NATIONAL INSTITUTE OF TECHNOLOGY SRINAGAR
HAZRATBAL, SRINAGAR, J&K - 190006

RAILWAY AND AIRPORT ENGINEERING (CIV-711)

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COURSE CONTENTS

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1	Importance of transportation systems, history of Railways and its development, development of Indian Railways.	3
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3	Track resistance and tractive effort, gauge problem, super elevation near branching of curves, gradients.	5
4	Track fittings and fastenings, points and crossings, station platforms, yards and sidings.	6
5	Classification of airports; planning, surveys, site selection of airports.	4
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7	Airport pavement design: difference between airport and highway pavements, introduction to various design methods, airport drainage.	6
Total		**36**

REFERENCES

S. No.	Name of Books/Authors/Publishers	Year of Publication
1	Railway Engineering by Satish Chandra and M.M. Aggarwal; Oxford University Press	2007
2	Railway Engineering by Rangwala S.C.; Charotar Publishers, Anand	2001
3	Airport Planning And Design by Khanna, Arora and Jain; Neem Chand Brothers, Roorkie.	2002

LECTURE 1
Introduction to Railway Engineering

Introduction

Since the human race has existed, transportation has played a significant role by facilitating trade, commerce, conquest, and social interaction. The primary need for transportation has been economic, involving personal travel in search of food or work, travel for the exchange of goods and commodities, exploration, personal fulfillment, and the improvement of a society or a nation. The movements of people and goods, which is the basis of transportation, always has been undertaken to accomplish those basic objectives or tasks that require transfer from one location to another. For example, a farmer must transport produce to market, a doctor must see a patient in the office or in the hospital, and a salesman must visit clients located throughout a territory. Every day, millions of people leave their homes and travel to a workplace— be it a factory, office, classroom, or distant city.

1.1 Importance of Transportation

Transportation is an essential element in the economic development of a society. Without good transportation, a nation or region cannot achieve the maximum use of its natural resources or the maximum productivity of its people. Tapping natural resources and markets and maintaining a competitive edge over other regions and nations are linked closely to the quality of the transportation system. The speed, cost, and capacity of available transportation have a significant impact on the economic vitality of an area and the ability to make maximum use of its natural resources. Examination of most developed and industrialized societies indicates that they have been noted for high-quality transportation systems and services. Nations with well-developed maritime systems (such as the British Empire in the 1900s) once ruled vast colonies located around the globe. In more modern times, countries with advanced transportation systems; such as in the United States, Canada, and European countries; are leaders in industry and commerce. Without the ability to transport manufactured goods and raw materials and without technical know-how, a country is unable to maximize the comparative advantage it may have in the form of natural or human resources. Countries that lack an abundance of natural resources rely heavily on transportation in order to import raw materials and export manufactured products.

If a society expects to develop and grow, it must have a strong internal transportation system consisting of good roads, rail systems, as well as excellent linkages to the rest of the world by sea and air. Thus, transportation demand is a byproduct derived from the needs and desires of people to travel or to transfer their goods from one place to another. It is a necessary condition for human interaction and economic competitiveness.

The availability of transportation facilities can strongly influence the growth and development of a region or nation. Good transportation permits the specialization of industry or commerce, reduces costs for raw materials or manufactured goods, and increases competition between regions, thus resulting in reduced prices and greater choices for the consumer.

Transportation is also a necessary element of government services, such as delivering mail, defense, and assisting territories. Throughout history, transportation systems (such as those that existed in the Roman Empire and those that now exist in the United States) were developed and built to ensure economic development and efficient mobilization in the event of national emergencies.

The career opportunities in transportation that engineering students have are exciting. In the past, transportation engineers planned and built the nation's railroads, highways, mass transit systems, airports, and pipelines. New systems, such as magnetically levitated high-speed trains or Intelligent Transportation Systems (ITS), will also challenge the transportation engineers in the future.

