People's Democratic Republic of Algeria

Ministry of higher education and scientific research

Mohamed Kheider University of Biskra

Faculty of Architecture, Urbanism, Civil Engineering and Hydraulic

Department of Civil and Hydraulic Engineering

Course handout :

Subject : Railway infrastructure

Level : 3rd Year License (sector : Public Works)

Author : Dr. BEN AMMAR Ben Khadda, Lecturer "A"

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Email : b.benammar@univ-biskra.dz

Lesson Plan

1- Overall information about the course

This section allows you to provide all the information regarding the course :

• This module is taught at Mohamed Kheider University in Biskra.

• Teaching unit : UED 3.1 - semester : 5

• Subject title : Railway infrastructure

• The hourly volume of the module is around 10:30 p.m. Or 01:30 of weekly lessons.

• Credits : 1

• Coefficient : 1

2- Presentation of the course

Infrastructure provides essential services that keep cities around the world running. Governments continue to invest to develop them based on their strengths.

The railway is among these infrastructures which can also connect isolated towns as well as the transport of goods over very long distances as well as the contribution to the preservation of the environment and sustainable development since this mode of transport makes it possible to take large loads.

This is why we study the techniques for creating railway infrastructures.

3- Content of the material :

- General information on rail transport

Interest in rail transport (Train, Metro, Tramway).

- Geometric characteristics of railway tracks

Rails and their metal structure, evaluation of loads and overloads.

- Behavior and sizing of railway tracks

- Sanitation works for a railway line

4- prerequisites

In order to achieve the course objectives, it is imperative to master the following modules :

- Resistance of materials 1.
- Ground Mecanic.
- Reinforced concrete, Construction materials 1.
- Metallic structures.

5- Evaluation method :

Review : 100%.

Summary

Preamble

This work is a course in the subject “railway infrastructure” aimed at graduates, masters in tracks and engineering structures and particularly at students in the 3rd year of an academic degree in public works. This handout is developed with the aim of allowing the student to assimilate and understand on a functional level, the railway infrastructure must present a relationship with the development of bases in the following areas :

- Operation and maintenance of the quality of railway infrastructure ;

- Development of railway infrastructure (planning, project study, financing and construction);

Infrastructure/rolling stock interface ; may also concern rolling stock projects.

- Organization and efficient operation of the railway infrastructure.

The aspect of security (which includes environmental protection) is not strictly speaking a criterion in this delimitation.

The notion of railway infrastructure, in its broad sense, covers both the network of railway tracks and passenger stations, the service tracks for the sorting and training of trains, the train storage tracks, the maintenance centers for railway rolling stock and various installations such as goods terminals, combined transport sites and even diesel stations, but also the key information which makes it possible to operate this equipment and develop a range of services.

Efficient transportation is a critical component of economic development, both nationally and globally. The availability of transportation affects global development patterns, and can stimulate or hinder economic growth within individual nations.

Transportation investments bring together factors of production into a network of relationships between producers and consumers to create a more efficient division of production, leverage geographic comparative advantage, and provide the means to expand economies of scale and scope. .

Chapter 1 : General information on rail transport

1.1 Introduction

Rail transport is the method of transporting individuals and goods by rail (by train).

The railway is a guided transport system used to move people and goods. It consists of specialized infrastructure, rolling stock and operating procedures that most often involve humans.

The technical characteristics of rail transport are that the bearing is steel on steel and the movement is in convoy.

Rail transport takes place on railway tracks, which includes : train, metro and tram. It has certain advantages over other modes of transport :

1. Transport by rail is often faster than by road (guidance system and absence of obstacles).

2. It is relatively inexpensive and allows the transportation of large loads.

There is a wide variety of transport systems deriving from the basic principle of the railway exists. The common points between these systems are iron-on-iron rolling and guidance. The variations lie in the structure and mode of operation.

1.2 In urban areas

1.2.1 The metro

In urban areas, due to the multitude of infrastructures (roads, pipes, etc.), and the need to transport a high number of passengers, the use of metros, based on underground or aerial infrastructures to limit the occupied space constitutes a solution favored by large cities.

1.2.2 The tram

To serve an entire metropolis, the Regional Express Network system is used. This involves setting up routes to transport a large number of travelers, often between suburbs and urban centers.

