Challenges & possible solutions for appropriate Track technology for mixed traffic regime of Semi high speeds & heavy axle loads based on global experience.

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Synopsis

Indian Railways have a challenging job to find appropriate track technology so that it can give maximum output with safety, comfort & efficiency of mixed traffic consisting of semi high speed trains & heavy axle load trains. To meet the growing expectations of traveling public. Indian Railways are going ahead in a big way to introduce semi high speed trains which should be cost effective & can be done expediously. Simultaneously, to meet growing demand of modern traffic and also to improve its financial viability so as to make railway self reliant, IR are planning to move trains on same routes with heavier axle loads. Track, being the basic infrastructure has to be updated/developed to provide appropriate track technology as to ensure that it meets the challenges of mixed traffic of semi high speed as well as of heavy axle loads.

The authors have made a detailed study of track standards required for high speed trains/semi high speed trains as well as trains with heavy axle loads on Indian Railways as well as of other developed railway system of world such as Japan, Germany, France, USA & other countries as well as UIC standards. Based on experience gained by Global Railways including Indian Railway the authors have made an effort to suggest

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appropriate Track technology, to give best output to IR for mixed traffic regime of Semi high speed & heavy axle load trains.

1. Introduction:

1.1 Indian Railways are planning in a big way to run high speed & semi high speed trains on IR to modernize its Railway system to meet the challenge of modern traffic of heavier & faster traffic as well as to meet the growing demand of travelling public. As the high speed trains are likely to cost very much (about Rs. 120 to 200 crores/km) & will be very time consuming. Indian Railways are giving lot of importance & priority to semi high speed trains, which can be run by upgrading the existing infrastructure with certain improvements including track, & is likely to be very cost effective as well as less time consuming. As such IR is having very ambitions programme of running many semi-high speed trains to meet the demand & expectations of travelling public consuming. As such IR is having very ambitions programme of running many semi-high speed trains to meet the demand & expectations of travelling public.

At the same time as a market strategy it is important to run heavy axle load trains to increase the Railway share in moving freight traffic and thereby improving its financial status and eventually making IR self reliant.

As track standards/ specifications are bit different in moving semi-high speed trains on one side & heavy axle load trains on other side, it is a challenging job for Railway engineers to optimize the track standards so as to move both types of traffic with maximum efficiency.

As there is hardly any literature available of running semi high speed trains on IR as well as on world Railways. It is proposed to make a study of high speed railway systems at global level & try to get idea of track standards for the same. Similarly, it is proposed to have a study of running heavy axle loads trains on Global railways including Indian Railways. Finally taking on overall view it is planned to suggest appropriate track technology which can give optimum output in mixed traffic regime of semi high speed & heavy axle loads traffic.

2. High speed trains & Semi high speed trains.

2.1 What is a high speed train?

The International Union of Railways (UIC) defines a high speed train as one that runs at over 250 kmph. on dedicated tracks or at over 200 kmph. on upgraded conventional tracks. A "high speed line" is thus a new line designed to permit trains to operate at speeds above 250 kmph throughout the whole journey, or at least over a significant part of the journey. Alternatively, it could also be an upgraded conventional line, suitable for carrying traffic above 200 kmph.

2.1 (a) What is Semi high speed train?

Semi high speed trains are generally those trains which run at operational speed of 160 to 1200 kmph with an average speed of about 110 kmph.

2.2 History of High Speed Railways in the world

The Construction of first high speed railways started in 1959 in Japan of Tokaido Shinkansen area. It started operations between Tokyo and Osaka on 1 Oct, 1964. This line is the world's busiest high-speed rail line, and carries more passengers than all other high speed rail lines in the world combined, including in Japan.

This revolutionary concept of high speed trains was caught on in Europe in the 1980s and in the last four decades, there has been spectacular technological progress allowing speeds to be raised to 350 kmph. and even higher and also ensuring near total safety and acceptable levels of comfort. The first high speed train TGV started between Paris & Lyon in 1981 and this was followed by expansion of TGV network to connect cities across France & in adjacent countries.

France taking the lead in Europe in 1981with the TGV, it was followed by Germany in 1991, Spain in 1992 and the rest of Europe in the last decade and a half. The USA was a late entrant to the HS club in late 2000, the latest members now being Korea and Taiwan. With substantial expansion of the HS network in Europe on the cards, China has also jumped onto the high speed bandwagon. The length of high speed lines in the world exceeding 250 kmph. is about 18000 kms.

2.2.1 (Indian Railways)- Mumbai-Ahmedabad High Speed rail corridor (Bullet Train)

The Mumbai-Ahmedabad high-speed rail corridor is an approved high-speed rail corridor project of connecting the cities of Mumbai (Maharashtra) and Ahmedabad (Gujarat) in India. If built, it will be India's first high-speed rail line.

Some of the high lights of this first high speed project on IR are follows:

(i) **General:** An MOU has been signed by the governments of India and Japan on 12 December 2015. The Ministry of Railways, have announced that Shinkansen technology would be adopted for the line, with technology transfer to support the 'Make in India' programme

(ii) **Cost:** The project is estimated to cost 97,636 crore (US$ 15 billion). Japan has agreed to fund 81% of the total project cost (INR 79,165 Crore), through a 50-year loan at an interest rate of 0.1% and a moratorium on repayments up to 15 years

(iii) **Technical Features:**

* Length of line	508 kms
* Track gauge	1,435 mm (4 ft 8 1/2, in) standard gauge
* Electrification	25kV AC overhead lines
* Operating speed	320-350 km/h
* Speed	320 to 350 kmph

(iv) **Completion Time:** The construction of High speed corridor will start once all the formalities including technical details are finalized. It will take about 7 years to complete the project and as such the project is likely to start by 2019 and completed by 2026.

2.3 Length of High speed network in world

As of April 2015, the total length of HSR networks in the world is 29,792 km. The table below lists the countries with an operational HSR network length of more than 100 km, with their route lengths, electrificatio n specification and gauge type.

