furnace Slag (GGBFS) supplied by Nuvoco Vistas Corporation Limited, (formerly Lafarge India Ltd.), Bangalore were used as mineral admixtures. Carbon fibres of 6mm chopped length supplied by M/s Baseer Fibres Private Limited, Bengaluru was uesd. Polypropylene fibers (Recron 3S) supplied by Ranka Udyog, Pvt, Ltd, Bangalore was used. CNTs supplied by Sigma-Aldrich was used. Ordinary potable water was used for mixing and curing purpose.

Mix proportions

The concrete mix having a compressive strength of 60 N/mm^2 was aimed in the present research investigation, the design mix proportion was obtained by ACI 211.4R-93 Method of mix design for high strength concrete. Based on the same, the mix proportions arrived are tabulated in table 2. The Polypropylene fibre, carbon fiber, Auracast 270M, Silica Fumes, GGBS and CNT's were included in this mix proportion as per the predetermined optimum percentages subject to the required workability. 8% of Silica Fumes is replaced by weight of cement, 21.6% of GGBS as replacement, 0.125% of weight of cement of carbon nano tube, 900gm/cubic meter of volume of concrete of polypropylene fibres, 0.5% of volume of concrete of carbon fibers and 0.4% of Super plasticizer by weight of cement were included into the concrete mix in the present investigation. Based on the trial mixes following compressive strength has been arrived for different concrete mixes under considerations and the same has been tabulated in table 3.

Test specimens: As per IRS-T 39 standard PSC railway sleepers were casted with trapezoidal cross sections with details as shown in the table 4 with a span of 2750mm,the general section details of conventional railway PSC sleepers is as shown in table 6, the sleepers were casted at Sri Maruthi Builders, Yeshwanthpur, Bangalore. The PSC railway sleeper test specimens consists of five different matrices as shown in table 5.

Experimental procedure: The experimental process consists of two phases i.e primary phase and secondary phase. In primary phase which consists of mixing of CNT with state-of-the-art procedure as shown below

Dispersion of CNTs: Dispersion of CNTs has been done at AZYME BIOSCIENCE PVT. LTD. BANGALORE, firstly water, surfactant, and CNTS are measured, and then mixed together. In order to ensure a well-dispersed solution, an ultrasonic mixer was used, which can deliver up to 500 watts at 20 kHz. An ultrasonic mixer is a device that uses a high frequency driver to transmit acoustical energy throughout a liquid medium. The energy in the shock waves is extremely high and significantly accelerates chemical reactions and breaks the clumps and agglomerations of particles. To reduce the chances of breaking the nanofilaments, CNTS were mixed for 20 minutes. In secondary phase casting of PSC railway sleepers as per IRS T-39 with the mix proportions as stated in table 1.

Casting the specimens: First of all, the moulds were cleaned, greased and oiled using mould release oil. The next step involves fixing the mould end plates using nuts and bolts. Then HTS 18no's of 3 ply 3mm dia strands reeled through all four moulds via bulk heads as well as the bench end plates. The stress bench was brought to the tensioning bed. The tensioning was carried out using hydraulic jack. Then initial pre-stressing force of 241KN was applied through the ends of the jack. The stress bench is then brought to the casting bed. Two high-frequency shuttering vibrators (8000 rpm) were fixed onto each mould. The mixed concrete with Carbon fibers, polypropylene fibers, CNTs, Silica fumes, GGBS, Auracast-270M was poured into each mould layer by layer, compacted with the help of shuttering vibrators. The stress bench was then put into the steam chambers, where each bench is subjected to steam curing for a period of about 11 ½ hours. If the required strength was achieved, the stress bench was taken out of the steam chamber. The end plate bolts were loosened, transferring the prestress to concrete. The mould end plates were opened, and the HTS wires were cut using welding electrodes. The long line method of prestressing is used to cast the railway PSC sleepers in the casting yard. The individual sleepers were then loosened using a tackle. The sleepers were demoulded from the moulds using demoulding tackle. The demoulded sleepers were put into sleeper-carrying trolleys.

Experimental Setup

Static Bending Test for Railway sleepers: The experimental program includes flexural behavior of test sleeper specimens under static loading The purpose of conducting the full scale static bending test of prestressed concrete railway sleeper test specimens under monotonic loading until ultimate stage is

- To study the load deflection curve.
- To investigate ductility index, energy absorption and toughness index characteristics computed from the area of the load deflection curve.
- To study the crack pattern, first crack load and ultimate load.

