



## Semi High-speed Trains on Indian Railways Network : Track and Vehicle side demand

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### Abstract

*The introduction of semi high speed trains into existing Indian rail infrastructure, poses several challenges. High speed train demands stable track structure and track maintenance within tight tolerances whereas heavy axle load sharing the same track, causes faster deterioration of track geometry. Rail-wheel interaction at semi high speed generates additional vibrations due to short-wave defects, which needs to be dampened both by vehicle bogie and track components. Towards vehicle side, at semi high speed, train-induced vibration (due to instability of the vehicle system or resonance) causes ride instability. Long wave defects (25-70 m) get activated and further causes passenger discomfort.*

*Rail/weld grinding eliminates the short wave defects. Use of soft, thick and resilient rubber-pad and more resilient elastic fastenings ensures more stable track geometry subjected to high vibrations caused by speeding trains / heavy axle loads. Track irregularities of medium and long wave lengths are maintained by using advance track tamping m/c with spatial curve measurement system and track tamping with respect to absolute co-ordinate system. On vehicle side, choice of proper primary and secondary suspension is fundamental for ensuring ride comfort. The secondary lateral damping and primary longitudinal*

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*stiffness are the two most sensitive parameters impacting the critical speed compared to the other bogie parameters of the train. Air-suspension with yaw dampers improves secondary suspension system. Track friendly cars with soft wheel set guidance are also required over a speed of 140 kmph.*

## **1. Introduction:**

### **A case of Tokaido Shinkansen**

- 1.1 The Tokaido Shinkansen railway was constructed in 1964 at a design speed of 210 km/h. The maximum speed of the railway was increased, step by step. It was increased to 220 km in 1985 and further to 270 km/h in 1992. Trains are now running at this speed. The series of speedups were achieved by improving electric facilities and rolling stock without changing the radius of curve, which is one of the fundamental features of track. The maximum allowable speed is 255 km/h for example, for a track having such dimensions as: radius of curve 2,500 m, actual cant 200 mm and cant deficiency 110 mm. In raising train speed further, the air spring type car body tilting system are used.
- 1.2 From the above case, it is obvious that the introduction of semi high speed trains in Indian rail network does necessitates introduction of semi-high speed coaches on reasonably good existing track structure. For a mixed operation of semi high speed train with heavy load freight operation, coaches must be designed as track friendly, so as to cause minimum track deformation. Track design, track components and track maintenance practices, also require improvements in order to cater for safe mixed operation with optimal efforts and expenditure.
- 1.3 The high speeding train generates vibrating forces at rail-wheel contact level, much different than what is generated at lower speed. The response of track structure also differs due to increased loading frequency and it behaves absolutely different at critical velocity of moving loads. At high speed, short wave defects generate high



frequency vibrations which are detrimental for derailment forces. Long wave defects cause low frequency vibrations which are related with passenger discomfort. Track components also require suitable enhancement to cater to the larger deflections due to semi high speed trains.

- 1.4 Track parameters like cant excess, cant deficiency, gradient etc are to be judiciously chosen, to ensure safety and minimize the rate of track deterioration. Track fasteners play an important role in ensuring dynamic track stability. Comparatively less stiff rubber pad do not transmits much high frequency vibrations down to sleepers and beneath and ensures stable track structure. High resilient elastic fasteners ensure monolithic track structure during defected track geometry under load.
- 1.5 From vehicle side, acceleration of wheelset, bogie and car body are to be ensured as per UIC 518. Substantial improvements in bogies like air suspension in secondary suspension system with yaw damping, optimal wheel set guiding stiffness for smooth steering of car body at curves etc are required. For coaches, ride index and equivalent conicity at semi high speed are to be ensured. Track friendliness of coaches is an important design concept. The target of track friendly vehicle is to minimize track and bogie deterioration and ensure smooth running even at some what deteriorated track geometry.
- 1.6 Thus, the objective of this paper is to sum up the suitable improvements in track design / track components, special requirement for semi high speed coaches and also to outline suitable maintenance practices for mixed traffic operation with semi high speed trains and heavily loaded freight. IRCON's successful experience in designing and maintaining semi high speed track on a meter-gauge track (SGEDT Project) along with freight operation at Malaysia has also been referred here.

