Global Heavy Haul Experience and Indian Railways

M. M. Agarwal
Former Chief Engineer, Northern Railway.

K. K. Miglani
Deputy Chief Engineer (TP), Northern Railway.

Prologue

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 the last 3 to 4 decades. Fortescue Railway in Western Australia is possibly the world’s latest heavy haul line which opened in 2008.

The authors have examined 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. The main problems which require to be addressed have been highlighted in the Paper along with possible remedial measures. The experience gained from these railways can be useful during the induction of heavy haul trains on Indian Railways.

- Editor

Introduction

The phrase “Heavy Haul” (HH) operation probably came into prominence with the first Heavy Haul Conference, held in Perth, Western Australia in 1978. Heavy Haul (HH) trains operate in some of the world’s most difficult conditions of terrain and climate, with rail temperatures up to 75°C in North West Australia, down to minus 50 degrees C in Canada, and with annual ranges of up to 80°C. Trains can be of 250 vehicles giving a trailing weight of some 30,000 tonnes and train lengths of more than 3 kms., with track curvature of 220m and grades of 2%.

By 1975-1980, Heavy Haul trains were being operated in Africa, Australia, Brazil, North America, Europe and Scandinavian countries. The growth has been
phenomenal since then and in most of the developed nations, these Heavy Haul Trains are running as an economic necessity.

It is proposed to take case studies of a few typical railways and discuss the various problems faced by them as well as remedial measures in construction as well as in operation and maintenance.

It may be brought out that some studies of Heavy Haul trains relate to earlier years. Though there have been many technical developments since then, yet some of the problems brought out in earlier days are still relevant in the present day context.

The case studies discussed in this Paper for running of Heavy Haul trains in different countries of the world not only relate to construction and maintenance of the track but also of some specific issues concerning the track. The case studies discussed in the paper are:

(i) Burlington Railway of North America for maintenance of Heavy Haul Railway lines.
(ii) Harmersley 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.
(viii) Heavy Haul operation on Narrow Gauge in Australia, Brazil & South Africa- 9th International Heavy Haul Conference.

It is felt that experience gained by different Railway systems of the world may be of considerable help to Indian Railways specially for running of 25 tonnes axle load trains on nominated sections of Indian Railway as well as for the Dedicated Freight Corridors.

The various case studies are discussed in subsequent paras along with the conclusions.
Burlington Railway of North America

Introduction

Burlington Railway of North America is one of the oldest Heavy Haul operated railway, constructed in the decade 1970-1980. The traffic carried on the railway was mostly coal and mixed traffic with an axle load of 30 tonnes and a 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.

Problems Faced

A study carried out indicated the following problems with the track on account of Heavy Axle loads:

(i) Rails
Rapid rail wear, Rail end batter and dipped joints, Cracked rails, Corrugation of rails.

(ii) Sleepers
(a) Wooden Sleepers - By far the most common wooden sleeper fastener used was cut spike and rail anchor. The problem faced was sleeper degradation causing deformation of track geometry and lesser sleeper life.

(b) Concrete Sleeper – The concrete sleeper fasteners were embedded in housing forming an integral part of the sleeper, with a self-tensioning spring clip located in the housing. In case of concrete sleeper there was no problem of any type except for the fastenings.

(iii) Fastenings – Different problems existed on different type of fastenings:

a) Wooden Sleeper – Problems experienced were lifting and lateral movement of the spikes giving poor gauge.

b) Concrete Sleeper - The problems faced were of low clamping force (toe load) and low rail creep resistance values. Also, the rubber pads suffered from abrasion, cutting and permanent set.
Conclusion

It may be brought out that subsequent upgradation of track structure and deployment of new technology has sorted out many of these initial problems caused during Heavy Haul operation.

Hamersley Railway of North Western Australia

Introduction

Hamersley Railway of North Western Australia used to transport iron ore over a standard gauge (1435 mm), single track of 388 kms, joining mines at Tom Price and Paraburdoo with two ship-loading points.