The tramway provides a more refined service by inserting itself into the urban fabric. However, its capacity per line is much lower than that of the metros. However, its significantly lower cost allows, for the same budget, to multiply the lines and therefore the places served and thus not to artificially concentrate the flow of travelers.

1.3 Special techniques

By its operating principle, a train cannot climb significant gradients. To compensate for this, the engineers had the idea of placing a third axis on which the convoy rests, this is the rack railway.

If the slopes are even greater, we use the funicular. Traction is then provided by a cable. In some cities (San Francisco for example), there are cable traction trams which allow the traction motor to be concentrated at a single point.

1.3.1 The cable car

The track is made up of one or more fixed supporting cables. This full-fledged railway installation was originally called an “aerial funicular”. The Flammarion dictionary of

1982 defines the cable car as a “type of railway whose vehicles travel on overhead cables acting as rails”.

The cable car on track

These lightweight systems are made up of guided cabins, towed by one or more cables.

To limit the space occupied, some have thought of monorail. This system is relatively little used for passenger transport but common in the industry with its load-bearing version (rail on the ceiling).

1.3.2 Evolution track (the lift train)

One of the avenues for development in the railway is the magnetic levitation train. Tests of this system are promising

Conversely, other experiments focus (or have focused) on gravitational trains, driven by gravity, like amusement park trains which, once launched, move forward thanks to their own inertia.

1.4 The advantages of rail transport

It has many advantages, the main ones of which are :

• Transportation of large quantities of goods over long distances

• High transport security

• Road relief

• Ecological transport due to low CO_2 emissions

• Metal-to-metal contact limits rolling resistance to a low value, which also allows high loads to be towed with power and on-board personnel often reduced to one man. In return, this metal-to-metal contact increases braking distances.

• Lane changes can only be made at switches, overtaking is impossible. This constitutes safety against accidents.

• The movement of wagons does not take place in isolation as on the road but in convoy.

• The throughput of a railway is greater than that of a 4-lane highway.

• The average cost per kilometer of a two-lane railway is half as expensive as that of a two-lane motorway under the same conditions.

• For the same number of kilometers transported, the railway consumes two to three times less fuel per tonne transported than a heavy truck.

Company-to-company deliveries are rarely possible by train. The disadvantages of rail transport are offset by the flexibility of road transport by truck. The intermodality of road/rail means of transport leads to a reduction in CO_2 emissions and protects the environment and is considered a sustainable mode of transport.

Rail transport is a more environmentally friendly means of transport than air, road or sea transport.

The train is much more energy efficient : it consumes 2 to 3 times less energy than road transport.

Rail transport emits few greenhouse gases, which are responsible for global warming :

- It emits 1.3 % of CO_2 emissions linked to transport in mainland France, compared to 93% for cars

- it requires very little fossil fuels

- the electricity necessary for locomotive traction comes in Algeria from sources that emit low greenhouse gases (nuclear and hydraulic energy)

Rail transport as collective transport of people benefits from the same ecological advantages as rail freight. Rail transport, on the other hand, is responsible for noise pollution, which has consequences in terms of health for those living near stations or railway lines.

The rail transport of goods or people requires the implementation of transfer infrastructures, to route and transport people to their train, and the goods or trailer and truck, to their platform, and to then perform the reverse operation. The infrastructures consist of passenger stations, marshalling yards, combined transport sites (gantry cranes, cranes).

Two relatively recent developments mark an inflection in this general evolution. These are :

• For passenger transport, in a few privileged countries, the advent of high speed.

• The capacity of rail transport to develop great power, from electricity, unlike road transport.

1.5 The current Algerian railway network

The current and future rail network includes three sets of lines :

Currently, the total length of the rail network is 4,626 km and will reach a length of 6,500 km in the next three years, including 3,854 km of operated lines, 449 km of double-track lines and 323 km of electrified lines (suburbs of Algiers and eastern mining line).