Before placing the sleeper specimen on the loading frame, all the specimens were white washed in order to facilitate marking of cracks. After white wash the sleeper specimen were placed on the loading frame with all the arrangement as shown in below figure, The load is applied with the use of hydraulic jack. At the same time deflection is also noted down with the help of LVDT. The first crack load and ultimate load is recorded also the cracking patterns are marked to study the crack patterns of the specimens. The loading is continued until the failure of test specimens.

Static Testing Machine: Static testing machine which is used in the present investigation is as shown in the below figure. The test specimens are simply supported over the span 2750 mm and tested by using loading frame. All the sleepers were tested by monotonic loading, The testing arrangement of the sleeper specimen is shown below. The sleepers were supported on two supporting end blocks. The clear span of the beam was kept as 2550 mm and is tested under monotonic loading. All sleepers were tested in the loading frame and the loading increment was applied to the test specimen from a hydraulic jack in turn loads are measured in load cell. First a small increment of load is applied to bring the surface of the test beam in contact with all attachments. First cracking load and ultimate load were observed. The entire testing operation of one specimen required 1 to 2 hours.

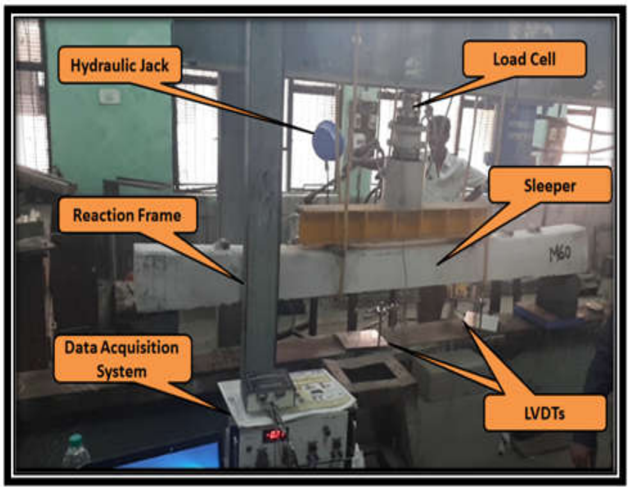

Figure 1. Test setup for monotonic loading condition

RESULTS AND DISCUSSIONS

Load Deflection Behaviour: The ultimate load carrying capacity for High Performance Concrete S1:M60 is 112.91 kN, S2:M60+CNT is 121.154 kN, S3:M60+CNT+PF is 128.34 kN, S4:M60+CNT+CF is 141.69 kN, (S5:M60+CNT+PF+CF) is 152.376 kN. The load deflection behavior up to yield point is as shown in the figure . The first crack loads of the five mixes in the present investigations M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M-60+CNT+PF+CF is 27.96kN, 29.67kN, 33.56kN, 37.25kN, 39.89kN respectively.

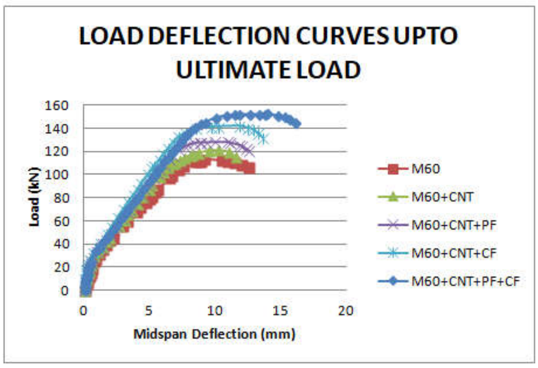

Figure 2. Load Deflection Curve upto Ultimate load

It is observed that from experimental results, first crack load has been increased by 6%, 17%, 25%, 30% with respect to control beam M60.