1.2 History of Railways

The history of railways is closely linked with civilization. As the necessity arose, human beings developed various methods of transporting goods from one place to another. In the primitive days goods were carried as head loads or in carts drawn by men or animals. Then efforts were made to replace animal power with mechanical power. In 1769, Nicholas Carnot, a Frenchman, carried out the pioneering work of developing steam energy. This work had very limited success and it was only in the year 1804 that Richard Trevithick designed and constructed a steam locomotive. This locomotive, however, could be used for traction on roads only. The credit of perfecting the design goes to George Stephenson, who in 1814 produced the first steam locomotive used for traction in railways. The first public railway in the world was opened to traffic on 27 September 1825 between Stockton and Darlington in the UK. Simultaneously, other countries in Europe also developed such railway systems; most introduced trains for carriage of passenger traffic during that time. The first railway in Germany was opened from Nurenberg to Furth in 1835. The USA opened its first railway line between Mohawk and Hudson in 1833.

The first railway line in India was opened in 1853. The first train, consisting of one steam engine and four coaches, made its maiden trip on 16 April 1853, when it traversed a 21-mile stretch between Bombay (now Mumbai) and Thane in 1.25 hours. Starting from this humble beginning, Indian Railways has grown today into a giant network consisting of 63,221 route km and criss-crossing this great country from the Himalayan foothills in the north to Cape Comorin (Kanyakumari) in the south and from Dibrugarh in the east to Dwarka in the west. Indian Railways has a glorious past of more than 150 years.

1.3 Developments of Indian Railways

Important developments in Indian Railways have been chronologically listed below.

1831-1833: The first idea of a railway line from Madras (now Chennai) to Bangalore conceived to improve the transport system of southern India.

1850: Construction of a railway line from Bombay to Thane started by the Great Indian Peninsula Railway Company.

1850: Work started for a railway line between Bombay and Kalyan on 31 October.

1853: First railway line from Bombay to Thane opened for passenger traffic for a distance of 21 miles (34 km) on 16 April.

1854: Railway line between Howrah and Hoogly (24 miles) opened for passenger traffic on 15 August.

1856: Railway line between Veyasarpady and Waljah (63 miles) opened for traffic under the banner of Madras Railway Company. In fact, this was the first proposal initiated in 1831 but could be completed only in 1854.

1866: Calcutta linked with Delhi, Amritsar, and Bombay.

1850-68: First stage of development of Indian Railways classified as the Early Guarantee System. The Government guaranteed a minimum percentage of return to shareholders in order to attract private enterprises to construct railways, but retained the right to purchase these railways at the end of 25 or 50 years.

A number of railway companies were formed for the construction of railways, namely, East India Railway (EIR), Great Indian Peninsula Railway (GIP), Bombay, Baroda, and Central India Railway (BB&CIR) and Madras State Railway (MSR), etc.

1871: Introduction of metric gauge in India on account of its being cheap and economic.

1903: 96-km-long Kalka–Shimla narrow gauge line opened to traffic on 9 November.

1905: Railway Board assumes office; established with one president and two members.

1925: As a general policy to assume control over company railways, the Government took over the management of East India Railway and Great India Peninsula Railway.

1925: First railway line electrified, consisting of the harbour branch line of GIP

1930: Indian Railways stretched over 66,300 route km

1936: Air conditioning introduced in passenger coaches

1947-51: At the time of independence, there were 42 railway systems consisting of 13 class I railways, 10 class II railways, and 19 class III railways. These included 32 lines owned by ex-Indian states. The Government of India decided to rationalize these railways to improve efficiency and facilitate better management,

1952: Railway Testing and Research Centre (RTRC) set up

1954: Position of chief commissioner for Railways renamed as chairman of Railway Board.

1955: Indian Railway Institute for Civil Engineering, Pune, set up.

1951-56: During the first Five Year Plan, there was special emphasis on rehabilitation and replacement of the assets overstrained and totally neglected during World War II. A sum of Rs 2570 million was allotted to Indian Railways out of a total plan expenditure of Rs 23,780 million.

1956-61: During the second Five Year Plan, the focus was on the development of rail transport capacity to meet the requirement of movement of raw materials and goods. A sum of Rs 8960 million (18.7%) was allotted to Indian Railways (IR) out of a total plan expenditure of Rs 48,000 million.

1961-66: The strategy adopted in the third Five Year Plan was to build up an adequate rail transport capacity to meet the traffic demands. It was proposed that this should be done through modernization of traction, i.e., by switching steam traction to diesel or electric traction in a progressive manner. Track technology and signalling were also improved to match the new traction system. During the third Five Year Plan, a sum of Rs 8900 million (11.9%) was allotted to Indian Railways out of a total grant of Rs 75,000 million.