S. No.	Country	In Operation (km)	Under	Total Construction (km)	Electrification Country (km)	Track Gauge (mm)
1.	China	19000	12000	31000	25 kV 50 Hz	1435
2.	Spain	3100	1800	4900	25 kV 50 Hz	1435
3.	Japan	2664	782	3446	25kV 50/60 Hz	1435
4.	France	2036	757	2793	25 kV 50 Hz (partially)	1435
5.	Turkey	1420	1506	2926	25 kV 50 Hz	1435
6.	Germany	1334	428	1762	15 kV 16.7 Hz	1435
7.	Italy	923	395	1318	25 kV 50 Hz, 3 kV DC	1435
8.	Russia	649	770	1419		1520
9.	South Korea	412	562	974	25 kV 60 Hz	1435
10.	Taiwan	345	0	345	25 kV 60 Hz	1435
11.	Uzbekistan	344	0	344		1520
12.	Belgium	209	0	209	25 kV 50 Hz	1435
13.	Netherlands	120	0	120	25 kV 50 Hz	1435
14.	United Kingdom	113	204	307	25 kV 50 Hz	1435
	TOTAL:	**32669**	**19204**	**51863**		

2.4 Track Structure used on High Speed Routes (HSR)

A study has been made of few high speed routes viz SNCF, Japanese Railways, German Railways (DB), Spain Railways Belgium Railways. From study of these railways it is observed that most of the leading railways operating at High speed use conventional track consisting rails fastened on PSC sleepers with elastic fastenings which are supported on World Railways ballast. 90% of the (HSR) High Speed track in the world is on conventional ballasted structure. French TGV marked a record of 525 kmph on conventional ballasted track, and conventional track is strong enough to bear the stresses of speed up to 300 kmph It is not the heavy structure which is required for HSR, but it is the High standard maintenance which is warranted for HSR. Track structures used over world railway are as under:

Item		**SNCF**	**German Railway**	**Japanese Railway**
1.	**Rails**	UIC 54 and 60 kg.	UIC 60 Kg	UIC 60 Kg.
2.	**Sleeper**	Concrete/Wooden	PSC/Polyurethane foam/Glass fibre	PSC/Polyurethane foam/Glass fibre
3.	**Sleeper Density**	1666	1724	1724
4.	**Fastenings**	TGV Nabla/ICE Vossloh	Leaf Spring/Wire Spring	Leaf Springs/ICE Vossloh

(i) **Rails :** For high speed routes, 60 kg rails are adopted by the railways world over. Standard length of 25 m in Japan, 54 m / 62 m in Germany and 108 m in France has been utilized. CWR is used to improve the ride quality and to reduce noise and vibrations.

(ii) **Sleepers & Sleeper Density:** Prestressed concrete sleepers have been a better choice as they have long life of 50 to 60 years. Sleeper density of 1660 is being used over Indian Railway and is adequate for high speed route as this is the maximum density to carry out machine maintenance.

(iii) **Fastenings :** Double elastic rail fastenings are necessary for the concrete sleeper track. Rubber pads are used as cushioning material between the rail and sleepers fastened by leaf spring/ wire spring/ TGV Nabla/ ICE Vossloh fittings for distribution of vertical load and for dampening the vibrations. SNCF uses two types of rubber pads. Normal rubber pads of 9 mm thickness with a resistance of 90 KN/mm and soft type rubber pads of same thickness with low resistance of 56 KN/mm. Soft type rubber pads are mainly used for noise mitigation.

2.5 Curves for High speed routes

Flat curves are generally adopted on high-speed track. Flat curves become necessary in view of restriction on maximum values of cant deficiency and cant excess along with maximum speed of operation. The minimum radius of curvature for the high-speed lines on developed HSR networks generally varies from 4000 m to 7000 m for standard gauge.

2.6 Geometric Parameters: Geometric parameters of the track for various HSR on world railway are as under

	Country	FRANCE		GERMANY		SPAIN		BELGIUM	Figures for various High speed Railway of world.
	Design Speed	**300**	**350**	**300**	**350**	**300**	**350**	**300**	**300-350**
1.	Min R of curvature (m)	4000	6250	3350	5120	4000	6500	4800	4000 to 6500
2.	Max. Cant (mm)	180	180	170	170	150	150	150	150 to 180
3.	Cant Deficiency (mm)	85	85	130	112	100	65	100	50 to 112
4.	Max. Cant Gradient	35	35	40	40	12.5	25	15-21	0.21 to 0.35%
5.	Min Verticat Radius (m)	16000	21000	14000	20000	24000	25000	20000	20000 to 25000
6.	Transition curve length (m)	300	350	408	476	360	460	420	---

1. Turnouts for high speed:

When the speed on straight track is above 250 Kmph, High speed turnouts with speed on curved track from 80 to 100 Kmph are warranted.

Type of design for Turnouts: These should have following specifications:

(i) Flatter Switch entry angle by tangential layouts thereby reducing the angle of attack and reduced lateral forces resulting in increased passenger comfort.

(ii) Movable nose crossing: Use of movable nose crossings housed in a specially designed cradle, thereby avoiding gap at crossing.

(iii) Flatter angle of crossing: Use of flatter angle of crossing i.e. 1 in 32 or 1in 24: 1 in 16 and 1 in 20 P & C (curved switches) permit higher speeds.

(iv) Special rail profile section: Use of asymmetrical profile section ZU- 1in 60 forged to standard rail profile (UIC 60) at the end.

(v) Spring operated switch setting device: Use of spring operated switch setting device to ensure proper flange way clearance.

(vi) Synthetic rail pads: Use of specially designed synthetic rail pads for reduced vibration of switch assembly.

2. Tunnels & Bridges:

These are special structures, which have to be properly designed for high speed trains

2.1 Tunnels: Tunnel cross sections on high speed lines will be guided by the aerodynamic phenomena in the tunnel during passing of trains with other structural and dimensional features.