- The standard gauge northern ring road linking Annaba, Constantine, Algiers, Oran with its extensions to the Eastern (Tunisia) and Western (Morocco) borders. This ring road constitutes the main artery of trade between the currently most developed regions in the country with connections connecting it to ports and various cities (Guelma, Skikda, Bejaia, Tizi Ouzou, Mostaganem, Arzew, Ain-Temouchent, El Ghazaouet , Jijel...),

- Ring road of the high plateaus

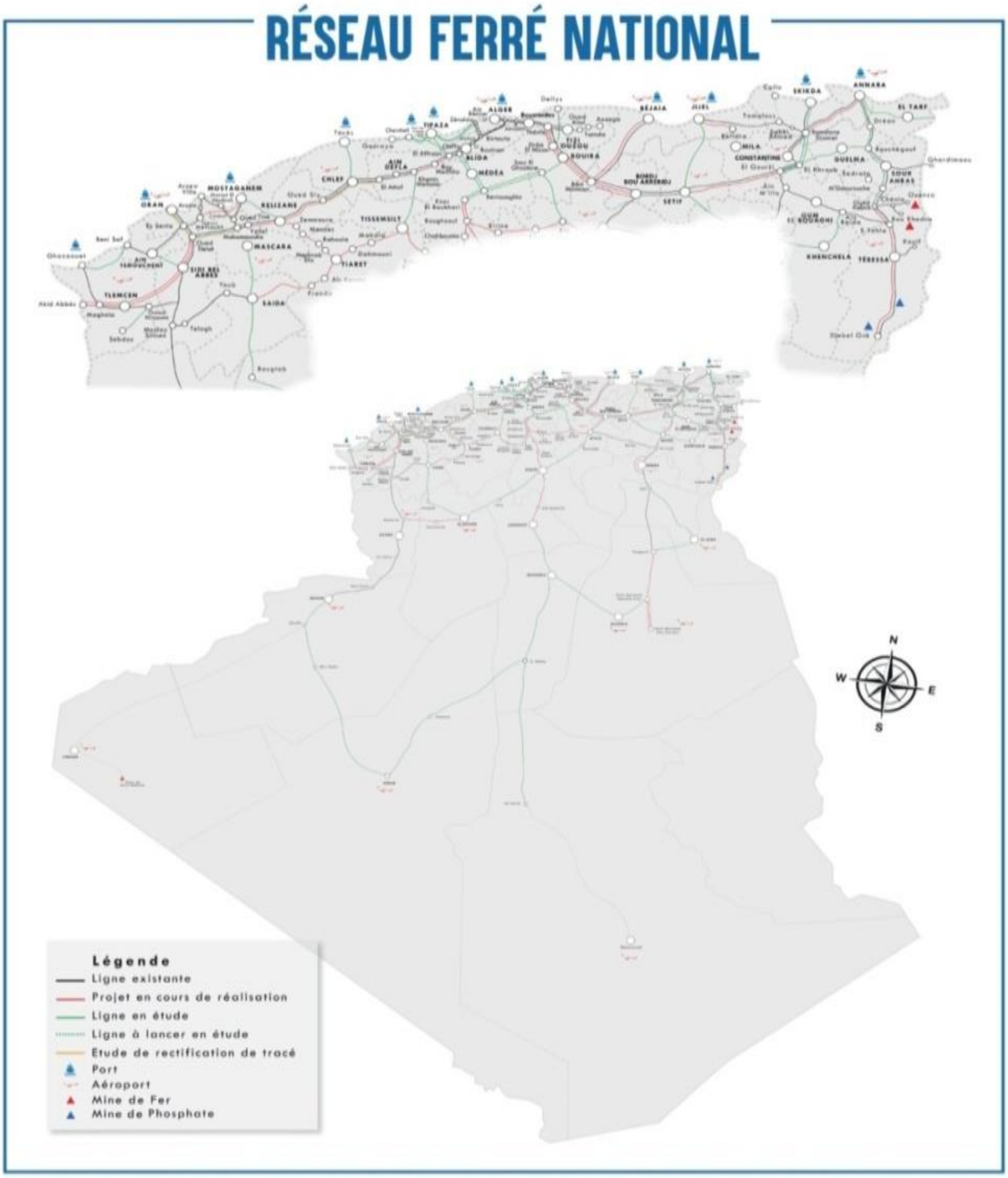
- Eastern mining line : (588 km) standard gauge Annaba/Djebel•Onk whose activity is essentially linked to the transport to the Annaba area of iron minerals from Ouenza - Bou-Khadra and phosphates from Djebel-Onk.

