Design and Development of Wider & Heavier PSC Sleeper and Fastening System for suitable for Semi-high speed and heavy Axle Load

*Sandeep Sharma
#Rituraj
Pranav Kumar**
S K Awasthi##

Synopsis :

Indian Railways has been contemplating to increase throughput to keep pace with increased freight traffic by allowing higher axle load on existing track. Dedicated Freight Corridors for heavy haul freight operations are under construction on Eastern and Western sectors. Dedicated freight corridor has already been planned for 25 t axle load operation at present and feeder routes from existing network are also planned to carry 25t axle load. Therefore, there is a need to upgrade & standardize the existing Track structure for 25t axle load on IR. Use of wider & heavier PSC sleeper and suitable elastic fastening system for 25t axle load is considered advantageous on numerous accounts for semi-high speed and heavy axle load both. Present paper highlights the advantages of wider & heavier sleeper and gives detail of design and lab testing of wider and heavier PSC sleeper along with its fastening components which will improve the track performance and shall be suitable for mixed traffic routes for running of semi-high speed and heavy axle load.

1. Introduction

In year 2008, RDSO had designed a 25T sleeper (Drg. RDSO/T-7008) keeping dimensional profile same as that of BG line sleeper

*Executive Director/Track-II/RDSO
**Director/Track-IV/RDSO
#Dy. Director/EF/RDSO
##Dy. Director/CS/RDSO

RDSO/T-2496. However, recently from the study of track structure being used worldwide for heavy axle load, it is learnt that various world railway use wider and heavier sleepers in comparison to Indian Railway sleepers, being advantageous in many respect for semi-high speed and heavy axle loads. Sleeper dimensions used on various world railway systems are given in following Table 1.

As per Railway Board instructions vide letter No. 2013/TK-II/22/2/2 dated 18.6.2013 and RDSO observations on this issue, design of wider & heavier sleeper was contemplated for achieving the following main advantages: viz.

i) Increased width and weight providing higher frame resistance against buckling, chances of reducing de-stressing temperature with likely reduction in rail/weld failures

ii) Increased rail seat area resulting in higher rubber pad life

iii) Reduced ballast pressure leading to reduction in ballast pulverization, deep screening cycle & enhanced drainage

Table 1 : Sleeper details in various world railway systems

S. No.	Name of Country	Gauge (mm)	Length (mm)	SECTIONAL DIMENSIONS						MAX. STATIC AXLE LOAD (KN)
				RAIL SEAT (mm)			MID SPAN (mm)			
				DEPTH	BOTTOM WIDTH	TOP WIDTH	DEPTH	BOTTOM WIDTH	TOP WIDTH	
1.	A	B	C	D	E	F	G	H	I	J
1	AUSTRALIA	1435	2500	212	250	**200**	165	250	200	245
2	CANADA	1435	2542	203	264	**216**	159	264	226	292
3	CHINA	1435	2500	203	280	**170**	165	250	155	245
4	GERMANY	1435	2600	214	300	**170**	175	250	150	221
5	GR.BRITAIN	1432	2515	203	264	**216**	165	264	230	245
6	HUNGRY	1435	2420	181	280	**204**	130	272	217	202
7	ITALY	1435	2300	171	284	**222**	150	240	190	221
8	IRAQ	1432	2515	203	264	**216**	140	264	231	245
9	JAPAN	1435	2400	220	310	**190**	195	250	180	164
10	RUSSIA	1520	2700	193	274	**177**	135	245	182	265

11	SWEDEN	1435	2500	220	294	**164**	185	230	150	222
12	S.AFRICA	1065	2057	221	245	140	197	203	140	221
13	U.S.A	1435	2591	241	279	**241**	178	279	**250**	321
14	INDIA (existing BG & 25T sleeper)	1673	2750	210	250	**150**	180	220	150	221 & 245
15	**INDIA (Wider Sleeper)**	**1673**	**2750**	**230**	**280**	**210**	**200**	**230**	**180**	**245**

From the data given in the table, it can be seen that existing IR sleepers are slender and light weight in comparison to sleepers being used in other world railways. These sleepers offer less Track frame resistance which is a important requirement for mixed traffic routes with operation of semi-high speed and heavy axle load and LWR on curves. Existing sleepers are less fit for higher impact load caused by flat wheels which results sometime to pre-mature failures of sleepers. Rubber pad is also a vulnerable components in the existing track which affects the performance of track substantially. Further, the existing design of sleeper has reached to saturation stage as it has already 20 number of HTS strands in RT-7008 design. Number of strands can not be increased further and this sleeper is difficult to upgrade for higher axle load beyond 25T.