Air compression waves generate while passing the trains through the tunnel at very high speed and therefore the aerodynamic air drag is considerably higher than in the open air, Tunnel air friction will also play a considerable role in pressure variation along the length of tunnel.

When train enters into the tunnel with very high speed, a compression wave is formed at the entrance of the tunnel. This compression wave propagates inside the tunnel and when it reaches at the exist, a portion of it radiates outside as a pulsed compression wave. These micro pressure waves cause explosive sound during the entry and existing of train in tunnel with heavy vibrations in train doors.

To reduce this effect, tunnel hoods are specially designed with pressure release shafts. The diameter of the hood is kept 1.4 to 1.5 times of the diameter of tunnel. This is also advisable to provide separate tunnels for separate lines to avoid the combined effect of micro pressure waves due to simultaneous passing of trains.

2.2 Bridges: Bridges as well as bridge approaches are the vulnerable points, where a thorough analysis for structural adequacy is required in view of running of high speed trains from safety and comfort criteria. For high speed trains the major issue before engineers is to strengthen the existing bridge network with minimum disruption to traffic and cost effectiveness. Each bridge will need to be tackled individually on case by case basis. This area is still a challenge.

3. Grade separation/Level Crossings:

Normally level crossing is not suitable for high speed train operation and therefore, for road transport, either road over bridges or road under bridges needs to be planned. However, in unavoidable circumstances, level crossings may be required. Then it must be interlocked with the signals. Sophisticated arrangement of interlocking the signals of train with that of road transport with help of video camera as used in JNR. Similar type of arrangements may be considered by IR also.

4. Tilting trains on curves: To overcome the limitation of speed on account of tight curves particularly on mixed traffic routes, where it is not possible to cant the track, vehicles with tilting suspension system having tilting mechanisms can be used. (See Fig. 1.1)

Depending on the curvature & other parameters, the train tilts on the curve and gives additional super elevation to the passengers. In actual practice, there is cant deficiency and passengers comfort is not affected on curves.

Fig 1.1 : Tilting train

5. Semi High Speed trains & Track Standards

5.1 Semi high speed trains are generally those trains which run at operational speed of 160 to 1200 kmph with an average speed of about 110 kmph.

5.2 Track Structure of Semi high speed routes

It is considered that the existing track structure can be upgraded to accommodate speed upto 160 kmph. The track structure required for speed higher than 160 kmph and upto 200 kmph has not yet been finally designed. However, following track structure is being contemplated for the speeds upto 160 kmph and for speeds 160 kmph to 200 kmph.

S.N.	Track	Track structure for speeds upto 160 kmph	Track structure for speeds 160 to 200 kmph
1.	Rails	60 kg & 90 UTS	71 kg & 90 UTS
2.	Sleepers	Mono block PRC sleeper	Mono block PRC sleepers
3.	Sleeper density	1660 no. per km.	1660 nos. per km.
4.	Fastenings	ERC clips mark III with rubber pad 6mm thick & liner — steel or GFN	Same as col.2
5.	Points & crossings	Thick web, head hardened switches and cast manganese crossings on PRC sleepers	Same as col.2
6.	Ballast cushion	50/300 mm depth with 150 mm sub ballast	Hard stone ballast with 300 mm cushion over 150 mm sub-ballast
7.	Formation	Stable with penetration of ballast	Well compacted and stable
8.	Miscellaneous	Existing track may serve the purpose	Constraints to be removed

5.3 Constraints to be renewed for introducing semi high speed trains faster than 160 kmph

(i) **Sharp Curves:** Sharp curves more than 1° will hve to be earned to get speed > 160 kmph. This will require survey of each curve including fixed installations and thereafter re-alignment should be undertaken keeping all constraints in view.

(ii) **Turnouts:** Loose heel switches should be removed and only fixed heel type switches should be continued to remain in the section where high speed trains are to be introduced. For speed higher than 160 kmph, turnouts on wooden sleepers should be replaced by turnouts on concrete sleepers.

(iii) **Fencing:** For speed higher than 160 kmph fencing of the entire section may become necessary. For speed upto 160 kmph, fencing can be need based in the vicinity of the habilitation and in approach of major bridges, level crossings etc.

(iv) **Formation:** Weak formation creates maintenance problems during monsoon seasons and sometimes even after that. Therefore, rehabilitation of formation must be undertaken before introduction of high speed; Properly designed blanket should be provided in areas having weak formation. This can be facilitated by use of aluminium alloy girders designed and developed by RDSO.

(v) Improvement of track geometry: Track geometry will require improvement so as to conform to higher standards.

5.3.1 Prescnt Position of Semi High speed Trains in India

Recently just in the start of 2016 (5th April 2016) India has inaugurated the semi high speed rail system in India. Gatimaan Express (Fig 1.2) is India's first semi high speed train and also the fastest train of India till date which runs at the top speed of 160 km/h from Delhi to Agra. After the great success Gatimaan Express and due to high public support the Government of India is planning to start these semi high speed trains on high priority.

5.4 Semi-high speed routes-Efforts to increase speed to 160-200 kmph.

Indian Railways aims to increase the speed of passenger trains to 160-200 km/h on dedicated conventional tracks. They intend to improve their existing conventional lines to handle speeds of up to 160 km/h, and plan to go for speed above 160 kmph after removing the constraints.

As brought out in Rail budget 2014 the railways are going to start high speed trains at 160-200 km/h on 9 routes.