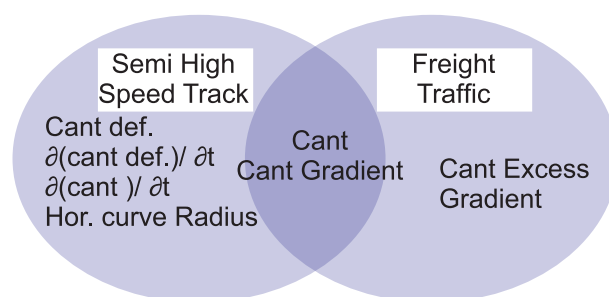


## 2. Track parameters / features for mixed operation

2.1 Running of high speed trains and goods train on shared rail network is not advisable because of capacity constraints and safety. However, High speed track can be design to permit other passenger train operation at faster speed (say >120 kmph). For example, India's high speed corridor between Mumbai-Gandhinagar can be designed for High speed trains (< 350 kmph) and other fast passenger trains. Semi high speed tracks can be designed to allow goods train operation.

2.2 Design of track, catering to mixed traffic of Semi high speed trains and Goods train, requires consideration of track parameters from both passenger and goods operation side. Cant has to be judiciously provided, considering passenger comfort, safety (overturning, wheel climbing), maintainability and cant excess for goods. For a mixed traffic of high speed trains and passenger trains, cant excess is determined from goods train consideration. Vertical curves have both ascent and descent. For heavy goods traffic, hauling (power supply) will be affected by ascent whereas, for semi high speed trains, breaking distance will be increased in descent part of vertical curves. Following diagram depicts deciding factors for track parameters, for mixed operation of semi high speed trains and goods trains.

2.3 Many freight trains in Japan use the same track as passenger lines but the axle load of freight ranges from 10 to 15 tons only. Even the goods train runs at comparatively faster speed. In Australia, heavier goods train share passenger tracks (fastest train = 140 kmph), but that on standard gauge. Only Victoria provinces in Australia, has about 3000 km of broad gauge track.







- 2.4 Indian Railway permanent way manual has classified track parameters for class A route where train speed is <160 kmph. The track structure catering to heavy goods train, has not much difference in track parameters for speed upto 160 kmph (class A) and speed upto 130 kmph (class B) route except for the minimum radius for vertical curves. For trains beyond 130 kmph speed, minimum vertical radius is 4000 m whereas for speed <130 kmph, the minimum radius requirement is 3000 m.
- 2.5 For mixed operation, practices in Europe and Japan have been reviewed. Common European Standard (CEN) and Technical Specification for Interoperability (TSI), highlights track parameters to be adapted for mixed operation of passenger and goods services. These standards are for standard gauge track. However, parallels can be drawn for Indian case i.e on broad gauge track. Following parameters specifies Indian track structure for 160 kmph track compared with CEN practices, for mixed traffic operation.

	<b>Common European Standard (CEN)</b> - <i>Mixed traffic</i> - <i>Train speed &lt;230 kmph</i> - <i>Standard gauge</i>	<b>Indian Railways</b> - <i>Mixed Traffic</i> - <i>Train speed &lt;160 kmph</i> - <i>Broad Gauge</i>
<b>Cant, Ca</b>	160 mm	165 mm
<b>Cd</b>	140 mm	100 mm
<b>Ce</b>	110 mm	75 mm
<b><math>\partial(\text{cant}) / \partial t</math> &amp; <math>\partial(\text{cant def.}) / \partial t</math></b>	30-45 mm / sec	35 mm / sec 55 mm / sec (max)
<b>Cant gradient</b>		1 in 720
<b>Gradient</b>	10 o/oo (Sweden) 12.5 o/oo (Germany)	10 o/oo
<b>Radius (min) H-Curve</b>		
<b>Radius (min) V-Curve</b>		4000 m



## 2.6 Track behavior under high speed train

At semi high speed trains, low frequency steady state vibrations and high frequency impact loads are generated. High frequency vibrations cause short wave defects affecting rail-wheel contact surface, wheels and bogie; thus related with safety against derailment. Low frequency vibrations are generally not cut off by primary suspension systems (i.e at bogie level) and hence it affects the sprung mass and causes passenger discomfort. Also, along the rail, the stiffness of track structure changes because rails are supported by sleepers separated by a distance of 600 mm. The stiffness is higher when the wheel passes over the concrete sleeper. These vibrations induced by the sleeper distance have a frequency  $f$  given by the equation  $f = V/D$  where  $V$  is train speed and  $D$  is the distance between two sleepers.