Trains consisted of three 2700kw diesel electric locomotives and up to 210 cars with a 30t axle load. Train length was over 2kms, and gross weight about 26,000 tonnes. On 100km an adverse grade of 0.4% existed between Paraburdoo and Tom Price.

Problems Faced

(i) Embankments: These were constructed in a short span of about one year without proper consolidation and as such gave problems of settlement, slippage and even failure.

(ii) Track: Degradation resulting in poor track geometry, fastening becoming loose, widening of gauge affecting cross levels and other track parameters.

(iii) General:

- The heavy axle loads, rising tonnage and train frequency had two important effects: increasing track degradation and decreasing time for repairs.
- By the mid-70’s, with tonnage at 55 MGT/year and expected to further increase, it seemed that track maintenance would limit the capacity of the system.

Remedial Measures

(i) Up gradation of track by using rails of 68kg/m, and proper consolidation of embankment. Improving quality of ballast and providing higher ballast cushion; use of Malaysian treated sleepers and better quality of fasteners.

(ii) Rail Profiling by proper rail grinding machine.

(iii) Monitoring of Track tolerances: Laying standard track tolerances and proper monitoring of the same.

(iv) Better track management system.
Conclusions

The up gradation of the track technology and better track management system gave dramatic improvement in wear rates, lesser input for maintenance, lesser use of man hours, lesser rail failures and improvement in track geometry.

Fortescue Railways of Western Australia

Introduction

Fortescue Railways of Western Australia is the world’s newest Heavy-Haul railway which was competed in April 2008.

Construction of the Project

The railway 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 in April 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.

Key Design Objectives

There were four key design objectives for the new railway:

- Minimize the impact on the environment
- Keep the overall track length to a minimum
- Minimize adverse gradients, although this was not entirely possible as banking locomotives are needed to push the trains out of the mine, and
- Achieve maintenance excellence and efficiency.

Track Structure

(i) Formation was mostly on embankments using local earth duly treated.

(ii) Rails of 68 kg per meter were imported from China with a tensile strength of 1100 Mpa.
Global Heavy Haul Experience and Indian Railways

(iii) Turnouts – Two types of turnouts 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.

(iv) 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.

Problems in Construction

(i) **Formation**: Fortescue faced a number of construction challenges. It was difficult to produce a good formation on some parts of the railway. There was also a lack of a suitable formation capping material and 1% cement-stabilised sand had to be used in some areas. The formation capping is a minimum of 200mm with 97% compaction.

(ii) **Ballast**: The quality of ballast also faced problems. The ballast had to be work hardened and the depth increased from 150mm to 250mm.

(iii) **Rails & Turnouts**: Special rails had to be imported from China with 68 kg per meter weight. Modern turnouts were used so that speed could go up to 70 km/h.

(iv) **General**: A key factor in designing the railway was to minimize operating and maintenance costs. Driver-only operation is the norm with train control situated in Perth, 1600km from the Pilbara.

Conclusion

Fortescue railway has set a new benchmark in heavy-haul railway operation, and no doubt other heavy-haul railways will be keeping a close eye on Fortescue to see how 40-tonne axle-load operation works in the long term.

Economics of running Heavy Axle Loads and Longer Trains in Sweden

**Background**

This is basically a study on the Economics of running heavier axle load and longer trains in Sweden.

Under increasing international competition, the movement of iron ore from mines in Northern Sweden to ports in Norway and Sweden, was looking for ways to reduce transportation costs and increase competitiveness.

As European railways came under increasing pressure to reduce operating costs, and to even show a profit in their freight (goods) operations, it was only natural
that they look at the costs and benefits associated with heavier axle loads and see if the benefits experienced elsewhere can also be realized in the European environment.

Study for Increase of Axle load and Longer Trains

a) A study was undertaken to increase axle load from the then 25 tonnes to 30 tonnes and also increase the length (size) of the train.