Fig 1.2: Gatiman Express

Brief details of 9 corridors for Semi-high speed routes:

Semi High-Speed Corridor	Max. Speed	Gauge (mm)	Distance (km)	Status
Delhi - Agra	160 km/h	1676	195	Inaugurated on 5 April 2016
Chennai - Hyderabad	160 km/h	1676	915	Approved in 2014 Railway Budget
Delhi - Chandigarh	160 km/h	1676	244	Approved in 2014 Railway Budget
Delhi - Kanpur	160 km/h	1676	441	Approved in 2014 Railway Budget
Mumbai - Ahmedabad	160 km/h	1676	493	Approved in 2014 Railway Budget
Mumbai - Goa	160 km/h	1676	606	Approved in 2014 Railway Budget
Mysuru - Bengaluru -Chennai	160 km/h	1676	495	Approved in 2014 Railway Budget
Nagpur - Raipur- Bilaspur	160 km/h	1676	413	Approved in 2014 Railway Budget
Nagpur - Secunderabad	160 km/h	1676	575	Approved in 2014 Railway Budget

These are multiple railway projects which are in different stages of implementation like doubling of tracks, electrification, new track laying, gauge conversion projects etc. Indian railways are in the process of finding and issuing guidelines to channelize all current and new efforts to run trains at semi-high speed.

Fig. 1.3 - TALGO Coaches

Talgo Trains on conventional rail-roads have been the fore-runners for "Higher-Speed Trains" or "High-Speed Trains" in Spain, France, Switzerland and Russia., Talgo coaches with their lower weight generate lower centrifugal forces and can run faster. Trains with Talgo coaches can run on the some track much faster may have the capacity to run on curved track much faster.

Trial Run of Talgo Coaches

Trial runs of Talgo coaches is being done recently on some sections of IR a speed of 115 kmph. Finally, Talgo trains will do extensive trial runs between Delhi-Mumbai at a speed of 115 kmph.

Talgo trains are one of the possible alternatives for running Semi-high speed trains on I.R.

6. Heavy Axle load trains

The phrase 'Heavy Haul operation' came into prominence with the first Heavy Haul Conference held in Perth in Western Australia in 1978. A large number of heavy haul trains are being operated in America, Australia, Africa, Europe, Brazil, Scandinavia and UK for last 3 to 4 decades.

The problems faced by some of the important heavy haul systems in the world railways, in construction and operation with special reference to Indian Railways are proposed to be highlighted in subsequent para. The experience gained from these railways can be useful for deciding the track requirements for heavy axle load on IR.

6.1 Experience of world Railways for design & maintenance of Track structure

It is proposed to take some typical cases of heavy haul operation & track structure adopted on the same & problems faced.

The studies were undertaken for the following Global Railways.

(i) Burlington Railway of North America for maintenance of Heavy Haul Railway Lines.

(ii) Hamersley Railways of North West Australia for maintenance of Heavy Haul Railway Lines.

(iii) Fortescue Railways of Western Australia for construction of Heavy Haul Railway line.

(iv) Economics of running heavy axle load and longer trains in Sweden (Europe)

(v) Maintenance of Heavy Haul Corridor of Union Pacific Railway.

(vi) Track Transition solutions for heavy axle load service-American Rail Roads

(vii) Effect of Heavy axle load on Bonded Insulation Joints-Research Study by TTCI (American Rail Road's).

6.1.1 Burlington Railways of North America :

Introduction: Burlington Railways of North America is one of the oldest Heavy Haul operated railway, constructed in the decade 1970-1980. Traffic carried in the railway was mostly coal and mixed traffic with an axle load of 30 Tonnes and maximum speed of 75 km per hour. The annual tonnage was 50 HGT. The gauge adopted was standard gauge of 1435mm.

Track Structure: The track consisted of 68 Kg per metre rail & with mostly wooden sleepers with cut spikes and also mono block concrete sleepers with special clips; maximum curvature was 220 metres radius.

6.1.2 Fortescue Railway of Western Australia

(i) Introduction: Fortescue railways of Western Australia is the world's newest Heavy- Haul, railway which was completed in April 2008. The railways project started in November 2006, construction of the formation could not start until July 2007 as a cyclone destroyed the recently-built construction camps which had to be replaced. This forced Fortescue to complete the railway in less than nine months to meet the target date.

Fortescue Railway opened on April 6 2008. It is designed to operate four 2.8km-long 240-wagon trains a day to enable it to carry 55 million tones a year initially. Trains are handled by two locomotives, with banking units for the first part of the trip.

(ii) Track Structure:

(a) **Formation:** Formation was mostly on embankments using local earth but duly treated.

(b) **Rails:** Rails of 68 kg per meter were imported from china with a tensile strength of 1100 Mpa

(c) **Turnout** : Two types of turnout are installed on the railway: 1:20 swing-nose tangential mainline turnouts designed for 70km/h operation, and 1:12 rail cast manganese tangential 40km/h turnouts for use in yards and sidings.

(d) **Sleepers & Ballast**: Pre-stressed monoblock sleepers were laid at intervals of 675mm. The ballast was initially laid to a depth of 150mm and then work-hardened and super-lifted to 250mm.

6.2 Results of experience of World Railways for heavy haul trains

Based on experience of world railways, the problem faced by these Railways in maintaining track as well as remedial measures are highlighted below:

(i) Formation: * Problem of settlement, slippage and even failure. * Special problems in yielding formation & bad quality soil.	* Soil stabilization by proper mechanical means during construction. * In case soil is not good, soil treatment of top capping soil should be done. * Yielding formation & poor quality of soil require special treatment. In some situations, even provision of Ballast filled Trench drains may help.
(ii) Rails: * Defects develop in rail; cracked Rails; Rapid rail wear; Excessive wear of rail on curves ; Scabbing of rail is more prominent particularly on steep gradients. * Develops high contact stresses between rail & wheel causing wheel burn, wheel scabbing.	* Up to 25 tones axle load, 60 kg 90 UTS rails sufficient; For higher axle loads, special heavy rails to be procured * **Rail Grinding Machine:** Reprofiling to be done by Rail Grinding machine for prolonging rail life as well to prevent defects in rail head. * **Mechanised USFD Testing of rails:** Use improved and mechanized USFD technology (Spurt cars etc.) for testing of rails.