## 2.7 Short Wave Defects:

Short wave defects are surface irregularities, corrugations, poor weld geometry etc. The wave length of defects is within 0-25 m and corresponding frequency is 5-120 Hz. They are related with Rail - Wheel interaction and managed at bogie level as it affects derailment forces. Short wave defects at rail-wheel interaction level can be eliminated by high speed on-track rail grinding (for rail) and through wheel scanning and profiling (for wheels).

## 2.8 Long Wave Defects:

They are caused due to ballast/formation settlement. It is related with Vehicle - Track interaction. Any forcing frequency generated at rail-wheel interaction, within the range of 0.5-10 Hz, is considered critical for the rolling stocks. Consider train @ 160 kmph; for  $\lambda = 0.5$ , is 89m. Thus, for train speed of 160 kmph, all surface defects up to 90 m must be eliminated. The chord measuring system in track m/c with chord length of 7.2 m and 9.6 m for measurement of top surface and alignment respectively are grossly inadequate in assessing the long wave track defects. For long wavelengths, Track

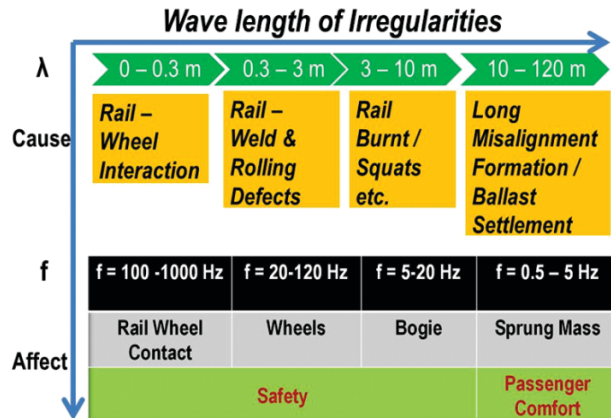


recording car that measure spatial curve based upon inertial principle of measurements (for example EM 250) should be used. Long wave defects can also be eliminated by using Absolute track geometry system (ex. EM-SAT / EM-SAT + GPS etc).

## 2.9 Exciting frequencies

between 5-120 Hz (0-10 m wave length) are associated with unsprung mass and very detrimental for Y/Q forces. Axle box acceleration represents these forces. Strong correlation between vertical forces (Q) and peak/individual vertical

track defects (especially in 3-10 m wavelength defects) are also observed. As such wave length band 0-25 represents Y/Q forces (axle / bogie acceleration), 25-70 m wave length represents car body acceleration at semi high speed and 70-150 m represents the same at high speed.



Wave length defects ->	0-25 m	25-70 m	70-150 m
Speed ↓	(Y/Q forces)	(Comfort: Semi HSR)	(Comfort: HSR)
< 160 kmph	√		
160 – 230 kmph	√	√	
>230 kmph	√	√	√

Relation between vehicle speed and excitation frequency for given short wave length defects (m) [5-120 Hz] are given below.

	40 km/h	80 km/h	160 km/h	300 km/h
4 Hz	2.8	5.6	11	21
8 Hz	1.4	2.8	5.6	10
16 Hz	0.69	1.4	2.8	5.2
31.5 Hz	0.35	0.70	1.4	2.6
63 Hz	0.18	0.35	0.71	1.3
125 Hz	0.089	0.18	0.36	0.67



## 2.10 The Rubber pads and Fastening

From dynamics response point of view, the stiffness of rubber pad plays an important role. If the rubber pad is less stiff, then under the given wheel load, there will be comparatively larger deflection in rail but it will isolate the high frequency vibration, from getting transmitted to sleeper, ballast and formation / structure. Stiffer rubber pad on the other hand, will cause lesser deflection (more acceleration on sleeper mass) and will not isolate much, the higher frequencies caused due to rail – wheel interactions. Thus less stiff but thick (10 mm) rubber pads are better suited for mixed traffic under semi high speed trains and heavy freight trains. With larger cross sectional area of rail and softer rubber pad, the difference in track stiffness at sleepers and between them is also minimized.