- Western penetrating, Eastern penetrating (El Gourzi – Hassi Messaoud) with normal gauge, and a central penetrating with narrow gauge.

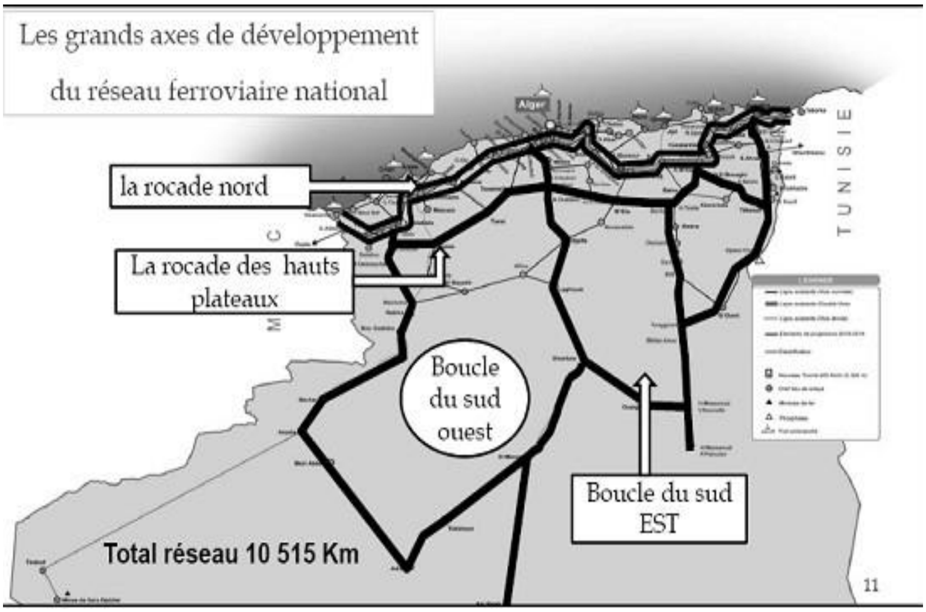
- South East loops and South West loop

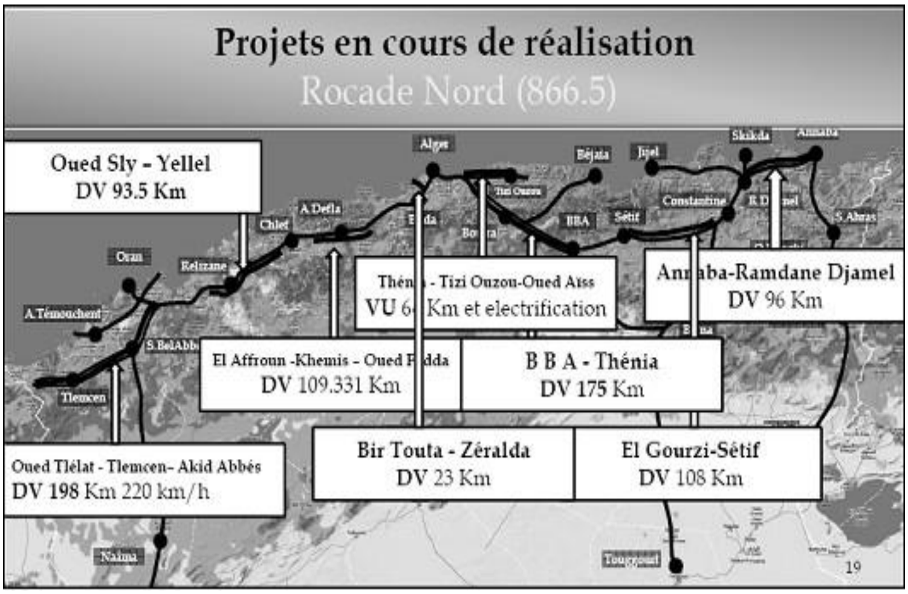
- The highlands ring road connecting the towns of Tébessa/Ain-M'Lila/Ain-Touta/M'sila.