(iii <u>Sleepers</u>: * <u>Wooden Sleepers</u> : Fast deterioration causing poor track geometry; lesser sleeper life. * <u>Concrete Sleepers</u> : Generally satisfactory but gets damaged, cracked or even broken in special locations like bridge approaches, on bridges and such other locations.	*Mono block PRC sleepers quite satisfactory in ordinary situations. *At special locations provide Special sleepers like **"Second Generation Tie"** to reduce stress on Plates.
(iv) <u>Ballast</u> : * Ballast not of desirable quality; lesser ballast cushion * Pulverization of ballast & clogging of shoulder ballast on account of heavier axle loads & dropping from the wagons.	* Better quality of ballast with full ballast cushion of 25 cm to 30 cm. If necessary, work hardening of ballast to be done to improve quality of ballast. * More frequent deep screening of ballast to be done

6.3 Dedicated Freight Corridor (D.F.C) of IR

In order to cater for heavy axle load traffic, Indian Railways have taken an ambitious project of dedicated freight corridor, where only heavy axle load freight trains will run.

6.3.1 Details of approved DFC Projects

Two projects approved as DFC projects are Western Corridor from Delhi to Mumbai (Dadri-Rewari-Vadodara-Mumbai) and Eastern Corridor from Delhi to Howrah (Khurja-Kanpur-Sonnagar-Howrah).

6.3.2 Standards of Construction of DFC

1	**Gauge**	B.G. 1676 mm*
2	**Rails**	60 kg 110 UTS-20 Rail panel (260 m) to be handled by mechanical track laying equipments.
3	**Sleeper**	PSC. 1660 Nos. per km. density for main line & 1540 Nos. per km. density for loop line.

4	**Points & Crossings**	60 kg. rail with, 1 in 12 curved switches and CMS crossings on PSC sleepers and thick web switches.
5	**Ballast**	300 mm cushion (Machine crushed) with present RDSO specification.
6	**LWR/CWR/ Welding**	20 rail panels are to be converted into LWR/CWRs with mobile Flashbutt welding /gas pressure welding. SKV welding should be avoided strictly. All in situ welds to be joggle fishplated.
7	**Gradient**	**Flat Territory** Mid section - I in 400 or flatter (compensated) **Yards - 1 in 1200** **Semi Ghat Territory** Mid section - 1 in 200 compensated or Yards - 1 in 1200 In the block section at a convenient location gradient of I in 1200 to be provided for future crossing station.
8	**Curvature**	**Flat Territory** Maximum Curvature-One Degree. **Semi Ghat Territory** Maximum Curvature-2 Degree.
9	**Formation**	**Top width of embankment**-7.5 m with 2: 1 side slope. **Track center**—5.3m Complete embankment should invariably be provided with turfing
10	**Cutting**	**Cutting Width** including drains-11.0 mtr. Side slopes to be designed depending on earth material. **Erosion,** Boulder fall, Earth slips blocking the drain etc. to be totally avoided

11	**Bridges**	Ballasted deck bridges with RCC Slab/RCC Box/PSC Slab/PSC Box girder. To ensure high quality concrete, use only Ready Mix concrete. Mobile ready Mix Plants can be planned which can be shifted at suitable interval. Use only high grade concrete with suitably designed admixtures to create economical structures.
12	**Road crossings/ Level crossings**	As far as possible, there shall be no level crossing. Complete length to be fenced on both sides
13.	**Maximum speeds**	100 kmph (Freight train)
14.	**Type of traffic & axle load**	25 tonne double stack container movement with 15000 tonne trailing loads: 30 tonne for bridges.

6.3.3 Track Maintenance

(i) Fully mechanized maintenance of the track and structure is suggested to keep human resources at minimum level.

(ii) Dedicated maintenance block of four hours daily with Engg, Deptt.

(iii) Through tamping of track and tamping of points & crossings should be done with CSM machine and UNIMAT machine.

(iv) BCM should be deployed for deep screening once in 10 years. Shoulder cleaning of ballast once in five years by FRM (SBCM),

(v) Isolated track defects should be attended by using light weight off track tie tampers to be moved by Rail Mounted Vehicle (RMV) simi)ar to Tower wagon.

(vi) Use of RMV and light weight motor trolley is recommended for quick and efficient attention of isolated track defects.

(vii) The track maintenance system can be divided into three tiers.

The top tier will be the back bone of the maintenance system comprising of CSM machine for tamping of plain track and UNIMAT machine for tamping points and crossings.

The middle tier consists of mobile maintenance gang (MMG) unit which are responsible for tamping of isolated spots conventionally known as slack picking.

The bottom tier comprises of track maintenance and monitoring gangs under sectional SE/JE.

7. Appropriate Track technology for mixed traffic require of Semi high speed & heavy axle load

The studies of Track requirements to run High speed railways, semi high speed railways as well as heavy axle load trains on IR and also for developed global Railways viz Japan, Germany, France, & USA etc as well as UIC standards have given certain ideas to adopt track standards/ specifications & other requirement of track technology for mixed traffic.

The studies are basically for 3 types of traffic requirement

* High speed traffic: (This is done as there is no global experience of semi high speed traffic)
* Semi high speed traffic on IR as well as on other global railways.
* Heavy axle load traffic on IR as well as on other global railways.

A close analysis of these track data highlight the following points.

(I) Track requirement for High speed traffic/semi high speed traffic & that of heavy axle load traffic based on global experience are summarized below. Many of these track requirement are similar, but in some cases some track requirements are very specific, which is not very relevant to other type of traffic.

(ii) Considering the track requirements of above types of traffic, an appropriate track technology has been suggested; which will give best output for running semi high speed trains as well as Heavy axle load trains.