- 2.11 The rail fasteners are normally elastic and it's stiffness is much less than the rubber pad. The flexibility of fastening ensures rail-sleeper contacts (minimum toe load), even deflected track structure under moving load. Therefore, use of less stiff R/pad and more elastic resilient fastenings will ensure more stable track behaviour for semi-high speed track. Heavier concrete sleeper decrease vertical movement of track structure under high speeding train, where inertia driven deflections are prominent. Beyond critical speed, the inertia driven displacements are even in upward direction. Padded sleepers (Rubber pad under sleepers) help increase sleeper-ballast contact area and thus better load distribution and better track stability. Therefore padded and heavier sleepers can be resorted to, for new track construction intended for both semi high speed trains and heavy freight traffic.

## 2.12 Turnout & Bridges

Canted T/O, with weldable SRJ and crossings are required to be provided throughout for high speed trains. However, as per TSI for High speed rail and Conventional rail, laying of rails without inclination is permitted through the switches and crossings, for speed < 200 kmph (G 6.1.9 of GI/GN7608). High speed T/O's (fully



canted and fully weldable, Thick web switches, Head hardened rails and explosively pre-heated crossing body) are desirable, and wherever feasible, exiting T/O assembly should be relaced by high speed T/O. Swing nose crossings are however required only for speed over 250-280 kmph.

- 2.13 The dynamic resonant effect is more prevalent for speed more than 200 or 220 km/h and for axle distance between 13 to 20 m. As per Euro codes EN1991-2 (2003), EN1990-A1 (2005) and the Spanish code IAPF (2007), dynamic analysis is mandatory for speed > 200 kmph. Therefore, no detailed dynamic analysis is required for existing bridges on Indian Railway networks for running semi high speed trains. However for old bridges, the overall health of existing bridges must be checked before introducing semi high speed trains. Study shows that simply supported bridges will have more augmented dynamic response at higher speed than continuous bridges.

### 3. Semi High Speed Rail: System Requirements

#### 3.1 OLE Requirements

Train speed and powering energy: The powering energy E to run a train is proportional to the train weight (mass) m and the square of speed V as given by the equation

$$E = mV^2$$

Where, E: Powering energy

m: Train weight (mass)

V: Train speed

When train speed is raised from 130 to 160 km/h with the train weight unchanged for example, the powering energy approximately 1.5 times is required, which requires strengthening of substations. The maximum starting current is larger for high-speed trains than with ordinary trains. Heavy-weight trains also consume much power. To raise train speed, wire tension is also required to be increased.



- 3.2 Semi high speed trains require huge amount of energy, provided through the national grid and use only single phase compared to the three-phase power of the grid. The technology that makes power exchange between grid and rail system possible is power conversion. A traction transformer fitted onboard, transfer's electrical energy from the catenaries to the motor by reducing the network's high voltage to low voltage. The traction converter is the intelligent link between the power supplies from the catenaries to the traction motors that power the vehicle. It provides the exact voltage wave patterns for the traction motors to control their speed and torque and the energy flow to the wheels. It also dynamically balances non-symmetrical loads, mitigates voltage fluctuations and eliminates harmonics (currents whose frequency is a multiple of 50 hertz, e.g. 250 hertz).
- 3.3 On SGEDT Project, some older version Malaysian Railway's locomotives were generating and feeding this kind of harmonics back into overhead lines. This resulted in voltage wave-shape distortion and had a number of undesirable effects. For compatibility purposes, harmonic dampers were installed to smoothen interferences in the OLE supply patterns that were principally caused by train with un-compatible locomotive.
- 3.4 The OLE and traction substations are designed as a low maintenance, high performance system. For semi high speed rail/ high speed rail, track recording cars housed with a pantograph is used to detect faults in overhead wires and record data such as contact force, contact resistance, height, stagger and wear of the contact wire.

### 3.5 S&T Requirements

A Transmission Based Train Control (TBTC) system is used for High speed railway (HSR) system. TBTC is a generic term for the combination of technologies required to provide a high integrity system of train protection and control that is free of trackside





signals. European Train Control System (ETCS) levels 2 and 3 are two examples of TBTC.