2. Trial Design options:

2.1 Four number of design alternatives were developed initially by RDSO considering aspects of tamping and shape optimization. Design with top rail seat width of 230 mm and bottom width of 300 mm against existing 150 mm and 250 mm respectively was found most suitable with use of 12 wires as against 20 wires of 3 plyx3 mm in existing design of PSC Sleepers for 25t axle load. Railway Board approved above design for lab testing vide letter dated 11.03.2014. Trial casting & testing of sleepers was done at Concrete sleeper plant, Anwarganj, Kanpur under NE Railway. The trial sleepers were tested for static bend tests and failure load. The trial sleepers passed the specified test loads as per design in SBT tests conducted at sleeper plant, Kanpur. Although, during SBT test in RDSO,

sleepers achieved design load test but the pattern of initiation of crack was sudden in some of the sleepers. During fatigue test, it was observed that initial crack of about 15mm length which developed at cracking load at rail seat, propagated fast with crack length more than 150 mm leading to failure of sleepers in 1.5 million loading cycle as against stipulated insignificant growth of cracks upto 2million cycles.

Fatigue Testing of Wider Sleeper

2.2 Therefore, taking cautious and economical approach, the wider sleepers were redesigned with 14 no. of HTS wires and keeping dimensional profile same. The revised design wider sleepers were casted and tested at CSP Kanpur, which were also not found to be satisfactory in SBT test. In all total 2 no. design alternatives were tried with 14 nos. HTS wires with same sleeper profile of 12 no. wire design for SBT test after casting sleepers at sleeper plant, Kanpur.

2.3 The failure of above two designs necessitated revision of design now using 16 no. of HTS wires with changed sleeper profile. Sleeper with top width at rail seat as 210 mm, bottom width 280mm and depth 230 mm was decided after a number of deliberations among the design personnel. Wider sleepers with 16 wires were casted & tested for SBT tests at Sleeper plant Kanpur. This sleeper has also been tested for fatigue test at RDSO which is found successful in SBT & fatigue tests.

2.4 Overall, in course of finalizing the design of wider sleeper, total 7 design options were studied and out of them 4 designs sleepers were casted & tested for SBT test in sleeper plants and 2 design options were tested for SBT & fatigue test at RDSO.

3. Design of wider PSC sleeper for 25t axle loads :

3.1 Though the existing PSC sleeper RDSO/T-2496 is being used for 22.5 t axle load operation and existing PSC sleeper RDSO/T-7008 has been designed to be used for 25t axle load which has same dimensional profile but wider & heavier sleeper has been taken up for design for 25t axle load to take care of following aspects:

a) Total stresses at rail seat and centre section of PSC sleeper to be brought down for improved performance and life
b) Adequate factor of safety
c) Ballast pressure to be reduced for reduction in ballast pulverization & increase in period of deep screening cycle and enhanced drainage
d) The sleeper is sufficiently wide to increase rail seat area to accommodate wider rubber pad to reduce pressure on rubber pad for its longer life and satisfactory performance.
e) The rail seat assembly is designed to provide flexibility to adopt any of 136RE (68 kg/m) and UIC 60 kg rail section.
f) A heavier sleeper is required to provide more longitudinal and lateral resistance to track to counter higher thermal forces on account of heavier rails as also the higher longitudinal forces like traction and braking, exerted by heavier trains.
g) PSC sleepers being used in other world railways are generally wider in section in comparison to IR sleepers RT-2496 & RT-7008. Details of PSC sleepers in other world railways have been given at Table-1.