1969-74: The fourth Five Year Plan was drawn with a renewed emphasis on the twin objectives of modernization of the Railways and improving the operational efficiency of the system by more intensive utilization of the existing assets of the Railways. A sum of Rs 10,500 million (6.6%) was allotted for the development of the Railways out of a total of Rs 159,000 million.

1974: Rail India Technical and Economic Services (RITES) formed.

1976: Indian Railway Construction Company (IRCON) formed

1978: First Metro rail introduced in Kolkata

1985: Computerized Passenger Reservation System introduced

1998: Konkan Railway system becomes fully operational on 26 January

1999: Darjeeling Himalayan Railway declared World Heritage Site by UNESCO

2002-2007: The Tenth Five Year Plan envisages an outlay of Rs 606,000 million, is 4% of a total outlay of Rs 15,256,390 million for the full plan.

1.4 Role of Indian Railways

Since its inception, Indian Railways has successfully played the role of the prime carrier of goods and passengers in the Indian subcontinent. As the principal constituent of the nation's transport infrastructure, the Railways has an important role to play.

(a) It helps integrate fragmented markets and thereby stimulate the emergence of a modern market economy.

(b) It connects industrial production centres with markets as well as sources of raw material and thereby facilitates industrial development.

(c) It links agricultural production centres with distant markets as well as sources of essential inputs, thereby promoting rapid agricultural growth.

(d) It provides rapid, reliable, and cost-effective bulk transportation to the energy sector; for example, to move coal from the coalfield to power plants and petroleum products from refineries to consumption centres.

(e) It links people with places, enabling large-scale, rapid, and low-cost movement of people across the length and breadth of the country.

(f) In the process, Indian Railways has become a symbol of national integration and a strategic instrument for enhancing our defense preparedness.

LECTURE 2
Indian Railways

2.1 Classification of Railway Lines in India

The Railway Board has classified the railway lines in India based on the importance of the route, the traffic carried, and the maximum permissible speed on the route. The complete classification is given below.

2.1.1 Broad Gauge Routes

All the broad gauge (BG) routes of Indian Railways have been classified into five different groups based on speed criteria as given below.

Group A lines

These lines are meant for a sanctioned speed of 160 km/h.

Group B lines

These lines are meant for a sanctioned speed of 130 km/h.

Group C lines

These lines are meant for suburban sections of Mumbai, Kolkata, and Delhi.

Group D and D Spl lines

These lines are meant for sections where the maximum sanctioned speed is 100 km/h.

Group E and E Spl lines

These lines are meant for other sections and branch lines.

D Spl and E Spl routes: Based on the importance of routes, it has been decided that few selected routes presently falling under D and E routes will be classified as D special and E special routes.

2.1.2 Metre Gauge Routes

Depending upon the importance of routes, traffic carried, and maximum permissible speed, the metre gauge (MG) tracks of Indian Railways were earlier classified into three main categories, namely, trunk routes, main lines, and branch lines. These track standards have since been revised and now the MG routes have been classified as Q, R1, R2, R3, and S routes as discussed below.

Q routes

Routes with a maximum permissible speed of more than 75 kmph.

R routes

Routes with a speed potential of 75 kmph and a traffic density of more than 1.5 GMT (gross million tonne(s) per km/annum). R routes have further been classified into three categories depending upon the volume of traffic:

(i) R1—traffic density more than 5 GMT

(ii) R2—traffic density between 2.5 and 5 GMT

(iii) R3—traffic density between 1.5 and 2.5 GMT

S routes

Routes with a speed potential of less than 75 kmph and a traffic density of less than 1.5 GMT. These consist of routes that are not covered in Q, R1, R2, and R3 routes. S routes have been further sub-classified into three routes, namely, S1, S2, and S3. S1 routes are used for the through movement of freight traffic, S3 routes are uneconomical branch lines, and S2 routes are those which are neither S1 nor S3 routes.

2.2 General Features of Indian Railways

Indian Railway is the second largest state-owned railway system in the world (after Russian Railways) under unitary management. The important features of Indian Railways are described here.

2.2.1 Track

Track or permanent way is the single costliest asset of Indian Railways. It consists of rails, sleepers, fittings and fastenings, ballast, and formation.