- 3.6 Ircon has provided ETCS Level 1 signalling adopting ATP along with the wayside signalling in SGEDT project. It is a philosophy that safety is guaranteed at the maximum speed of 160 km/h or less, when wayside signals and an automatic train protection (ATP) system with a speed pattern checking function are used (ETCS level 1). However, this method is not affirmatively effective for speeds over 160 km/h. ETCS level 2 is required for speed over 160 kmph. Cab signalling is required for speed over 230 kmph.
- 3.7 In ETCS Level 1, trains are equipped with ETCS on-board equipment and track side equipments as Eurobalises (Transponders). Eurobalises are for spot transmission of variable information from track to train. It determines the movement authorities (MAs) according to the underlying signaling system, and transmit MAs and track description data to the train. The on-board track equipment receives MA and track description related to the transmitting balise, does continuous speed monitoring, provide sort of cab signalling to the driver and take action incase the driver fails to comply signal aspects/ speed restrictions etc.

#### **4. Vehicle side demand for semi high speed train**

- 4.1 Track friendliness of vehicles is an important consideration in vehicle-track interaction. Firstly, track friendliness means that the vehicle produces low or moderate forces on the track and/or produces low abrasive wear or rolling contact fatigue on the track. Secondly, track friendliness sometimes also means that the vehicle is able to run on non-perfect track, i.e. with considerable geometrical irregularities, with favourable response regarding forces on track as well as ride quality. This aspect is important in order to avoid excessive maintenance cost at higher speeds. In the future, the marginal cost for track deterioration is being proposed to be included in the track access charges on a number of European rail networks. Track friendliness depends on different vehicle



properties and features, such as low axle load and un-sprung mass, ability of the wheel sets to steer radially in curves, low centre of gravity and others. Track friendliness also means lesser maintenance of bogie and coach itself. For this, bogies are designed to have less moving parts, and the items which are subjected to wear and tear should have longer work life (say 10 lakh km).

- 4.2 Low Axle load, low cg, shorter wheel base and stiff car body configuration are basic requirements for high speed coaches. At semi high speed, apart from Y/Q forces at rail-wheel contact and lateral & vertical vehicle body acceleration, dynamic stability of car body on straight & curve tracks, also needs to be ensured.
- 4.3 Various simulation studies conducted in past conclude that, 99.85 percentile value of Y/Q forces over a 2 meter track interval (modified Nadal criterion as per UIC 815, denoted as  $(Y/Q)_{2m/0.9985}$ ), increases with increase of ride velocity but do not exceed the limiting value of 0.8 upto 200kmph speed. However, lateral track irregularities are of greater significance for increase in Y/Q forces at higher speeds.
- 4.4 For Ride comfort, lateral and vertical acceleration of vehicle's center of gravity is assessed. The vertical stiffness of primary suspension system and damping of secondary suspension system have significant effect in lateral acceleration where as the stiffness of secondary suspension system has significant effect on vertical acceleration of car body. The ride comforts are evaluated as per UIC 513 R and ISO 10056. The vehicle body acceleration in lateral and longitudinal directions are to be limited within  $2.5 \text{ m/sec}^2$ . The maximum value for acceptable ride index is also reduced to 2.5 (lateral) / 2.75 (vertical) at 160 kmph, compared to a value of 3.0 for speed upto 130 kmph.
- 4.5 For dynamic stability at higher speed, stiffer wheel set guidance are required to avoid hunting motion. However, with stiff wheel set guidance the risk of increased wear of rail and wheels on tight curves is prominent. Generally, the wheel set vibrations are to be



restricted at bogie level itself and certain amount of wheel set guidance is necessary to curve hunting. But above a certain amount of guiding stiffness, further increase in stiffness has minimal effect in terms of hunting stability. Soft wheel set guidance allows better radial self steering. Longitudinal flexibility of wheel set is also essential for better radial self steering. Therefore, a bogie with relatively soft wheel set guidance in combination with appropriate yaw damping is required for better dynamic stability of car body. For speed >200kmph, stiff bogie with yaw dampeners are usually needed.