In addition, the effect of introducing new equipment, with radial trucks, and improved net to tare ratios, was incorporated in the analysis as also the effect of increasing operating speed from the existing 50 km/hr to 60 km/hr.

b) The approach used was based on a methodology previously developed by ZETA-TECH and used in a series of heavy axle load studies on North American railroads. This methodology used for analysis track component behavior observed on several North American railways, which indicates that, on a per-axle basis, track cost increases can be non-linear with increases in axle loads. In the analysis of the track and its key components, this heavy axle load effect was addressed through the development of a set of damage factors, with separate damage exponents and damage factors calculated for each track component and component failure mechanism.

Results of the Study

The analysis showed the following results

a) Operation of 68-wagon trains with 100 tonne load capacity (30 tonne axle load) produced a reduction of approximately 30% in direct operating costs over the base case (52 wagons of 80 tonne capacity), taking into account the expected increase in track maintenance costs as a consequence of the increase in axle loads.

b) Assuming a “worst case” increase in track costs, savings remained in the range of 27%.

c) The increase to 30 tonne axle loads reduces costs by about 50% more than simply increasing train length, without increasing axle loads.

d) The increase in axle loads also reduces the number of trains that must be operated to carry the current and future volumes of iron ore, freeing up line capacity for other traffic and allowing more efficient scheduling of maintenance work.
Conclusions

- Based on the results of this study, a decision was made to purchase new heavier axle load equipment, with 100 Tonne capacity (30 tonne axle load) and radial bogies.

- Prototype orders were also placed, with 68 train-sets of 68 wagons each, to be ordered upon completion of acceptance tests.

Maintenance of Heavy Haul Corridor of Union Pacific Railway

Introduction

A study was undertaken by The American Railway Engineering and Maintenance-of-Way Association (AREMA) of four important Heavy Haul routes of Union Pacific Railway sometimes in 2003. Out of four corridors, one corridor of Heavy coal route had 80% traffic having 34 to 37 tonnes axle load.

The weight of these Heavy Haul trains have been increasing year by year and in the year 2003, there were about 35 Heavy Axle Load (HAL) trains and each train was carrying about 15,000 tonnes.

Track Structure: UPRR HAL Standard Track Section

Track Structure consisted of (i) 141# Rail Section (ii) Concrete Ties (iii) 12” Ballast under Concrete Ties (iv) 18” Shoulder Ballast (v) Concrete Bridges (vi) Concrete Crossings (vii) Concrete Turnouts (viii) Moveable Point Frogs.

Track Maintenance

(i) The track was being maintained mechanically with the help of Heavy Track Machines consisting of Tamper, Track Finishing Machine, Primary Surfacing Unit, Undercutter, Rail Grinder, Switch Grinder.

(ii) The rail joints were mostly welded by Flash Butt Welder and only at few locations the welding at site was done by Thermit Welding.

(iii) Ultrasonic inspection of Track was done with the help of Mobile Rail Testing Trolley.

(iv) Rail detection was done with the help of Rail Testing Cars.

(v) Trench Drains – Special Ballast filled Trench Drains were provided as shown in Fig.1.
The benefits of the Trench Drains were (i) Removes Water From Subgrade (ii) Opportunity to Observe Subgrade (iii) Minimal Interruptions to Train Operation.

Problems of Heavy Axle Load Track and Remedial Measures

(i) Failure of Glued Bonded Joint: The problem arises because either the insulation gets broken or there is failure of glue which bonds the joint.

(ii) Failure of Concrete Tie Plate: The tie plate gets damaged or broken particularly on receiving end. This happens because of the heavier loading conditions. The solution lies in providing second generation TIE, which gives about 25% less stress on the plates (Fig. 2).
(iii) Failure of Concrete Ties on Bridges: The concrete ties got damaged due to Heavy Axle Loads. Cracks developed on the Ties particularly on bridges as seen in the picture. (Fig. 3)

![Concrete Ties on Concrete Bridge - HAL Line](image)

**Fig. 3**

The remedial measure lies on providing the following:
- 100-ft. Long, 8" Hot Mix Asphalt (HMA) Underlayment
- 100-ft. Long, 8" Geocell Subballast Reinforcement.
- Cement Stabilized Backfill, 6.75 ft. Deep, 10 ft. Long with a 2:1 Taper, Upward
- Standard Track Construction (12" ballast on compacted embankment)

(iv) Failure of rubber pads (Fig. 4): There is also the possibility of rubber pads failure as shown in the picture.