7.1 Track structure for various types of traffic on global Railways & recommended track of structure on IR

	Track structure high speed Railways of World	**Track structure of Semi high speed Railways.**	**Track structure for heavy axle load trains of world**	**Track structure for DFC**	**Recommended track structure for IR**
1. Rail	About 60 kg/m CWR	71 kg & 90 UTS	60to 68 km routes	60 kg 110 UTS	60 kg UIC rails
2. Sleepers	Concrete sleepers or Glass fibre glasses	Mono block PRC sleepers	Mostly PSC Sleepers. Some places wooden sleepers	PSC Sleepers	PSC sleepers
3. Sleeper Density	1660 to 1724 sleepers per km	1660 nos per km.	With ballast cushion 150 to 200 mm, 1660 to 1800	PSC 1660 Nos. per km.	1660 sleeper per km
4. Fastenings-Double Elastic fastenings type	Leaf spring/TGV noble/Vossloh with rubber pads	ERC clips mark III with rubber pad 6mm thick	Special type of fastening	---	Double Elastic fastening
5. Ballast *	Ballasted track with 30 to 40 mm ballast cusion or ballastless track	250/300 mm depth with 150 mm sub ballast	Hard stone ballast with 300 mm cysguib iver 150 mm syv-ballast	Machine crushed ballast with 300 mm ballast cushion	Hard stone ballast having cushion of 250-300 mm with 150 mm sub-ballast.
6. Minimum radius of curve	varying from 4000 m to 6500 m	7250 m	6000 to 10000 m	1750 m	1750 mm
7. Max. superelevation (Cant)	varying from 150 mm to 180 mm	140 mm	180 mm	--	165 mm
8. Cant deficiency	varying from 50 mm to 112 mm	65 mm	100	--	75 mm (In special cases 100 mm)
9. Minimum vertical radius	varying 20000 m to 25000 m		24000 m	--	4000 m
10. Maximum gradient	0.15 to 0.20 %		0.1 % or 1 in 1000	1 in 400	1 in 400

* Ballasted track was earlier used for most of the HSR, where maintenance is easy. Presently ballasted track is generally used for speed upto 220 kmph & after that ballastless track which is cost effective is used.

7.2 Recommendation for appropriate track technology for mixed traffic regime of semi high speeds & heavy axle load

7.2.1 General: Track technology should be suitable for mixed traffic consisting of semi-high speed trains at a speed of 160 to 200 kmph& heavy axle load trains having axle load of 22.9 to 25.0 tones.

7.2.2 Track Structure

(i) **Formation:** Formation should be stable so as to take heavy load and also for speed of 160 to 200 kmph

* Soil stabilization by proper mechanical means during construction.
* In case soil is not good, soil treatment of top capping soil should be done.

(ii) **Rails:** 60 kg UIC rails having 90 UTS are recommended which can be suitable for semi high speed (160 to 200 kmph) as well as high axle load traffic up to 25 tonne axle load.

(iii) **Sleeper:** Prestressed concrete (PSC) sleepers are recommended. The sleeper density should be 1660 sleeper per km.

(iv) **Ballast:** Ballasted track is recommended with full ballast cushion of 250 mm to 300 mm with 150 mm sub ballast. If necessary, work hardening to be done to improve quality of ballast.

(v) **Fitting & fastenings:** Due to heavy axle load, there is possibility of heavy wear & tear on fitting & fastening as per global experience. There are mainly

* Fastening get loose very fast and thereby effecting track geometry.
* Rubber pads get damaged early. Heavy crushing of rubber pads as can be seen in Figure 1.4

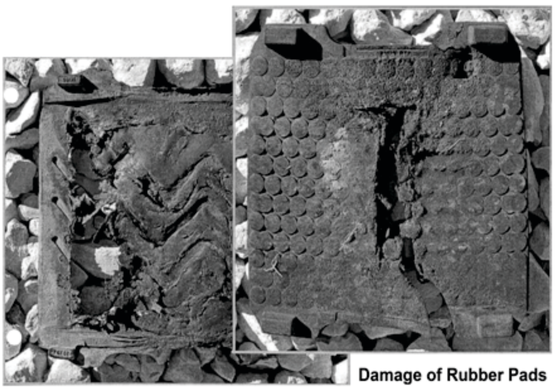

Fig 1.4: Rubber pad failure due to heavy traffic

* Glued Insulated Joint start failing because either insulation gets broken or failure of glue which bonds the joints.

* Short Service life of bonded Insulation joint which is sometimes as short as 12 to 18 months; This is almost the lowest than possibly all other surface components

In order to overcome these problems, the following suggestions are made.

(i) Double elastic fastenings are recommended.

(ii) To carry heavy axle load & to avoid failure of rubber pad, develop better design of rail pads like 'Three Point Pad' (See Fig 1.5)

(iii) Bonded Insulated Joints are worst effected & their design to be further improved by looking after the problems in current design, maintenance & operation

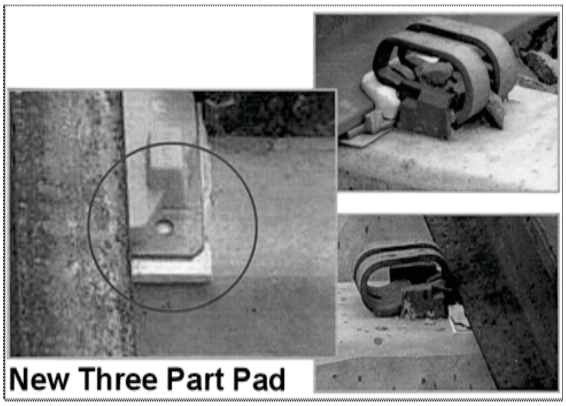

Fig 1.5 : Three Point Pad

(vi) Points & Crossing:

* To be modernised to cater for higher speed of atleast 50 kmph & preferably 75 kmph to 100 kmph.
* Thick web, fixed heel type, head hardened switches with flatter entry & cast mangense crossing.
* Indian Railways have already designed a new high speed turnout of 1:12 type which have potential of 50 kmph (See Fig 1.6)

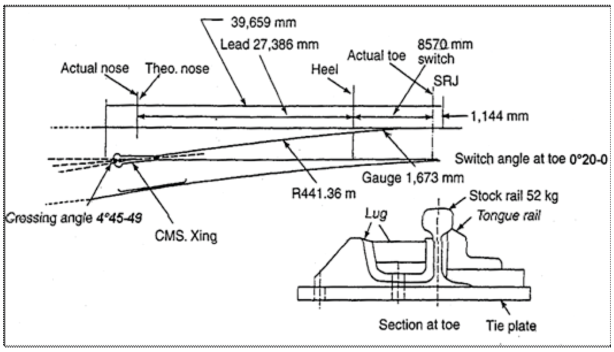

Fig. 1.6: Modern 1:12 Turnout for speed potential of 50 kmph.