- 4.6 At high speed, equivalent conicity is an important parameter and it gives an appropriate measure of overall dynamic stability of the car body. UIC 518 stipulates the maximum value of equivalent conicity as 0.4 for speed over 140 kmph and upto 200 kmph, whereas this value is 0.5 for coaches designed to run at a speed upto 140 kmph and below. The UIC 518 specifications are for standard gauge and equivalent conicity are calculated with actual wheel profile and actual rail profile of test track with lateral wheel set movements being at  $y = \pm 3\text{mm}$ . The same limiting value of  $y = \pm 3\text{mm}$  must be considered for broad gauge also. Therefore the suspension and damping parameters of coaches are to be enhanced for ensuring maximum equivalent conicity of 0.4. The secondary suspension system is improved by air spring suspension / nested flexi coil spring with rubber and also by providing yaw, lateral and vertical dampers. The primary suspension system may be providing with control arms for better curve negotiation. The transverse bogie accelerations are to be constrained below  $4 \text{ m/sec}^2$ . The maximum transverse car body accelerations are to be contained below  $1.5 \text{ m/sec}^2$ . The standard deviation for car body acceleration must be below  $0.2 \text{ m/sec}^2$ .
- 4.7 At higher speeds, micro processor based axle mounted disk breaking system is used. It reduces the wheel tread wear also. For heavy freight operation, wheel profiling can minimize derailment



forces. For better wheel profile, uses of on line wheel-scanners or at least wheel scanners at maintenance depot are essential. An improved design with optimal un-sprung mass of freight bogie will also help reducing the track deterioration.

### **5.1 Maintenance of Semi high speed track shared with freight traffic and IRCON experience of maintaining 'Semi high speed track' Project at Malaysia**

France, Italy, Spain, Belgium and Korea has fully ballasted track for High speed trains. They have maintenance depot at an average of 50-70 km distance. Maintenance approaches include time based and condition based maintenance, and broadly speaking, all of these countries implement both approaches. France, however, currently uses time based maintenance but plans to use a condition based approach in future. Many freight trains in Japan use the same tracks as passenger lines. The axle load of freight ranges from 10 to 15 tons whereas the axle load of passenger cars is 11.4 tons. Due to noise and vibration issues, night time maintenance is performed daily after the passenger operation is closed and a confirmation car runs before the first train of next day. The confirmation car has a lighting device and CCTV to identify the obstacles and it is operated at 70km/h to 110km/h. The trend in Semi/high speed rail systems is towards remote track monitoring which relies on data collected via well-developed diagnostic systems, suitably analysed, and used to inform long term maintenance strategy.

- 5.2 The track tolerances for regular/planned maintenance at high speed; along with individual peak value - standard deviations are also calculated to judge the overall dynamic stability of running vehicle. The standard deviations are calculated for three wave length ranges; 0-25 m, 25-70 m and 70-150 m (longitudinal level) / 70-200m (alignment). EN 13848-5:2008 specifies track tolerances limits for different train speeds. The maintenance tolerances for semi high speed track as per EN 13848-5:2008, Annexure B is given below.



	Alignment		Vertical		Twist ( 3 m base)
	Individual peak	St. dev (200m); 0-25 m	Individual peak	St. dev (200m); 0-25 m	
130-160 kmph	6 – 9 mm	1.0 - 1.3 mm	8 – 15 mm	1.4 - 2.4 mm	4 mm / m
160-230 kmph	5 – 8 mm	0.8 - 1.1 mm	7 – 12 mm	1.2 - 1.9 mm	

### 5.3 IRCON experience in Design & Maintenance of Semi High speed track on Metre gauge

Ircon commissioned the “Design, Construction, Completion, Testing, Commissioning and Maintenance of Electrified Double track project between Seremban to Gemas(98 Tr-Km), Malaysia in July'2013 and also completed the two year maintenance period in July'2015. This is a meter gauge track with maximum design speed of 160 kmph and maximum operating speed of 140 kmph. The goods trains are running at 90 kmph. Following are salient track features

- Maximum Cant:100 mm
- Maximum Cant Deficiency:70 mm
- Maximum cant Excess:65 mm
- Ruling gradient:1%, Min Change of Gradient for VC:0.4%
- Axel Load: Freight- 20 tonnes, Passenger- 15 tonnes

5.4 The track structure comprises of UIC 54 kg Rail with prestressed monoblock concrete sleepers and Pandrol Fastclip fastenings (Elastic, resilient and Anti-vandal type). This is a continuous Welded Rail (CWR) passing through bridges, curves, points and crossing and stations. High speed Turnouts have been provided which are fully canted (1:20) and fully weldable with thick web switches and explosively depth hardened manganese crossing.