![Damage of Rubber Pads](image)

**Fig. 4**
The solution lies in providing ‘New Three Part Pad’ (Fig. 5).

![New Three Part Pad](image)

**Fig. 5**

(v) Spalling on Rails: The spalling on rails takes place particularly on curves (Fig. 6).

- **Spalling**
  - Low Rail on Curves
- **Rail**
  - Premium Quality Steel
  - Superior Wear Characteristics

![Spalling on New Premium Rails](image)

**Fig. 6**

The solution lies in providing premium quality steel for rails having superior wear characteristics.
Introduction

Track transition areas such as bridge approaches, level crossings, and special track work can give significant maintenance problems under heavy axle load traffic and can generate impacts that contribute to accelerated degradation and shortened component life.

The Transportation Technology Center, Inc. (TTCI), Pueblo, Colorado, a subsidiary of the Association of American Railroads (AAR), made a study and evaluated the effectiveness of currently accepted track transition designs.

Some of the important findings of this study are discussed in subsequent paras.

Main Problems in Track Transition Areas

One important problem in mainline track is the performance of track transition such as those found at bridge approaches, level crossings, and special trackwork. In these locations, the track structure, and often the load environment, changes significantly over a very short distance. This can result in increased dynamic loading and needs track maintenance.

Problems at a track transition can be divided into three categories:

(i) Differential Settlement: Differential settlement is where two segments of track settle at different rates, such as the bridge to bridge approach track transition. Railroad bridges are built on deep foundations and are relatively immune to subgrade settlement. In contrast, the approach consists of fill and has a large amount of settlement compared with the bridge structure. The running surface deviation that develops in this situation can contribute to high dynamic loads as high as three times the static wheel load.

(ii) Track stiffness case: The track stiffness case is the abrupt stiffness change that occurs in the track transition.

One typical case is of a concrete span ballasted deck bridge with concrete ties and can have a very high track modulus compared with the surrounding track. The abrupt stiffness change by itself does not contribute to higher dynamic loads, but coupled with a running surface deviation, can induce high impact loads.

(iii) Track damping case: The track damping case addresses energy dissipation of high dynamic loads. Track damping differs between different
track structures at a track transition. For example, on a bridge approach energy is dissipated through the track structure, subgrade, and surrounding ground. On a bridge structure, some energy is dissipated in the ballast layer, but much of the energy can reach the bridge structure. It is important to understand the types of impacts and design damping into the track structure to alleviate potential damage. Two types of impacts viz. wheel dynamic impact & wheel balance are generated at track transition with running surface defects, wheel impact and wheel bounce.

Research Studies

Research studies are being done for all the three Parameters viz. settlement, stiffness, and dampening track transition cases mentioned earlier. Apart from theoretical work, predictive tools are being developed to aid in designing effective track transitions. Field evaluations are being conducted to monitor the effectiveness of track transitions in place.

As far as theoretical work is concerned, parametric studies have been done using NUCARS™ and Geotrack™ software to look at the effects of track damping and stiffness. A differential settlement model has been developed to help predict settlement for different track structures.

The research studies have been done under the following main topics (i) Geotrack™ study (ii) NUCARS™ study (iii) Differential settlement model (iv) Laboratory & field testing (v) Fast & revenue service testing for bridge approach transitions (vi) Study for special track work transitions

Conclusions

(i) Theoretical work suggests there are opportunities to improve performance of track transition areas. NUCARS™ modeling suggests that adding damping to a track structure can improve impact attenuation by up to 30 percent. Different ways to add damping to the track are being investigated. Rail seat pads, tie plate pads, ballast mats, and subgrade treatments are all potential solutions. Some typical damping pads are given in Fig. 7.

(ii) The parametric study using Geotrack™ suggests the best method for raising approach track stiffness is subgrade treatment. The study also suggests the best method of reducing bridge track stiffness is to alter tie to pad properties.