The national railway network in operation :



By 2023, the length of this rail network will be 12,500 kilometers.





The Algerian railway network has recently experienced electrification in certain sections, which should soon lead to the installation of high-speed trains which should connect the country's most important cities. The stakeholders in the rail transport sector are the SNTF group (Société Nationale des Transports Ferroviaires “SNTF” = traffic manager and its thirteen subsidiaries), the National Agency for Studies and Monitoring of the Realization of Rail Investments (ANESRIF), the INFRAFER Company and some private infrastructure construction and maintenance companies.

This network extends over 4,626 km and has more than 200 stations mainly covering the north of the country. It is made up of 2,888 km of normal roads :

Since 2004, it has experienced electrification in certain sections, which should soon lead to the installation of high-speed trains which should connect the most important cities in the country (Bordj Bou Arréridj-Khemis Miliana, Boumedfaa-Djelfa, Touggourt-Hassi Messaoud, Oued Tlilat- Moroccan borders, Relizane-Tiaret-Tissemsilt, Oued Sly-Yellel, Algiers-Annaba, Algiers-Sétif-Tizi Ouzou, Algiers-Oran, Oran-Tlemcen, etc.).

Current railway projects include the electrification of 1,000 km of railway tracks and the construction of 3,000 km of railways.

The Algerian network is the second largest in kilometers on the African continent.

Metro : Algiers Metro.

Tramway : Constantine Tramway, Oran Tramway, Algiers Tramway, Sidi Bel-Abbés, Ouargla, Mostaganem, Sétif and Annaba.

1.6 Institutional stakeholders

Project management for railway sector projects is ensured by the National Agency for the Study and Construction of Railway Infrastructure (ANESRIF). The management and operation of the entire railway network is entrusted, under the concession regime, to the National Railway Transport Company (SNTF).

The railway is the complex set of services and structures which can transport goods and passengers across the territory of a country, if we consider the material basis of the railway distinguishes two main parts :

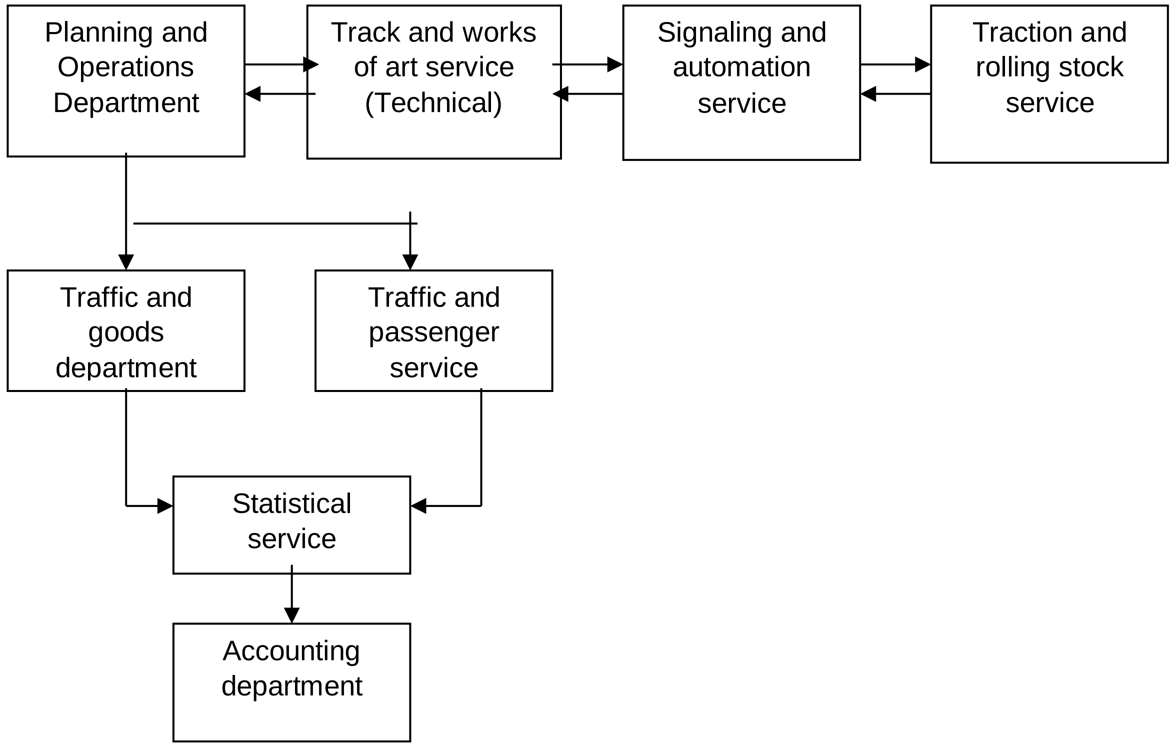
a- Fixed installations ;

b- Rolling stock.