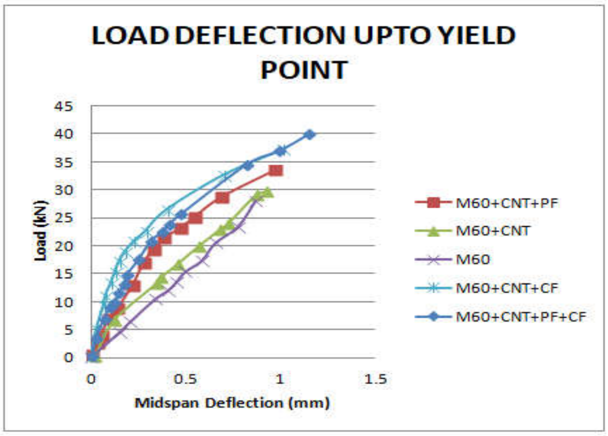

Figure 3. Load Deflection Upto Yield Point

It is experimentally evident that for the last sleeper specimen M-60+CNT+PF+CF first crack load has been significantly enhanced to 30% in comparison with M60 grade concrete. It is observed that all curves show linear variation up to first crack load and behave nonlinearly with further increase in load. All the curves are linear up to the formation of the first crack and they become non-linear due to the formation of multiple cracks and the propagation of the same up to the ultimate load. In case of M-60 concrete control test specimen, a sudden drop in the load was noticed beyond the peak load and further load dropped at a reduced rate. The variation of slope within the linear portion up to first crack load is shown in the below figure. It is conclusive that the stiffness of the concrete matrix with carbon fiber increases when compared to polypropylene fibers and CNT.

Variation of slope of linear linear trend within load deflection curve: The variation of slope within the linear portion up to first crack load is shown in Figure.

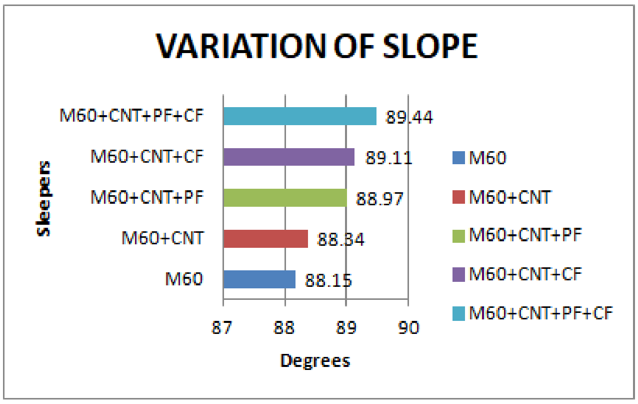

Figure 4. Variation of slope of linear trend within load deflection curve

Deflection Variation: Deflection at yield and ultimate loads are noted down through LVDTs and the same are tabulated below. The Yield deflection obtained for various concrete matrices M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M-60+CNT+PF+CF are 0.869, 0.93, 0.97, 1.01 and 1.151 respectively. The Ultimate deflection obtained for various concrete matrices M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M-60+CNT+PF+CF are 9.12, 10.189, 10.981, 11.856 and 13.952 respectively. It is observed that the Yield and Ultimate Deflection for M-60+CNT+PF+CF is greater than other concrete matrices and the least is for M60.

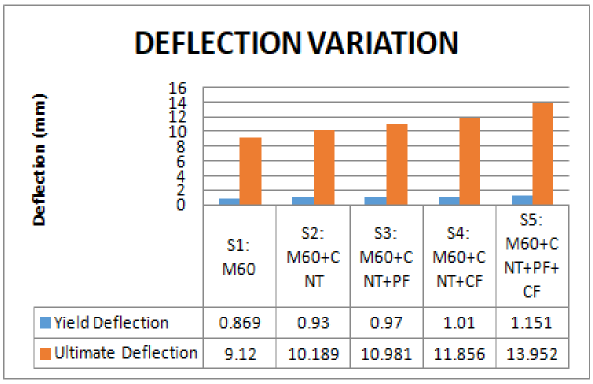

Figure 5. Deflection Variation

Ductility Index: From the experimental results improvement of ductility in the concrete was observed by incorporating fiber and CNT.