New High Speed Turnouts for Passenger Yard (1 in 12) (Fig. 1.6)

The main features of 1 in 12 turnout with a speed potential of 50 kmph are as follows:

(i) Length: Its overall length is almost equal to the present standard 1 : 12 turnout, to facilitate easy replacement,

(ii) Switch: If consists of non-overriding thick web switch (ZU-2-49 type) having entry angle of 0°20'0″

This will provide high lateral rigidity and longer life to turnout.

(iii) Crossing: The crossing is of CMS type having angle of 4°45'49″

(iv) The stock rail head is prevented nom lateral rotation by using a special spring leaf clip to fasten the inner foot of the stock rail. Additionally, sturdy fittings are used on the outside of stock rail to minimize dynamic gauge widening.

(v) Check rails: Check rails have been provided at level with main rail.

7.2.3 Track Geometry:

1. Maximum Curvature: Maximum curvature should not be sharper than 1° (Radius 1750 metres), it should be preferably 0.5 degree (3500 metres)

2. Max. Super-elevation: In order to provide proper comfort to traveling public as well as to provide safety to passengers/goods, maximum superelevation of 165 mm is recommended.

3. Cant deficiency: To cater for semi high speed train as well as heavy axle load, maximum cant deficiency is normally limited to 75 mm. In special cases, it can be taken 100 mm.

4. Vertical Curve: A very smooth vertical curve is necessary for semi high speed railway to provide maximum comfort to passengers.

   The minimum vertical radius recommended is 4000 m for safe & smooth ride.

5. Ruling Gradient: Considering comfort of passengers & safety of passenger/goods, max. gradient recommended is 1 in 400 & in yards it should be 1 in 1000.

7.3 Track Maintenance

For running semi high speed trains & heavy axle load trains also, it would be necessary to have modern system of maintenance coupled with proper monitoring system. The following points need to be emphasised.

* Track has to be maintained mechanically by track tamping machine followed by crib & shoulder consolidator. Regular screening & management of ballast should also be done by Ballast cleaning machine and modern ballast regulator.

* Regular monitoring of track is required to be done by objective assessment of track by Track recording car. Track Management system, which is already being processed on IR, should be standardized & implemented early Future track maintenance & monitoring of track should be done based on the results of Track management system.

* Isolated track defects should be attended by using light weight off track tie tampers.

* Dedicated maintenance block of four hours daily should be available with Engg, Deptt. To carry out regular maintenance of track.

(i) **Rail Grinding:** Due to heavy loads rail develops defect like Rapid rail wear & excessive wear of rail on curves.

Reprofiling should be done by Rail Grinding machine for prolonging rail life as well to prevent defects in rail head.

(ii) **Bridges:**

* Signs of distress on some of the bridges resulting in cracks & deterioration of other bridge components, sleepers get cracked on bridges in some cases.

* Bridges should be designed for heavier loading. Quality of bridge construction requires to be improved.

(iii) **Track Transition areas (Bridge approaches, Level crossings & special track works)**

Problems:

* Due to differential settlement, extra track stiffness and differential damping track components gets damaged quite early.

* Increased dynamic loading & need for extra track maintenance.

Remedial measures:
Extra track maintenance is required of these difficult locations

* To introduce better track management cum information system so that monitoring of track maintenance & other aspects of track management can be supervised/controlled.

(iv) **Bridges:**
Bridges as well as bridge approaches are the vulnerable points, where a thorough analysis for structural adequacy is required in view of running of semi - high speed trains as well as heavy axle load trains from safety and comfort criteria. For high speed trains the major issue before engineers is to strengthen the existing bridge network with minimum disruption to traffic and cost effectiveness. Each bridge will need to be tackled individually on case by case basis. This area is still a challenge.

(v) **Level Crossings:**

Normally level crossing is not suitable for such movement of operation and therefore, for road transport, either road over bridges or road under bridges needs to be planned. However, in unavoidable circumstances, level crossings may be required. Then it must be interlocked with the signals. Sophisticated arrangement of interlocking the signals of train with that of road transport with help of video camera as used in Japanese National Railway. Similar type of arrangements may be considered by IR also.

(vi) **Fencing:** For speed higher than 160 kmph fencing of the entire section may become necessary. For speed upto 160 kmph, fencing can be need based in the vicinity of the habilitation and in approach of major bridges, level crossings etc.

7.4 Improvement in Rolling Stock, Signalling etc.

Other infrastructure items particularly rolling stock has to be improved/designed for running semi high speed & heavy axle load trains. The following points require to be highlighted.

(i) **LHB Coaches:** LHB coaches are cleared for regular operation upto a maximum speed of 160 kmph. However for higher speed all the coaches will have to be air conditioned to avoid dust ingress and air blast.

(ii) **Tilting trains:** To overcome the limitation of speed on account of tight curves particularly on mixed traffic routes, where it is not possible to cant the track, vehicles with tilting suspension system having tilting mechanisms can be used. (See Fig. 1.1)

Depending on the curvature & other parameters, the train tilts on the curve and gives additional super elevation to the passengers. In actual practice, there is cant deficiency and passengers comfort is not affected on curves.

For mixed traffic requirement, including heavy axle load, Tilting trains are not recommended for IR.