2.2.2 Locomotives

In the year 2003–04, Indian Railways owned a fleet of 7817 locomotives including 45 steam locomotives, 4769 diesel locomotives, and 3003 electric locomotives. Diesel and electric locomotives, which are more than twice as powerful as steam locomotives, have progressively replaced steam locomotives. Owing to the heavy investments involved in replacing all the existing steam locomotives with diesel and electric locomotives, steam locomotives were gradually phased out, and it was decided that these should be retained in service till the expiry of their codal life or 2000 AD, whichever is earlier. Accordingly, most steam locomotives of the Indian Railways have been phased out.

2.2.3 Traction

The traction mix has significantly changed in the last two decades and Railways have been progressively switching over to diesel and electric traction. Though steam locomotion involves the least initial costs, it is technologically inferior to diesel and electric traction in many respects. On the other hand, diesel and electric locomotives have superior performance capabilities, the electric locomotive being the more powerful one of the two. Electric traction is also the most capital intensive and, therefore, requires a certain minimum level of traffic density for its economic use. In broad terms, the traction policy on Indian Railways envisages the extension of the electrification of high-density routes as dictated by economic and resource considerations and the dieselization of the remaining services.

2.3 Undertakings Under Ministry of Railways

Several agencies provide technical and consultancy services to the Railways. These agencies work under the control of the Ministry of Railways, Government of India. For example, the funds for the Railways are raised by the Indian Railway Finance Corporation (IRFC). Similarly, the catering and internet ticketing services of IR are looked after by another agency called Indian Railway Catering and Tourism Corporation Ltd (IRCTC). A brief description of the various agencies working under the Ministry of Railways is given in the following sections.

2.3.1 Rail India Technical and Economic Services Ltd

The Rail India Technical Economic Services Ltd (RITES), a Government of India Undertaking, provides consultancy services on all aspects of the Railways from concept to completion. RITES is closely linked with Indian Railways and is in a privileged position to draw freely upon the huge pool of experience, expertise, and technical know-how acquired over a century of operations for Indian Railways.

2.3.2 Indian Railways Construction Company Ltd

IRCON International Ltd, a public-sector undertaking under the Ministry of Railways, was incorporated in 1976 as an Indian Railway construction company, as a specialized agency to undertake major railways projects both in India and abroad.

2.3.3 Indian Railway Finance Corporation

IRFC was incorporated as a public limited company in December 1986 with the sole objective of raising funds for the railways from the market based on the requirement of the Ministry of Railways to partly finance the plan outlay and meet the developmental needs of IR.

2.3.4 Container Corporation of India Ltd

Container Corporation of India Ltd (CONCOR) was incorporated in March 1988 under the Companies Act 1956 as a public-sector enterprise under the Ministry of Railways.

2.3.5 Konkan Railway Corporation Ltd

The company was formed with the participation of four states, namely, Maharashtra, Goa, Karnataka, and Kerala, along with the Ministry of Railways with Rs 8000 million as equity and Rs 27,500 million raised in bonds, funding the total cost of the project of Rs 35,500 million.

2.3.6 Indian Railway Catering and Tourism Corporation Ltd

IRCTC is a new corporation under the Ministry of Railways. Some of the important projects undertaken by the corporation are the following:

Catering services: IRCTC has awarded 17 contracts for on-board catering services in trains, taking the total number of trains covered to 71. These include 5 Rajdhani, 2 Shatabdi, 17 Jan Shatabdi, and 47 mail/express trains.

Internet ticketing system: The facility of booking railway tickets through the internet has been extended all over the country. Payment is accepted through credit cards, debit cards, or direct debit to the account of the customer.

Packaged drinking water project: The first Rail Neer plant of the corporation was inaugurated in May 2003, and a second in February 2004. Good quality drinking water is supplied to passengers and other rail users.

2.3.7 RailTel Corporation of India Ltd

RailTel is a public-sector undertaking under the administrative control of the Ministry of Railways. RailTel was incorporated in September 2000 with an authorized capital of Rs 10,000 million.

2.3.8 Rail Vikas Nigam Ltd

Rail Vikas Nigam Limitd (RVNL) is a special purpose organization set up to execute two vital components of National Rail Vikas Yojna launched by the Government of India. Its main objectives are to undertake projects of development, financial resource mobilization, and execution of projects on a commercial basis using largely non–budgetary funds.