4.2 Considering the above factors, a new wider PSC sleeper design (RDSO/T-8527) has been developed using 16 nos., 3 plyx3mm HTS strands. In this design, the design rail seat load has been taken as

17.2 t, which is derived from the existing design practices of PSC sleepers. The comparison of salient features of the wider sleeper design vis-à-vis that of existing sleepers are as follows:

S. No.	Parameter	BG line Sleeper (22.5T)	25 T Existing Sleeper	25 T Wider Sleeper
1	RDSO Drawing No.	RT-2495 & 2496	RT-7008	RT-8527
2	Grade of Concrete	M-55	M-60	M-60
3	HTS Strands (3mm dia x 3 ply)	18 No.	20 No.	16 No.
4	Initial Prestress	70%	75%	75%
5	Prestress Loss	30%	30%	30%
6	Axle Load	22.5 T	25T	25T
7.	Weight	267 kg	267 kg	332 kg
8	Dimensions : - Length - Depth at rail seat - Depth at centre - Width at top at rail seat - Width at Rail seat bottom	 2750 mm 210 mm 180 mm 150 mm 250 mm	 2750 mm 210 mm 180 mm 150 mm 250 mm	 2750 mm 230 mm 200 mm 210 mm 280 mm

4.3 The wider sleeper design has been done using the 16 nos. 3 ply x 3mm HTS strands which are as against 18 nos. & 20 nos. in existing design of sleepers to drawing no. RT-2496 & RT-7008 respectively. Thus the nos. & weight of HTS strands have been reduced substantially in wider sleeper design. The weight of wider PSC sleeper is 332 kg and against 267 kg in existing design of RDSO/T-2496 & RDSO/T-7008 sleepers, which is almost 24% higher.

Existing 25 t & wider sleeper

4.4 The HTS strands are to be tensioned to 75% of the breaking load as against 70% in existing design of RT-2496 & 75% in RT-7008 sleeper. This will result in better use of material. However, the loss of prestress has been taken as 30% of initial prestress as in the case of existing design.

4.5 The depth of sleeper at rail seat has been increased to 230 mm to restrict the bending stresses generated from higher axle load. The depth of sleeper at center section has also been increased to 200 mm.

4.6 The top width for the sleeper has been kept as 210 mm to facilitate a larger bearing area for rubber pad to enhance its performance and longer life.

4.7 The bottom width of the sleeper has been kept as 280mm to limit the ballast pressure as well as to facilitate machine packing.

5. Discussion on important structural parameters:

The important structural parameters of the new design of wider sleeper (RT-8527) and existing sleepers (RT-2496 & RT-7008) have been tabulated below:

S.No.	**Design parameter**	**Values for RDSO/T-2496 (22.5t axle load)**	**Values for RDSO/T-7008 (25t axle load)**	**Values for RDSO/T-8527 (25t axle load)**
1.	B.M. imposed: - At rail seat bottom - At center top	 1.19 t-m -1.25 t-m	 1.32 t-m -1.38 t-m	 1.26 t-m -1.43 t-m
2.	Resultant stresses: - At rail seat bottom - At center top	 23.4 Kg/cm^2 -17.3 Kg/cm^2	 32.4 Kg/cm^2 -7.6 Kg/cm^2	 13.7 Kg/cm^2 -15.7 Kg/cm^2
3.	Resisting Moment: - At rail seat bottom - At center top	 2.41 t-m 1.58 t-m	 2.72 t-m 1.83 t-m	 2.83 t-m 1.95 t-m
4.	Factor of safety: - At rail seat bottom - At centre top	 2.02 1.27	 2.06 1.32	 2.24 1.36
5.	Failure moment - At railseat bottom	 4.66 t-m	 5.06 t-m	 5.59 t-m
6.	Load factor	3.92	3.82	4.42

7.	SBT Loads - Cracking load at Centre top - Cracking load at rail seat bottom - Failure Load at rail seat bottom	60 KN 230 KN 370 KN	65 KN 270 KN 490 KN	68 KN 280 KN 535 KN

5.1 It can be seen that the resultant stresses at rail seat bottom are 13.70 kg/cm^2, which are lower than the value of 32.4 kg/cm^2, in existing design of RT-7008 sleeper. These stresses can be considered as quite safe. However the resultant stresses at centre top are –15.7 kg/cm^2 which is of the same order as in existing design i.e. – 17.29 kg/cm^2 for RT-2496 sleeper and within permissible limit.