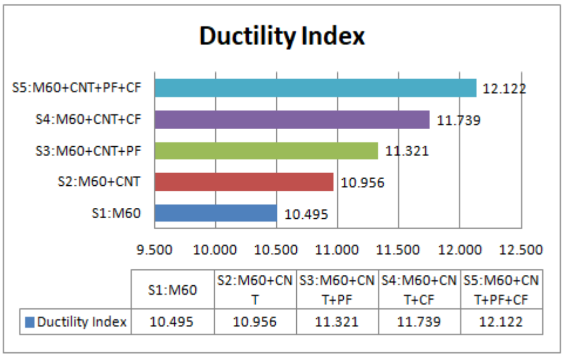

Figure 6. Ductility Index

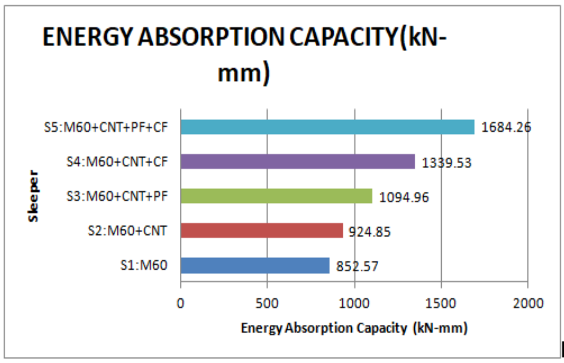

Figure 7. Energy Absorption Capacity

Table 1. Test specimens

Test specimens	S1	S2	S3	S4	S5
Concrete matrices	M60	M60+CNT	M60+CNT+PF	M60+CNT+CF	M60+CNT+PF+CF

Table 2. Mix proportions for different concrete matrices

From the results it can be seen that there is increase in Ductility w.r.to M60 by 4%, 8%, 12% and 16% for M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M-60+CNT+PF+CF prestressed concrete railway sleeper specimens respectively. It is observed that the Ductility Index for M60+CNT+PF+CF is higher than all other concrete matrices.

Mix	cement	Fine aggregate	Coarse aggregate	w/c	water	Carbon fiber	Polypropylene fiber	Super plasticizer	GGBS	Silica fumes	CNT
Test specimen	(kg/m³)	(kg/m³)	(kg/m³)		(kg/m³)	(kg/m³)	(kg/m³)	(litres/m³)	(kg/m³)	(kg/m³)	(litres/m³)
S1:M60	450	477.69	1124.64	0.373	168.15	-	-	2.02	138.2	51.15	-
S2:M60+CNT	450	477.69	1124.64	0.373	168.15	-	-	2.02	138.2	51.15	0.631
S3:M60+CNT +PF	450	477.69	1124.64	0.373	168.15	-	0.9	2.02	138.2	51.15	0.631
S4:M60+CNT +CF	450	477.69	1124.64	0.373	168.15	8.8	-	2.02	138.2	51.15	0.631
S5:M60+CNT +PF+CF	450	477.69	1124.64	0.373	168.15	8.8	0.9	-	138.2	51.15	0.631

Table 3. Compressive strength obtained for different concrete matrices

Properties	Age	M60	M60+CNT	M60+CNT +PF	M60+CNT+ CF	M60+CNT+P F+CF
	(Days)	(N/mm²)	(N/mm²)	(N/mm²)	(N/mm²)	(N/mm²)
Compressive strength	7	39.60	40.20	40.80	41.40	42.00
	15	60.12	60.94	61.55	62.98	65.22
	28	67.53	69.47	70.31	72.15	74.90

Table 4. Materials required for respective test sleeper specimen

Mix	cement	Fine aggregate	Coarse aggregate	water	Carbon fibre	Polypropyl ene fiber	Super plasticizer	GGBS	Silica fumes	CNT
Test specimen	(Kg)	(Kg)	(Kg)	(litres)	(Kg)	(gm)	(ml)	(Kg)	(Kg)	(ml)
S1:M60	54.93	58.25	137.25	9.63	-	-	220	16.86	6.2	-
S2:M60+CN T	54.93	58.25	137.25	9.63	-	-	220	16.86	6.2	68.66
S3:M60+CN T+PF	54.93	58.25	137.25	9.63	-	108	220	16.86	6.2	68.66
S4:M60+CN T+CF	54.93	58.25	137.25	9.63	1.06	-	220	16.86	6.2	68.66
S5:M60+CN T+PF+CF	54.93	58.25	137.25	9.63	1.06	108	220	16.86	6.2	68.66

Table 5. Dimension of Test Specimens

Details of Mix	Dimension (mm) as per RDSO		
	At Centre	At Railseat	At Ends
S1:M60	150x220x180	150x250x210	150x270x235
S2:M60+CNT	150x220x180	150x250x210	150x270x235
S3:M60+CNT+PF	150x220x180	150x250x210	150x270x235
S4:M60+CNT+CF	150x220x180	150x250x210	150x270x235
S5:M60+CNT+PF+CF	150x220x180	150x250x210	150x270x235