2.3.9 Pipavan Railway Corporation Limited

Pipavan Railway Corporation Ltd (PRCL), a joint venture of the Ministry of Railways and Gujarat Pipavan Port Limited (GPPL) with equal equity participation, was formed to execute the Surendra Nagar–Rajula–Pipavan port gauge conversion/ new line project.

2.3.10 Centre for Railway Information Systems

Centre for Railway Information Systems (CRIS), which is an autonomous body under the patronage of Ministry of Railways, was established as a non-profit-making organization and entrusted with the design, development, and information of all major computer services of the Railways.

2.3.11 Indian Railway Welfare Organisation

Indian Railway Welfare Organisation (IRWO) an autonomous body under the patronage of Ministry of Railways, was registered on 25 September 1989 under the Societies Registration Act for meeting the specific needs of housing for serving and retired railway employees.

-------------------------End of unit 1----------------------------

LECTURE 3
Permanent Way

3.1 Permanent Way

The track or permanent way is the railroad on which trains run. It consists of two parallel rails fastened to sleepers with a specified distance between them. The sleepers are embedded in a layer of ballast of specified thickness spread over level ground known as formation. The ballast provides a uniform level surface and drainage, and transfers the load to a larger area of the formation. The rails are joined in series by fish plates and bolts and these are fastened to the sleepers with various types of fittings. The sleepers are spaced at a specified distance and are held in position by the ballast. Each component of the track has a specific function to perform. The rails act as girders to transmit the wheel load of trains to the sleepers. The sleepers hold the rails in their proper positions, provide a correct gauge with the help of fittings and fastenings, and transfer the load to the ballast. The formation takes the total load of the track as well as of the trains moving on it. The permanent way or track, therefore, consists of the rails, sleepers, fittings and fastenings, the ballast, and the formation as shown below.

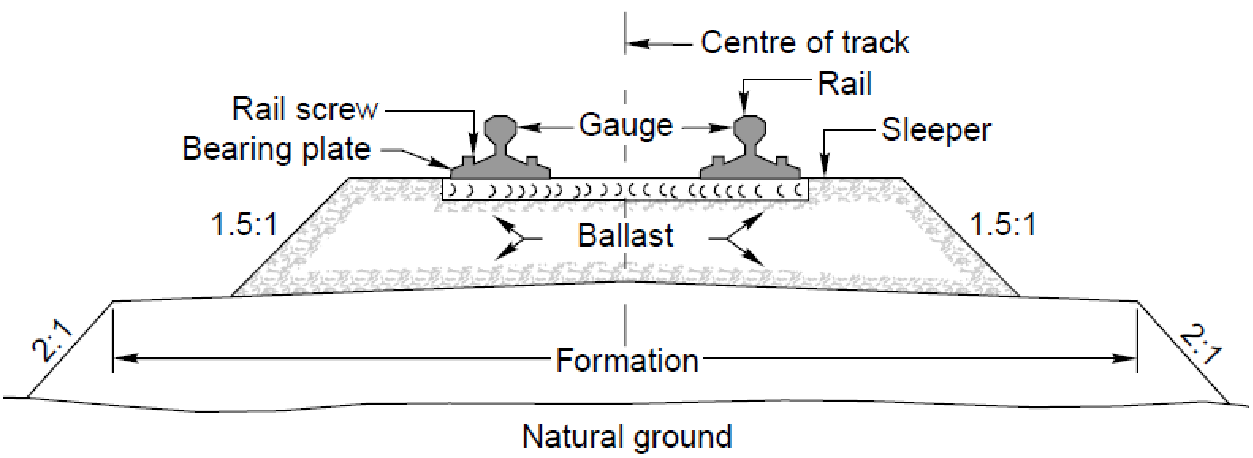

Fig. 3.1 Various components of a track

In early days, a temporary track used to be laid for carrying earth and other building material for the construction of a railway line; this temporary track used to be removed subsequently. The track is also called the permanent way in order to distinguish the final track constructed for the movement of trains from the temporary track constructed to carry building material.

3.2 Requirements of a Good Track

A permanent way or track should provide a comfortable and safe ride at the maximum permissible speed with minimum maintenance cost. To achieve these objectives, a sound permanent way should have the following characteristics.

(a) The gauge should be correct and uniform.