(iii) Field testing indicated that different tie materials can provide effective ways to improve the track stiffness transition. Plastic ties installed on bridges in concrete tie territory have been successful in eliminating the stiffness differential for the first 240 MGT.
Concrete ties with rubber pads also helped in lowering the modulus below that of the approach and increasing the damping properties of the bridge structure. Thus, this method appears capable of addressing both track stiffness and damping issues and is a promising solution because the desired properties can be designed into the pads.

(iv) A good number of predictive tools is being developed to provide a way to design effective track transitions to address stiffness, damping, and differential settlement. Field testing has proved that these are effective ways to address each of these issues.

**Effect of Heavy Axle Load on Bonded Insulation Joint-Research Study by TTCI (American Rail Roads)**

*Introduction*

Heavy Axle Load (HAL) coal traffic, with higher speeds and higher traffic densities, places a significant performance demand on bonded insulated rail joints (bonded IJs) (Fig. 8).
While bonded Insulated Joints (IJ) are essential as an operational need they also introduce weak points in the track which cause increased maintenance and service disruptions. Bonded IJs are also a potential safety risk. These things get further aggravated when Heavy Axle Loads pass on these joints.

It may be brought out that Bonded IJ performance on heavy haul coal routes has significantly declined as the load environment has become more severe. Today, bonded IJ service life may be as short as 200 MGT. This short service life is lower than virtually all other running surface components including turnout frogs and switch points.

On high tonnage routes, bonded IJs may be replaced within as little as 12 to 18 months with direct costs of thousands of dollars per mile per year. Indirect costs such as crew labor and schedule disruption due to train delay can be higher, especially on lines running to full capacity. With such short service lives, the economics of developing a longer life bonded IJ are compelling and is a technical requirement.

In order to critically examine the design of existing bonded insulation joints, their failure modes, recent design evaluation, a research study was done by the Transportation Technology Centre (TTCI), Pueblo, Colorado, in collaboration with some other organizations.

Service Life of Bonded Insulation Joints

The research studies taken on specific projects brought out that the following important factors adversely affect service life of these joints due to Heavy Axle Loads.

- Higher average wheel loads from larger capacity cars.
- Higher dynamic loads from higher speeds and a stiffer track structure.
- Higher longitudinal forces from elimination of other rail joints and better rail anchoring.
- Higher traffic density which reduces opportunities to perform bonded IJ maintenance activities such as surfacing and running surface flow grinding. The service life of a bonded Insulated Joints is classified differently from many other track components because it can deteriorate and fail rapidly.

Effect of Axle Load, Dynamic Load, and Traffic Volumes

The effects of static load (axle load), dynamic load, and traffic rates are interwoven in evaluating bonded IJ performance on HAL routes. As the railways have
increased car capacity, they have also increased traffic rates, raised train speeds, increased track stiffness, increased tensile stress in the rail.

With these conditions in mind, it was perceived that the heavier loads and higher speeds were generating more mechanical component defects. The effect of all three factors (static load, dynamic load and traffic rates) have been significant in raising the severity of the service environment experienced by track components such as bonded IJs.

**Failure Mode Analysis**

In order to better understand failure mechanisms, a sample of 20 IJs removed from revenue service was collected and examined by TTCI. The joints were from lines that carry coal traffic predominantly in 286 Kip cars.

Some of the important results arrived after examination of the sample were:

(i) Many joints have more than one defect.

(ii) There are several common modes that limit service life for bonded IJs in HAL service. Some of these are related to quality control issues in components and assembly.

There are also service life-reducing aspects related to the design and capacity of the joint. These occur with structural aspects of the joint or components within the joint. These situations begin with the joint becoming a running surface discontinuity. This discontinuity generates dynamic loads at the joint which damage the foundation. Due to lower stiffness of joint, the deflection becomes significantly larger than deflections typically found in surrounding track.

(iii) Cause of the poor foundation condition in this case is the dynamic loading generated by the running surface discontinuity of the IJ. The combination of high dynamic forces and larger deflections at the IJ cause the foundation to fail here before it does in open track. The foundation condition causes cracking in the glue or epoxy at the top-centre of the joint bar to rail interface.