5.2 The factor of safety values at rail seat is 2.24 in the new design which is more than the value in existing designs of 2.02/2.06. The factor of safety values at center are 1.36 in the new design which is more than the value of 1.27/1.32 in existing designs. The load factor values is 4.42 in new designs as against the value of 3.92/3.82 in existing designs and is considerably higher.

5.3 This design of wider sleeper is futuristic design with 16 numbers of HTS strands which can be further increased for axle loads more than 25T say upto 35-40T without changing the sleeper profile as changing of sleeper profile frequently, poses manufacturing related problems viz. change of moulds, change in casting machine in long line method etc. thereby increasing the cost of sleeper.

6. Trial casting and laboratory testing:

The trial casting of wider PSC sleepers for the purpose of laboratory investigation i.e. Static Bend Tests and Fatigue tests was done at Concrete sleeper plant, Anwarganj, Kanpur under N E Railway. All the sleepers have passed static bend tests (Rail seat bottom, centre top, centre bottom) successfully. Three nos. of sleepers were subjected to fatigue tests in Track Machine Lab, RDSO. All the sleepers have withstood fatigue test load successfully for specified 2

million cycles. Trial scheme / monitoring proforma along with drawing of wider sleeper have been sent to nominated zonal railways vide RDSO letter dated 24.10.2016.

7. Design of rail seat assembly for wider sleeper:

Rail seat assembly for the wider sleeper has been designed. Rail seat Assembly for wider PSC sleeper shall be as per Drg. No. RDSO/T-8529. In this rail seat assembly, fastening Components are as under:

a) ERC MK III/V	RT-3701/5919
b) GFN 66 Liner	RT-6938 & 6939 (with 60kg UIC Rail) & RT- 6937 (with 136 RE Rail)
c) 10 mm thick CGRSP	RT-8528 (wider rubber pad)

ERC Mk-III & ERC Mk-V are existing components used on IR & shall be procured from RDSO approved sources.

10 mm thick wider CGRSP (RT-8528) for use with wider PSC sleeper has been newly designed. This rubber pad shall be procured from the shortlisted firms of 10mm thick CGRSP (RT-7010). The rubber pad width has been increased from existing 125 mm to 185 mm thereby increase in rubber pad area by 48%.

GFN 66 liners are also existing component for 25t axle load sleeper (RT-7008) & shall be procured from existing RDSO approved sources for any drawing of GFN-66 liners.

8. Field Trial Status:

8.1 A detailed report on design of wider & heavier sleeper for 25t axle load along with its rail seat assembly had been prepared and sent to Railway Board along with drawings vide RDSO letter dated 21.01.2016 for approving field trial and to nominate zonal railways for the conducting the field trial.

8.2 Railway Board vide letter dated 06.10.2016 has approved the field trial of this wider and heavier PSC sleeper (RT-8527) along with its fastening components in 5 zonal railways e.g. ECoR, SECR, SER, WCR, NCR. The Railway Board has instructed to conduct trial in a

stretch of 15 km length and the trial stretch should be suitably indentified by CTE's and should generally be on busy routes identified for 25T operation and should also cover curves & gradient to the extent possible.

9. Road ahead for development of new fastening components for wider sleeper:

9.1 Wider PSC sleeper (RT-8527) has been designed by RDSO using the same elastic fastening components as being used for normal PSC sleeper. The existing elastic fastening components are ERC Mk-III/V, GFN-66 insulating liner & 10mm thick composite grooved rubber sole plate.

9.2 The existing elastic rail clip ERC Mk-V is a clip having 23mm dia. (Grade 55Si7 silico-manganese spring steel rounds). With a view to enable its use on existing PSC sleeper earlier, its leg was machined and diameter was reduced to suit the existing insert. The reduction in diameter was achieved through precise profiling, which requires special care during manufacturing. Insulating liners and rail pads of same raw material were suitably modified to suit the wider sleeper.