Rolling stock includes :

- Traction means (different types of locomotives) ; wagons ; cars ; self-propelled.

The organization of the railway company is essentially based on an organization chart made up of several services, each service fulfilling a specific mission.



a) operating lever

A maneuvering lever is a means of changing train direction from a main track to a second main track or to a service track.

b) Rail joint

The fishplates are steel plates of approximately small length (25 to 30 cm) which match the shape of the core of a rail, which serve as a means of fixing using the bolts of two cut rails.

c) Free garage

The free garage marks the limit of the part of the track to be occupied by parked vehicles. On the theoretical position of the free garage, the distance between two tracks is 3.57 m. For safety reasons, the free garage will be installed 1.0 m away from the theoretical free garage.

d) Dock

It is used at railway stations, the platform level is set at 55 cm above the rail level, measured at the edge of the platform. In order to avoid any stagnation of water, the covering will be laid at a slope of 2%. The dimensions of the quay are : width 6.00 m, length ≥ 300 m.

e) Track marking

A railway line boundary constitutes a kilometric and hectometric boundary using kilometric and hectometric posts which will be installed to the left of the direction of the train.

f) Dilation device

There are two types of track, the tracks which include expansion devices installed every three lengths of 18 m, and the tracks made in LRS (long welding resistance) these are tracks which do not include expansion devices. In this case (LRS) the joints between two rails (made every 18 m in the straight part and greater than or equal to 6 m in the curve) are made by aluminothermic welding.

g) Ballast guard wall

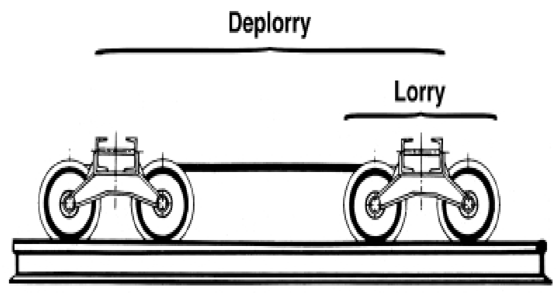
These are L-shaped sections made of lightly reinforced concrete, which serve to protect the ballast slope shape and to keep the ballast. Generally used on curves and in longitudinal profile areas where the line level is important.

1.7 Equipment necessary for railway construction or renewal work

A) Common tools

- Diplory

Used for transporting all types of materials on rail. These devices are composed of two elements absolutely independent of each other or connected by a towing bar. They also allow rolling storage. These elements can be spaced at the desired distance.



- Forks and shovels

Generally used for ballast adjustment, especially on curves and in cleaning, cleaning and clearing work.

- Ripper pliers

It is a steel lever with beveled ends, one end of which is curved. It is used in many professions for its primary function, to serve as a lever.

- Handcars

It is a means of transporting workers on the track offering space for four adults, at least two of whom must pedal to move the handcar forward. The other passengers are seated in a seat. Depending on the energy exerted while pedaling, the speed can vary between 5 and 15 km/h.

- Screwdrivers

Lag bolt tightening work - Rail attachment bolts and fishplate bolts (Track renewal and maintenance).

B) Specious devices

- Regaleuse

Machine used in ballast slope shape adjustment, construction and maintenance of railway track (ballast and rail).

- Gantry for installing and removing railway panels

This machine is used for removing or installing either mounted panels of rails and sleepers or rails and sleepers separately.

- Tractors and locomotives

Which is used for traction and movement of a series of attached wagons or a series of passenger transport locomotives.

Tractor locomotive

- Ripper

It is used for shifting and adjusting the axis in the event of misalignment of one of the parts of the track.