(iv) The weakened epoxy bond allows moisture intrusion and larger deflections. Due to this, the situation becomes that of a disassembled bonded IJ with glue debonding and water intrusion. As the glue debonds, the joints become subjected to “pull-apart” because of the longitudinal forces in the rails. “Pull-apart” damages insulating components such as thimbles and end posts as well as mechanical joint components such as bars and bolts. (Fig. 9)
Conclusions

(i) Improving performance of Insulated Joints

(a) Improving the performance of bonded IJs can be accomplished by improving any of the weaknesses in current designs, maintenance and operations. The efforts to improve the design is based on the following points:

(i) Reducing deflections
(ii) Reducing component relative movement
(iii) Increasing the strength of failure prone components.

(b) Reducing Deflections.
Several methods have proved effective in reducing maximum bonded IJ deflections. These include:

(i) Supported bonded IJs
(ii) Multiple tie plates
(iii) Longer Joint bars
(iv) Larger (cross section) joint bars.

(ii) Performance requirements of bonded Insulation Joints
Research studies have suggested draft performance requirement of Insulated Joints. These requirements are a first draft based on the observed problems with existing bonded IJS in HAL service and the service environment measurements made. These have been tentatively laid down by American Rail-Roads.
Advanced design for bonded Insulation Joint
Based on the research studies, a design has been developed based on observation of current designs, analysis and modeling work, and the requirements of the draft performance guidelines. This design will have the following features:

- Reduce bonded IJ-caused dynamic loads with less running surface and more damping running surface design from AAR Frog.
- Longitudinal profile.
- More damping: Mitigates effects of dynamic loads.
- Lower Deflections: by having Foundation with larger bearing area on ties and ballasts, continuous support.
- Components: having Stronger insulator and more environmentally stable epoxy.
- Assembly with improved rail and bar surface preparation: to eliminate surface contamination.

Heavy Haul Operation on Narrow Gauge in Australia, Brazil & South Africa (9th International Heavy Haul Conference)

Introduction

A research study was done to examine the competitiveness and sustainability of narrow-gauge heavy-haul railways in the globalized economy. The details of this research were discussed in the 9th International Heavy Haul Conference held in Shanghai in 2008.

Key Narrow Gauge Issues

(I) Several parameters constrain narrow gauge railways, in particular axle load and, axiomatically, distance between rails.

- First, Standard gauge railways have attained 40 tonnes, while narrow gauge railways have not advanced beyond 30 tonnes: Competitiveness and sustainability are constrained pro rata.
- Second, the distance between rails influences vehicle stability vis-à-vis centre of gravity height and train speed.
- Third, back-to-back distance between locomotive wheels determines how large a traction motor will fit. This influences locomotives and cars.

(II) Problem of Gauge Dependence: Locomotives’ narrow gauge traction motors cannot match the performance of standard gauge traction motors.
In addition, low tractive effort locomotives do not cost materially less to maintain than high tractive effort locomotives. Since the narrow gauge locomotive fleet to perform a given transport task is larger than for standard gauge the cost of locomotive maintenance is also higher.

(III) Problem of Gauge Dependence Cars
Because of lesser carrying capacity & lower load-to-tare ratio, a narrow gauge railway could need up to 30% more cars than a standard gauge railway for the same throughput.

Study Conducted

A research study was conducted in Australia, Brazil & South Africa concerning viability of using Narrow gauge for Heavy Haul Operation.

Following were the results of the study.

a) Queensland, Australia
   • 26-tonne axle load just beats the heavy haul threshold. Locomotives are relatively light and expensive.
   • The short haul distance reduces turnaround time to offset a possibly higher cost structure due to higher rolling stock prices.

b) Brazil
   Its 25-tonne axle load is on the heavy haul threshold, but it has recognized the challenge of increasing it, and looks set to lead this parameter in due course.

c) South Africa
   South Africa will need to work on overall competitiveness in iron ore haulage.

Conclusions

(i) Narrow gauge heavy haul railways have lagged the crucial axle load parameter: International Heavy Haul Association (IHHA) conference proceedings suggest they have not yet tried to catch up.