Table 6. General section Details

Mass (kg)	Gauge Length (mm)	Total Length (mm)	Top Width (mm)	At centre (mm)		At Rail Seat (mm)		At Ends (mm)	
				Soffit Width	Depth	Soffit Width	Depth	Soffit Width	Depth
206.0	1675	2750	150	220	180	250	210	270	235

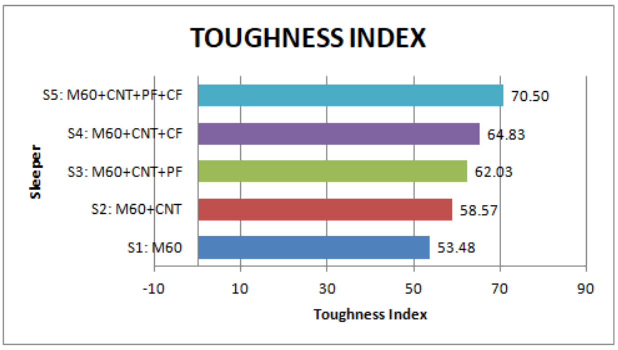

Figure 8. Toughness Index

Energy Absorption Capacity: The Energy absorption capacity of given material can be obtained from the load versus deflection curve of the specimen. The value of Energy absorption capacity was computed from the area under the load deflection curve for different concrete mix beams under investigation. The experimentally obtained values of Energy absorption capacity M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF and M-60+CNT+PF+CF prestressed concrete railway sleeper test specimens are 852.57 kN-mm, 924.85 kN-mm, 1094.96 kN-mm, 1339.53 kN-mm and 1684.25 kN-mm respectively. It is observed from that from experimental results, energy absorption capacity has been increased by 8%,22%,36%,49% respectively with respect to M60. It is experimentally evident that for M-60+CNT+PF+CF Energy absorption capacity has been significantly enhanced to 49% in comparison with M60 grade concrete.

Toughness Index: It is can be seen from experimental result that the flexural strength increases with addition of CNT and fibers. However, the toughness of the CNT and polypropelene and carbon modified fiber reinforced prestressed concrete railway sleeper test specimens appear to have significant increase in toughmess index in comparison with other concrete mix matrices. From the results it can be seen that there is increase in toughness w.r.to M60 by 10%, 16%, 21% and 32% for M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M-60+CNT+PF+CF prestressed concrete railway sleeper specimens respectively. There is significant increase in touhness index of M-60+CNT+PF+CF when compared to other concrete matrices.

Crack Pattern: According to the criteria of IRS T-39 the prestressed concrete railway sleeper must be able to take the reference load without cracking. All the prestressed concrete railway sleeper specimens in the present investigation clearly met this criterion. Cracks in PSC railway sleeper specimens were visually observed during the static test. Observations of crack were carried out using magnifying glass. The cracks were almost fully closed and could be generally noticed only when looking at the PSC railway sleeper specimen from the side during loading. In general, the cracks in the PSC railway sleeper specimen is referred to as residual cracks since the cracks were closed in the unloaded condition due to prestress. The length of the residual crack is the main indicator for the durability and serviceability of the PSC sleeper in practice. Under the loading the behavior of the prestressed concrete railway sleeper specimens of M-60+CNT+PF, M-60+CNT+CF, M-60+CNT+PF+CF deferred from others. In these cases the prestressed concrete railway sleeper specimens with Polypropylene fibers, Carbon fibers and CNT, the first crack and the ultimate load of the PSC railway sleeper specimen have been found to improve significantly with respect to other PSC railway sleeper specimen and showed better post peak load deflection performance. The energy absorption and ductility index given by these PSC railway sleeper specimen were significantly higher than the other concrete matrices used in this investigation.

Conclusion

Based on the results of the experimental investigation the following conclusion are drawn.

Load Deflection Behaviour

- The PSC railway sleeper specimen S5(M-60+CNT+PF+CF) has improved first crack and the ultimate load with respect to other PSC railway sleeper test specimen(S1,S2,S3,S4) and showed better post peak load deflection performance.
- The CNT modified with polypropylene fiber and carbon fiber concrete S5:(M-60+CNT+PF+CF) test specimen exhibits a smooth or a flat descending portion of the curve beyond peak load. This indicates the improvement in the dimensional stability and structural integrity of a test specimen even beyond the peak load .
- All cracks were initiated at the base of the PSC railway sleeper specimen and propagated towards the compressive zone beneath the applied load. When the load reached maximum the concrete crushed and spalled.
- The first crack loads of the five mixes in the present investigations S1(M-60), S2(M-60+CNT), S3(M-60+CNT+PF), S4(M-60+CNT+CF), S5(M-60+CNT+PF+CF) is 27.96kN, 29.67kN, 33.56kN, 37.25kN, 39.89kN respectively. It is observed that from experimental results, first crack load has been increased by 6%, 17%, 25%, 30% with respect to control specimen S1(M60).
- It is experimentally evident that for the last sleeper specimen S5(M-60+CNT+PF+CF) first crack load has been significantly enhanced to 30% in comparison with S1(M60) grade concrete.