- Track stabilizer train (or dynamic track stabilizer)

Use : compaction of the ballast by lateral vibration.

Dimensions : Length : 29.48 m

Maximum speed : 80 km/h

Total mass : 69 T

- Loading wagons and transport of materials

It is used for loading and transporting materials (ballast, earthworks materials).

- Stripper

It allows the ballast to be loaded, removed and sorted for possible reuse by dumping it on the track.

- The Bourreuse

A tamper (the exact term is tamper-straighter-self-leveler, because modern machines fulfill these three functions, which was not the case with the first machines) is a railway work machine used for positioning the track and compacting ballast under the sleepers. The principle of mechanical track jamming was invented by Auguste Scheuchzer.

The machine acts via vibrating metal picks, the tampers are plunged into each side of the sleepers and compress the ballast layer by mechanical tightening. The double vibratory and compressive action constitutes the tamping.

The operation is carried out at the same time as a rectification of the route, the longitudinal and transverse leveling (slope) of the track. This rectification occurs by raising the level of each line of rail since it is impossible to lower it.

2.1 Constitution of a railway

The constituent elements of the railway track are : ballast, sleepers, rails and their accessories.

The rails are attached to the sleepers which rest on the ballast. This extends horizontally outside the rails over a length of approximately 1 m.

The transverse profile (cross profile) of a double track line with fast circulation in a straight alignment is established on the plain is shown in figure 1.

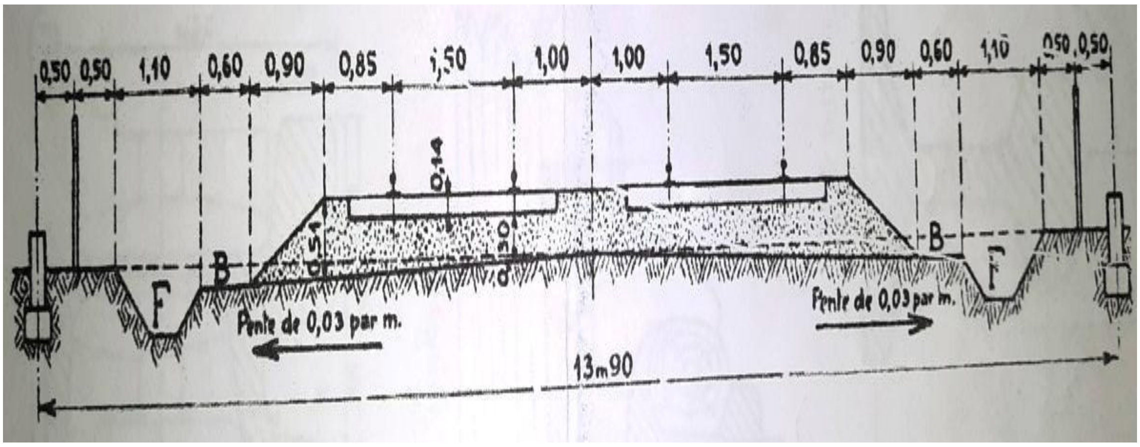


Figure 1 : Transverse profile of a double-track line.

Figure 2 gives the cross section of a single track line.