   Even if narrow-gauge axle load were to increase, the question arises—whether space between the wheels accommodate traction motors that could develop sufficient torque to utilize a materially higher axle load.

(ii) Narrow gauge heavy haul railways have lagged in the axle load contest. To compensate, they have maximized train length. However, as long as locomotive traction motors must fit between the wheels they drive, they would trail standard gauge ratings.
(iii) In conclusion, unless the railways innovate, globalization could move narrow-gauge heavy-haul railways from mainstream to margin, as has already happened in the double stack and high-speed intercity market spaces.

**Summary and Conclusions**

*Track Defects on Account of Heavy Axle Loads*

(i) **Formation**
- Problems of settlement, slippage and even failure.
- Special problems in yielding formation & bad quality soil.

(ii) **Rails**
- Defects develop in rail; cracked Rails.
- Develops high contact stresses between rail & wheel causing wheel burn, wheel scabbing.
- Rapid rail wear; excessive wear of rail on curves.
- Scabbing of rail is more prominent particularly on steep gradients.

(iii) **Sleepers**
- Wooden Sleepers: Fast deterioration causing poor track geometry; lesser sleeper life.
- Concrete Sleepers: Generally satisfactory but get damaged, cracked or even broken in special locations like bridge approaches, on bridges and such other locations.

(iv) **Ballast**
- Ballast not of desirable quality; lesser ballast cushion.
- Pulverization of ballast & clogging of shoulder ballast on account of heavier axle loads & droppings from the wagons.

(v) **Fittings & Fastenings**
- Fastenings get loose very fast thereby affecting track geometry.
- Rubber pads get damaged early. Heavy crushing of rubber pads.
- Glued Insulated Joint start failing because either insulation gets broken or failure of glue (which bonds the joints) takes place.
• 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.

(vi) Points & Crossings
• Quick wear, frequent renewal necessary.
• Breakage of CMS crossings at few locations.
• Lesser speed adversely effecting the traffic output.

(vii) Track Maintenance
• Track geometry deteriorates very early due to heavy loads.
• Existing maintenance system may not be able to cope with the increase in work load due to heavy axle load & allied problems.
• Increase in weld failures specially of thermit welded joints.

(viii) 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.

(ix) Track Transition areas (Bridge approaches, Level crossings & special track works)
• Due to differential settlement, extra track stiffness and differential damping Track Components gets damaged quite early.
• Increased dynamic loading & need for extra track maintenance.

Suggested Remedial Measures

(i) General
• The operation of heavy axle load trains is a economic and technical necessity & as such Heavy Haul trains today run on most of the developed Railways of the World.
• For Narrow Gauge, the running of heavier axle load beyond 30 Tonnes has technical problems because of limitation of Gauge. Instead longer trains are suggested for N.G. to meet the traffic demands.
(ii) Formation

- Soil stabilization by proper mechanical means during construction.
- In case the soil is not good, soil treatment of top capping soil should be done. Refer case of Fortescue Railway of North-West Australia where 1% cement stabilization was done of top 200 mm soil and with 97% compaction.
- Special treatment of formation/back fill to be done on bridges.
- Yielding formation & poor quality of soil require special treatment. In some situations, even provision of Ballast filled Trench drains may help as done in case of Union Pacific Railway (See Fig. 1)

(iii) Rails

- Up to 25 tones axle load, 60 kg 90 UTS rails are sufficient; For higher axle loads, special heavy rails to be procured.
- It may be brought out that as per survey carried by JRP-2 initiated by UIC there is a relationship between rail section & axle load (See Fig.10). 60 kg rail section would suffice for an axle load up to 25 tonnes.

![Relationship between Axleload and Rail Section used](image)

- **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.
- **Roll longer rails** to reduce welds and also to improve performance.
(iv) Sleepers
- Mono block PRC sleepers are quite satisfactory in ordinary situations.
- At special locations Special sleepers like “Second Generation Tie” to reduce stress on plates as done on Union Pacific Railway (See Fig. 2).

(v) Ballast
- 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 by mechanized methods.