Static Test

- From the results it can be seen that there is increase in toughness w.r.to S1(M60) by 10%, 16%, 21% and 32% for From the results it can be seen that there is increase in Ductility w.r.to S1(M60) by 4%, 8%, 12% and 16% for S2(M-60+CNT), S3(M-60+CNT+PF), S4(M-60+CNT+CF), S5(M-60+CNT+PF+CF) prestressed concrete railway sleeper specimens respectively. It is observed that the Ductility Index for S5(M60+CNT+PF+CF) is higher than all other concrete matrices.
- The Yield deflection obtained for various concrete matrices S1(M-60), S2(M-60+CNT), S3(M-60+CNT+PF), S4(M-60+CNT+CF), S5(M-60+CNT+PF+CF) are 0.869, 0.93, 0.97, 1.01 and 1.151 respectively. The Ultimate deflection obtained for various concrete matrices S1(M-60), S2(M-60+CNT), S3(M-60+CNT+PF), S4(M-60+CNT+CF),S5 (M-60+CNT+PF+CF) are 9.12, 10.189, 10.981, 11.856 and 13.952 respectively. It is observed that the Yield and Ultimate Deflection for S5(M-60+CNT+PF+CF) is greater than other concrete matrices and the least is forS1(M60).
- The experimentally obtained values of Energy absorption capacity S1(M-60), S2(M-60+CNT), S3(M-60+CNT+PF), S4(M-60+CNT+CF) and S5(M-60+CNT+PF+CF) prestressed concrete railway sleeper test specimens are 852.57 kN-mm, 924.85 kN-mm, 1094.96 kN-mm, 1339.53 kN-mm and 1684.25 kN-mm respectively. It is observed from that from experimental results, energy absorption capacity has been increased by 8%,22%,36%,49% respectively with respect to S1(M60). It is experimentally evident that for S5(M-60+CNT+PF+CF) Energy absorption capacity has been significantly enhanced to 49% in comparison with S1(M60) grade concrete.
- From the results it can be seen that there is increase in toughness w.r.to M60 by 10%, 16%, 21% and 32% for S1(M-60), S2(M-60+CNT), S3(M-60+CNT+PF), S4(M-60+CNT+CF) and S5(M-60+CNT+PF+CF) prestressed concrete railway sleeper specimens respectively. There is significant increase in toughness index of S5(M-60+CNT+PF+CF) when compared to other concrete matrices.

REFERENCES

Agarwal G.C. and Agwekar, P.G.2012. "A study on high strength PSC sleepers.

Chaitra. B. R. 2007. "An experimental investigation on the design of PSC sleeper with slag cement".

Chaturvedi, S.K., Yadav, D.S. et al. 2011. "A detail investigation on PSC sleepers production and quality control",

Gonzalez-Corominas1, A., Etxeberria1, M., Ignasi Fernandez, 2012. "A comparative analysis of structural behavior of PSC sleepers made with HPC and HPRAC"

Harish. G.R. "Dynamic Behaviour of Railway PSC Sleepers using Modified SBR Latex Fibre Reinforced Concrete "PhD Thesis submitted to Bangalore University, April 2016

IRS/T-39 1985 Special grade cement for use in concrete sleepers.

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

IS: 1343 -1980 Practice for PSC .

Ramamani, R. 2007. An experimental investigation on PSC sleeper with steel filings under static behaviour.

Sakdirat Kaewunruen and Alex M. Remennikov. 2007. "Investigations of static and dynamic performance of railway PSC sleepers", SEM Annual Conference and Exposition on Experimental and Applied Mechanics., Spring_eld., Massachusetts

Shintaro Minouraa, 2017. Tsutomu Watanabea, Masamichi Sogabea, Keiichi Goto-"Analytical study to evaluate loading capacity of PSC sleepers using LS-DYNA.

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