(iii) **TALGO Coaches (See Fig 1.3)**

Talgo Trains on conventional rail-roads have been the fore-runners for "Higher-Speed Trains" or "High-Speed Trains" in Spain, France, Switzerland and Russia., Talgo coaches with their lower weight generate lower centrifugal forces and can run faster. Trains with Talgo coaches can run on the some track much faster may have the capacity to run on curved track much faster.

Trial Run of Talgo Coaches

Trial runs of Talgo coaches is being done recently on some sections of IR a speed of 115 kmph. Finally, Talgo trains will do extensive trial runs between Delhi-Mumbai at a speed of 115 kmph.

Talgo trains are one of the possible alternatives for running Semi-high speed trains on I.R.

8. Conclusions & recommendations

8.1 Object of the paper: To meet the growing expectations of traveling public. Indian Railways are going ahead in a big way to introduce semi high speed trains on Indian Railway which should be cost effective & can be done expediously. Simultaneously, to meet growing demand of modern traffic and also to improve its financial viability so as to make railway self reliant, IR are planning to move trains on same routes with heavier axle loads. Track, being the basic infrastructure has to be updated/developed to provide appropriate track technology as to ensure that it meets the challenges of mixed traffic of semi high speed as well as of heavy axle loads.

Based on experience gained by Global Railways including IR, an effort has been made to suggest appropriate technology to give best output to IR for mixed traffic requirement of semi-high speed (160 to 200 kmph) & heavy axle load trains (22.9 to 25.00 tones)

8.2 Procedure adopted:

The authors have made a detailed study for track requirements for Indian Railways as well as other developed global railway viz

Japan, Germany, France, Sweden, USA Australia etc for 3 types of traffic.

* High speed traffic: (This is done as there is no global experience of semi high speed traffic)
* Semi high speed traffic on IR as well as on other global railways.
* Heavy axle load traffic on IR as well as on other global railways.

A close analysis of these track data highlight the following points.

(I) Track requirement for High speed traffic/semi high speed traffic & that of heavy axle load traffic be based on global experience have been summarised. Many of these track requirements are similar, but in some cases some track requirements are very specific, which is not very relevant to other type of traffic.

(ii) Considering the track requirements of above types of traffic, an appropriate track technology has been suggested; which will be best output for running sense high speed trains as well as Heavy axle load trains

8.3 Recommended Track structure to suit the requirement of mixed traffic

Track Items	Recommended track structure
1. Formation	Formation should be stable so as to take heavy load and also for semi-high speed of 160 to 200 kmph
2. Rail	60 kg UIC rails having 90 UTS are recommended which can be suitable for semi high speed (160 to 200 kmph) as well as high axle load traffic up to 25 tonne axle load.
3. Sleeper	Prestressed concrete (PSC) sleepers are recommended. The sleeper density should be 1660 sleeper per km.
4. Ballast	Ballasted track is recommended with hard stone ballast having full ballast cushion of 250 mm to 300 mm with 150 mm sub ballast. IF necessary, work hardening to be done to improve quality of ballast.
5. Fitting & Fastenings	(i) Double elastic fastenings are recommended. (ii) To carry heavy axle load & to avoid failure of rubber pad, (Fig 1.4) develop better design of rail pads like 'Three Point Pad' (See Fig 1.5)

6. Points & Crossing	To be modernised to cater for higher speed of atleast 50 kmph & preferably 75 kmph to 100 kmph. Indian Railways have already designed a new high speed turnout of 1:12 type which have potential of 50 kmph (Fig 1.6)
7. Maximum Curvature	For comfort & safety it should not be sharper than 1° (1750 m)
8.Maximum superelation	In order to provide proper comfort to traveling public as well as to provide safety to passengers/goods, maximum superelevation of 150 mm is recommended.
9. Vertical Curve	A very smooth vertical curve is necessary for semi high speed railway to provide maximum comfort to passengers. The minimum vertical radius recommended is 4000 m for safe & smooth ride.
10. Ruling Gradient	Considering comfort of passengers & safety of passenger/goods, max. gradient recommended is 1 in 400.

8.4 Track Maintenance:

For running semi high speed trains & heavy axle load trains also, it would be necessary to have modern system of maintenance coupled with proper monitoring system. The following points need to be emphasised.

* Track has to be maintained mechanically by a fleet of modern track machines.
* Regular monitoring of track is required by sophisticated/modern track recording car etc.
* Isolated track defects should be attended by off-track tampers.

8.5 Bridges:

Bridges should be designed for heavier loading. Quality of bridge construction and maintenance requires to be improved.

8.6 Level Crossings

* No Unmanned level crossing
* Manned level crossing should be avoided. However, in unavoidable circumstances, it must be interlocked with signals.

8.7 Improvement in Rolling Stock, Signalling etc.

Other infrastructure items particularly rolling stock has to considered for running semi high speed & heavy axle load trains.

Rolling Stock:

With regard to Rolling stock, the following points require consideration.

LHB Coaches: LHB coaches are cleared for regular operation upto a maximum speed of 160 kmph. However for higher speed all the coaches will have to be air conditioned to avoid dust ingress and air blast.

* **Tilting trains:** To overcome the limitation of speed on account of tight curves particularly on mixed traffic routes, where it is not possible to cant the track, vehicles with tilting suspension system having tilting mechanisms can be used. (See Fig. 1.1)

  For mixed traffic requirement, tilting trains are not recommended for IR.

* **TALGO Coaches (Fig. 1.3)**

  Talgo Trains on conventional rail-roads have been the fore-runners for "Higher-Speed Trains" or "High-Speed Trains" in Spain, France, Switzerland and Russia., Talgo coaches with their lower weight generate lower centrifugal forces and can run faster. Trains with Talgo coaches can run on the some track much faster may have the capacity to run on curved track much faster.

  Talgo trains are one of the possible alternatives for running semi-high trains on IR.

9. Summarising:

Based on experience of global railways including Indian Railways, Appropriate Track-technology has been suggested, including track standards, track maintenance etc which is likely to meet the challenge of mixed traffic regime of running of semi high speed trains as well as heavy axle load trains.