5.5 The equivalent cant has been provided as 100 mm (max), based upon the equivalent speed calculated as per UIC formula. The number of trains was decided based on the maximum projected



traffic at the peak of track utilisation.

$$\text{Equivalent speed} = \frac{\sqrt{F1 N1 S1^2 + F2 N2 S2^2 + F3 N3 S3^2}}{\sqrt{(F1 N1 + F2 N2 + F3 N3)}}$$

Where

F1 = 3, F2 = 2, F3 = 1 (Factors)

N1, N2 & N3 = No. of High speed trains, Passenger trains and Goods train

S1, S2 & S3 = 180 kmph, 120 kmph & 90 kmph speed respectively

## 5.6 Challenges in running Semi high speed trains on meter gauge

Trains running with same inclination on curved track, with similar radius of curve, will have same speed on both broad gauge and meter gauge track. However, Swedish experiment on standard gauge track shows that at high speed, the lateral track shift forces, root mean square over 100 m, against mean track gauge over 100 m, shows a significant increase in lateral forces i.e a very strong correlation, if mean track gauge is less than 1434 mm (G-1mm). As per IRPWM para 403(1), the gauge tightness is limited to -2 mm for meter gauge straight track (& curve with R > 290 m), where as it is -5 mm for broad gauge straight track (& curve with R > 350 m).

- 5.7 For higher speed, mean track gauge over 100 m is a more reasonable way to control the equivalent conicity and indirectly the stability. The wheel diameter also influences the impact of dynamic forces acting on the axlebox bearings, especially by applying smaller wheels. Therefore, stricter gauge tolerances (tight gauge) and also stricter alignment tolerances (as it has similar effect on equivalent conicity as that of tight gauge) are required for meter gauge track, as against the broad gauge track, for the same speed.
- 5.8 The European Standard EN13843-5 only applies to high speed track and conventional plane track of standard gauge or other wide gauge like 1524mm, 1668mm etc. For the meter gauge track, tolerances and especially gauge and alignment tolerances are more stringent, almost comparable to those which are applied for standard/ broad gauge for speed 230-300 kmph. SGEDT track tolerances (160 kmph on meter gauge) are also similar to what are prescribed for 230-300kmph track on standard/broad gauge.





	<b>Standard Gauge/ Broad Gauge (as per EN 13848-5)</b>	<b>Meter Gauge (as per SON, SGEDT Project)</b>
<b>Speed</b>	230-300 kmph	160 kmph
<b>Gauge (tight)</b>	-3 mm	-2 mm
<b>Alignment</b>	4-7 mm	6 mm
<b>Vertical profile</b>	6-10 mm	10 mm
<b>Twist</b>	3 mm/m	2 mm/m

### 5.9 Following design features and maintenance practices helped Ircon immensely, in efficiently maintaining the semi-high speed track along with freight operation

#### a) **High initial quality of track laying, Dynamic Track stabilization and Rail grinding**

Tracks were laid in a fully mechanised way with tight construction tolerances, as per EM-120 specification for semi high speed track. Rail/weld grinding was performed to ensure desired straightness as per UIC specifications. Long welded rails continuing through points & crossings have been provided all through the stations. AT welding were only allowed for distressing joints and at T/O assemblies at SRJ, intermediate portion and at back-leg of crossings.

#### b) **Fully weldable, fully Canted T/O assembly**

The T/O's are canted as 1:20 like normal tracks with Thick web switches. Self lubrication type bearing plates have been provided to reduce regular maintenance. Head hardened rails have been used in T/O assembly to reduce wear and tear. Even the Glued joints are of head hardened Rail and with inclined joints

#### c) **Efficient Track Fastenings and heavy sleepers**

Thick (10 mm), ultraviolet stabilised and less stiff Rubber pad (stiffness = 40-100Kn/mm), Elastic resilient Pandrol fastclips (suitable for high speed as well as heavy haul freight tracks) and heavier track sleepers (223 kg, 2 m long) were used to ensure better dynamic track stability under high speeding trains and lesser rate of track deterioration.