(b) The rails should have perfect cross levels. In curves, the outer rail should have a proper super elevation to take into account the centrifugal force.

(c) The alignment should be straight and free of kinks. In case of curves, a proper transition should be provided between the straight track and the curve.

(d) The gradient should be uniform and as gentle as possible. The change of gradient should be followed by a proper vertical curve to provide a smooth ride.

(e) The track should be resilient and elastic in order to absorb the shocks and vibrations of running trains.

(f) The track should have a good drainage system so that the stability of the track is not affected by waterlogging.

(g) The track should have good lateral strength so that it can maintain its stability despite variations in temperature and other such factors.

(h) There should be provisions for easy replacement and renewal of the various track components.

(i) The track should have such a structure that not only its initial cost is low, but also its maintenance cost is minimum.

3.3 Track Specifications on Indian Railways

Most of the railway lines on Indian Railways are single lines, generally with a formation 6.10 m (20 ft) wide for broad gauge and 4.8 m (16 ft) wide for metre gauge. The formation is generally stable except in areas where clayey soil or other types of shrinkable soils are found. Most of the track is straight except for 16% of the track on BG and MG and 20% of the track on NG, which is on curves. The maximum degree of curvature permissible is 10° on the broad gauge, 16° on the metre gauge, and 40° on the narrow gauge.

The ballast used most often is broken stone ballast, but in some areas, sand, moorum, and coal ash have also been used. About a 20 cm to 30 cm (8" to 12") cushion of ballast is normally provided below the sleepers to transfer the load evenly and to impart the necessary resilience to the track.

The different materials used to construct sleepers are wood (31%), cast iron (42%), and steel (27%). Experience has shown that cast iron sleepers are not suitable for high-density routes. Prestressed concrete sleepers have recently been developed by Indian Railways and are proposed to be progressively laid on group A and B routes. Sleepers are laid to various sleeper densities varying from (M + 7) to (M + 4) or 1540 per km to 1310 per km depending upon the weight and volume of traffic. Here M stands for length of rail in metres. (M + 7) means 20 sleepers per rail length for BG and 19 sleepers per rail length for MG.

The rails standardized for Indian Railways are 60 kg and 52 kg for BG and 90 R, 75 R and 60 R, for MG (in 90 R, 75 R, etc., R stands for revised British specifications). Rails are normally rolled in 13 m (42 ft) lengths for BG lines and 12 m (39 ft) lengths for MG lines. The rails are welded together to form longer rails and are laid progressively on the track in order to reduce maintenance costs and noise levels and thereby provide more comfortable travel. The rails are welded in depots in three rail panels, normally by the flash-butt welding method, to form short welded rails (SWRs). Long welded rails (LWRs) are also being progressively introduced on various routes of Indian Railways. Thermit welding is normally done at the site to convert short welded rails into long welded rails. The fastenings used are mostly screw and rail spikes, keys, etc. In recent times, elastic fastenings such as elastic rail clips and IRN202 clips have also been standardized on Indian Railways.

The turnouts used are normally 1 in 8.5 for goods trains and 1 in 12 as well as 1 in 16 for passenger trains. 1 in 20 turnouts were also designed sometime back for permitting higher speeds on the turnout side, but these have since been discontinued. Curved switches and thick web tongue rails have also been recently introduced to permit higher speeds at turnouts.

3.4 Coning of Wheels

The tread of the wheels of a railway vehicle is not made flat, but sloped like a cone in order to enable the vehicle to move smoothly on curves as well as on straight tracks. The wheels are generally centrally aligned on a straight and level surface with uniform gauge, and the circumference of the treads of the inner and outer wheels are equal.

The problem, however, arises in the case of a curve, when the outer wheel has to negotiate more distance on the curve as compared to the inner wheel. Due to the action of centrifugal force on a curve, the vehicle tends to move out. To avoid this, the circumference of the tread of the outer wheel is made greater than that of the inner wheel. This helps the outer wheel to travel a longer distance than the inner wheel.