9.3 With the introduction of wider sleeper, indigenous elastic fastening system having better features with enhanced service life has been conceived in order to further strengthen the fastening system for wider sleeper. For this purpose, following improvements in the three fastening components have been considered:

a) A new elastic rail clip of uniform 23mm dia. (Grade 55Si7 silico-manganese spring steel rounds) has been developed. Although this new clip will necessitate a new type of insert but this new ERC will have no machining in its leg. The new elastic rail clip having uniform diameter of 23mm will avoid extra machining, provide ease in manufacturing and full utilization of material.

b) Use of high viscous nylon liners being used worldwide has been thought of. The material high viscous nylon has been proposed in place of glass filled nylon for its better elongation and hence better

impact properties. Heat stabilized grades provide excellent long term heat ageing and property retention. Cost saving is expected on account of no breakage, increased life of operation, reduced down time and manpower requirement along with the advantage of heat stabilized raw material and differentiated color for identification.

c) Use of high performance pads has been thought of. The pads have been so designed that they are self locating on the sleeper and tend to attenuate the dynamic stress from axle loads and wheel impact from train movements. These pads shall provide high resilience with an increased life expectancy.

9.4 Status of development of new Fastening Components for wider sleeper :

a) ERC of uniform 23mm dia.:

Prototype of new design of elastic rail clip has been got manufactured from willing vendors of ERC. Necessary testing of the new ERC was conducted in RDSO laboratory and the required modifications were done in two prototype trials. The desired properties of the new design of ERC could be achieved after three trials. Thus work of development of new ERC of uniform diameter has been completed.

b) High Viscous Liners:

Generic specifications for high viscous nylon liners have been prepared in association with M&C Directorate/RDSO and Request for Proposal shall be floated after Railway Board's approval.

c) High Performance Pads:

The qualifying specifications and criteria of High Performance Pads drawn are performance based. In the specification of 'High Performance Rail Pad', the raw material of the Rail pad is Natural Rubber. Few reputed sources of various raw materials required for manufacturing such rail pads by the vendors have been incorporated in the raw material clause of the specification itself

along with specifying certain qualifying parameters for Rail pads made of raw material other than natural rubber also i.e. TPE, TPU, PU, EVA, HDPE etc. being used worldwide. Generic specifications of these pads have been prepared in association with M&C Directorate/RDSO and Request for Proposal shall be floated after Railway Board's approval.

d) SGCI Insert:

A new type of insert to accommodate this new clip has been developed. Drawing of the insert has been prepared and its prototype also has been casted for manufacturing based on the new design of ERC.

10. Conclusions:

10.1 The new sleeper has successfully passed the laboratory investigations. After satisfactory field trial, the sleeper can be finalized for regular adoption for 25t axle load on IR & DFCCIL tracks. This sleeper design is futuristic design which is upgradable to even higher axle load upto 35T without changing the sleeper profile and by increasing number of strands.

10.2 This PSC sleeper has been designed using the existing design practices for the existing PSC sleepers for 22.5t/25t axle load. The weight of the new wider PSC sleeper is 332kg and against 267 kg in existing design, which is almost 24% higher and 40% wider rail seat. The structural parameters viz., resultant stresses, factor of safety and load factor are quite better than the existing design. Rubber pad area also increased by 48% which will reduce stresses on rubber pad substantially and increase its life.

10.3 Field trial of new design of wider sleepers (RDSO/T-8527) along with its fastening components is being carried out to judge the performance under field conditions. This sleeper is expected to improve the track performance considerably due to more track frame resistance and increased life of rubber pads. This sleeper will

be more suitable for tracks with mixed traffic routes of semi-high speed and heavy axle loads.

References:

(1) IRS Specification of PSC Sleeper for BG & MG (IRS T-39, 5th rev. 2016)

(2) UIC Code 713-2004, Design of Monoblock Concrete Sleepers

(3) AS 1085.14—2003 – Australian Standards for Prestressed Concrete Sleepers