**d) Fully fenced track with NO level crossing**

The track is fully fenced and to avoid level crossings at less TVU locations, Pedestrian bridges /Motor cycle Pedestrian bridges have been provided.

**e) Throughout track side drain;**

Extremely efficient track side drainage system with detention ponds on upstream of bridges to buffer flash floods, slope drains and toe drains at formation etc have been provided, along the entire track length. A simulation of flow through full network of open channel was conducted by HACRAS (Hydrology analysis centres through river analysis software) and water profile, sediment transport etc were generated for proper drainage design.

**f) Advance Mechanised Track Maintenance**

Dedicated track M/c's with spatial curve measuring system and fitted with Automatic Lining Control (ALC unit), were utilised for track construction and maintenance. ALC unit not only helped removing long wave defects but also, during maintenance measuring run records could be imported to office computer/laptop for analysis and planning maintenance activities. For T/O monitoring, a hand held electronic T/O Diagnostic System was used.

**g) Track tamping with Absolute Co-ordinate System**

If the track tamping operation for levelling and lining is always carried out on a relative reference base (smoothing mode), a shift of the track coordinates occurs and the dynamic forces on the track increases, for high speed trains. In fact in smoothing mode of tamping, shorter wave defects may get converted into long wave defects. The formation of goose neck at the start of transition curve is one such example. To overcome this negative loop, track tamping was always done on absolute coordinate base system, in order to restore the original position of the track and to lower the rate of degradation.



## 6. Conclusions:

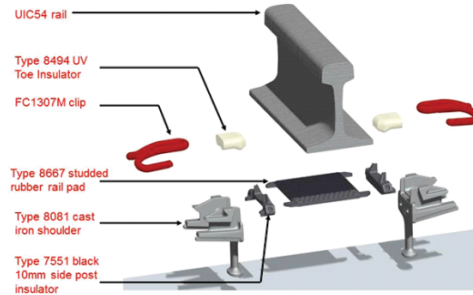
- 6.1 At higher speed, different vibrating forces of wider frequency range, are generated at rail-wheel contact and propagate both upwards through bogie and downwards into track. These forces / vibrations at rail-wheel contact level are to be minimised and needs to be properly dampened by tack components and bogie/ car body, for ensuring safety and comfort.
- 6.2 On track side, use of thicker (10 mm) and less stiff rubber pad (stiffness  $< 100 \text{ km/mm}$ ) is required to cut-off high frequency forces generated at high speed. More resilient elastic fastenings ensure sufficient toe load, even at deflected track geometry; thus producing more stable dynamic track response. Use of heavier concrete sleeper also adds to dynamic stability of track. For track maintenance, short wave and long wave defects are to be eliminated, to ensure safety and passenger comforts. Short wave defects are eliminated by periodic grinding. Long wave defects can be eliminated by track tamping using track m/c with spatial curve measurement system. During track recording, standard deviations of track parameter are also to be checked. For speed above 160 kmph, track tolerances for high wavelength ranges i.e. 25 – 70 m are also to be complied.
- 6.3 On vehicle side, vertical stiffness of primary suspension and lateral stiffness of secondary suspension are most important among other bogie parameters and hence requires adequate enhancement. Air spring suspension with Yaw, lateral & vertical dampers are to be provided in secondary suspension system. Optimal wheel set guidance stiffness is to be ensured for smooth wheel steering. Equivalent conicity of the vehicle is to be checked ( $< 0.4$ ) over 140 kmph and Ride index are also to be ensured ( $< 2.75$  for vertical,  $< 2.5$  for horizontal), over 160 kmph speed. For better wheel profile, use of wheel-scanners is to be introduced. Transverse accelerations at wheel, bogie and coach levels, are to be complied as per UIC 518 specification. As such a special track friendly vehicle capable of



ensuring dynamically stable running behavior at high speed, even at slightly deteriorated track, is essentially required.

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## Rail Fastenings & Fully Canted, Fully Weldable T/O Assembly



## Track Views, Electrification, Bi-Directional AutoSignalling & Gemas Station Building