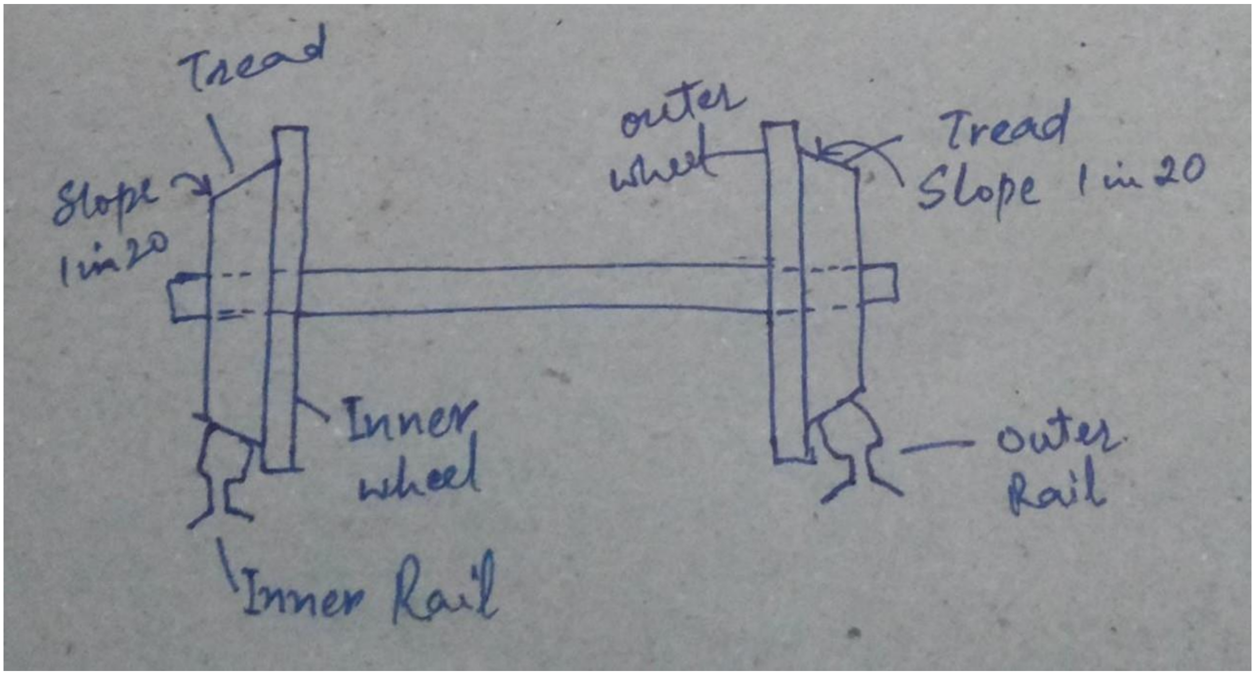

Fig. 3.2 coning of wheels

The wheels of a railway vehicle are connected by an axle, which in turn is fixed on a rigid frame. Due to the rigidity of the frame, the rear axle has a tendency to move inward, which does not permit the leading axle to take full advantage of the coning. The rigidity of the frame, however, helps to bring the vehicle back into central alignment and thus works as a balancing factor.

The coning of wheels helps to keep the vehicle centrally aligned on a straight and level track also. Slight irregularities in the track do occur as a result of moving loads and the vagaries of the weather. The wheels, therefore, move from side to side and therefore the vehicles sway. Due to the coning of wheels, this side movement results in the tread circumference of one wheel increasing over the other. As both the wheels have to traverse the same distance, this causes one wheel to slide. Due to the resistance caused by the sliding, any further side movement is prevented. If there was no coning, the side movement would have continued and the flange of the wheel would have come in contact with the side of the rail, causing jerks and making the ride uncomfortable.

Coning of wheels causes wear and tear due to the slipping action. It is, however, useful as
(a) it helps the vehicle to negotiate a curve smoothly,
(b) it provides a smooth ride, and
(c) it reduces the wear and tear of the wheel flanges.

3.5 Tilting of Rails

Rails are tilted inward at an angle of 1 in 20 to reduce wear and tear on the rails as well as on the tread of the wheels. As the pressure of the wheel acts near the inner edge of the rail, there is heavy wear and tear of the rail. Lateral bending stresses are also created due to eccentric loading of rails. Uneven loading on the sleepers is also likely to cause them damage. To reduce wear and tear as well as lateral stresses, rails are titled at a slope of 1 in 20, which is also the slope of the wheel cone. The rail is tilted by ‘adzing’ the wooden sleeper or by providing canted bearing plates.

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Note: For any queries / clarifications, contact
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