(vi) Fittings & Fastenings
- Quality of fitting & fastening and rubber pads to be improved.
- Develop better design of rail pads like ‘Three Point Pad’ as done by Union Pacific Railway (See Fig. 5)
- Bonded Insulated Joints are worst effected & their design needs to be further improved by looking after the problems in current design, maintenance & operation. The bonded insulation joint should be designed based on standard ‘Performance Requirement’ for HAL Service and particularly ensuring reduced dynamic loads, lower deflections & stronger insulator & other components.

(vii) Points & Crossings
- To be modernized to cater for higher speeds of 75 kmph to 100 kmph. Refer Swing Nose Turnouts 1:20 designed for 70 kmph for Fortescue Railways of Western Australia.

(viii) Track Maintenance
- Complete mechanization of track maintenance & track renewal works.
- Fixing proper tolerances for HAL trains & better monitoring of track tolerances.

(ix) Bridges
- Bridges should be designed for heavier loading. Quality of bridge construction requires to be improved.
- As cracks sometimes develop in concrete ties on bridges, it is
necessary that sub-base of bridge requires to be strengthened by making it a compacted embankment. The sub-base can be upgraded by providing hot mix as under layment, Geocell sub-ballast Reinforcement, cement stabilized back fill & 12” ballast.

(x) Special case for Track Transition Areas  
(Bridge approaches, Level Crossings & Spl. Track work)

- Improving Track structure for track transition area such as Bridge approaches, level crossing & special track works.

- The studies suggest that proper damping devices on track can improve track impact by 30%. Provide special damping devices like Rail seat pads, Tie Plate pads, Ballast pads, etc., to improve track performance.  
  (See Fig. 7)

- Development of Predictive tools to provide a way to design effective Track Transitions to address stiffness, damping & differential settlement.

- Installation of Plastic ties installed on bridges in concrete. Tie Termitary can be successful in eliminating the stiffness differential.

- Concrete Ties with rubber pads can help in lowering track stiffers & damping issues and as such improve track performance.

(xi) Track Management cum Information System

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

World Railways’ Experience and Indian Railways

Introduction

Indian Railway took a bold decision in the year 2001-02 to run heavier axle load than the existing axle load of 20.32 tonnes in an effort to enhance the traffic capacity of Railways to handle the increased traffic as well as to increase its financial viability.

A pilot project of (CC+8+2) with an axle load of 22.9 tonnes was implemented on 20 routes initially and later on 14 more routes after a positive feedback from the different railways. The major routes are on the South Eastern Railway, East Coast Railway, SEC Railway and Eastern Railway. Presently CC+6+2T is in operation nearly on 26000 route kms and CC+8+2T on 5000 kms.
The experience gained by IR in a short span of a few years was almost on similar lines as experience gained by other railway systems of the world. Heavy wear & tear of rails, cracked rails, more frequent renewal of fittings & fastenings such as support clips, insulation joints, rubber pads, poor track geometry due to axle loads, problems on bridges, etc., are some of the typical examples.

**Remedial Measures Suggested**

The remedial measures suggested to mitigate the effects of heavier axle load based on experience gained by different Railways have been brought out earlier. These remedial measures are quite detailed and some of them are very special and these can be of immense use to Indian Railways for running of heavier axle loads. Indian Railways have already nominated some lines for running of heavier axle load of 25 tonnes (called feeder lines). Dedicated freight corridors with an axle load of 30 tonnes have been planned on the golden quadrilateral out of which two corridors (Mumbai & Howrah corridors) are already sanctioned. The work on these projects is likely to start shortly.

**Concluding Remarks**

It is felt that the experience of more than three decades gained by different railway systems of the world could be of considerable use to Indian Railways for running of heavy axle loads.

**References**


4. The Impact of Track Technology on Heavy Haul operations-WR, Lecture in Conference by I.C.E. held at University of Nottingham, 2006.


7. Turnround of Indian Railway by increasing axle load – A Joint Study by IIM Ahmedabad & Railway Staff College, Vadodara, July 2006.


*****

Humanity is acquiring all the right technology for all the wrong reasons.

– R. Buckminster Fuller