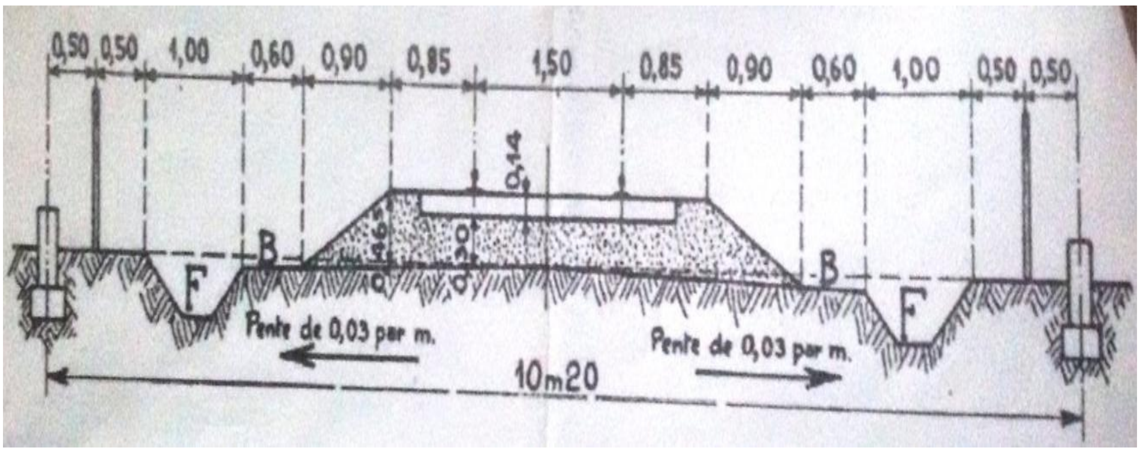


Figure 2 : Transverse profile of a single-track line.

2.2 Characteristics of a track

When building a railway, we initially limited ourselves to establishing a single-track line, but even if we foresee that in the future traffic will be very important, we expropriate from the start a strip train wide enough to subsequently accommodate the 2nd track. The structures (tunnels, viaducts, etc.) were originally built for 2 lanes. The gauge of the track, that is to say the distance between the interior edges of the rail beads, is 1,435 m. Which gives a center distance of 1.5 m.

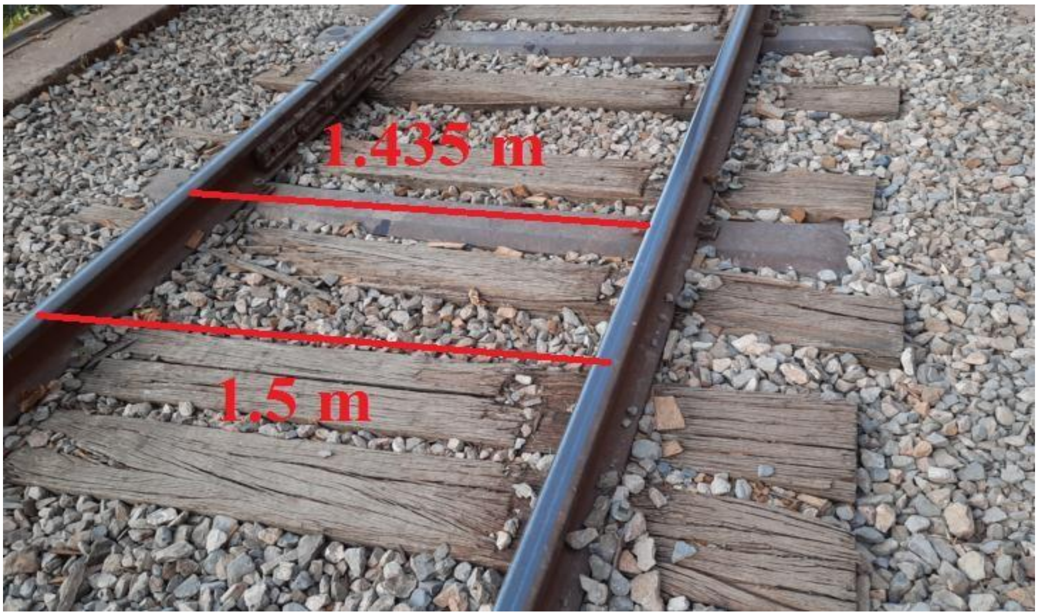


Figure 3 : Gauge between two rails

The spacing between the tracks must allow 2 trains to pass each other without brushing against each other even if a door opens. In the guys we give the gap a width of 3 meters less.

2.3 Components of the railway track

2.3.1 The rail

By definition, the rail is a beam for distributing wheel loads in the vertical, transverse and longitudinal direction and serves to guide and hold the axle, the steel/steel wheel-rail contact having the characteristic of limiting the resistance to the advancement through a reduced contact surface and to transfer the loads to the crosspiece via the attachment system.

2.3.1.1 Type of rails

The rails are characterized by :

• Their profile

• The grade of steel they are made of.

There are different profiles and shades of rail, adapted to the uses for which they are intended. The majority of rolled profiles at the beginning of the railway only had a limited life, on the other hand, the double mushroom and the Vignole rail were widely used. It is appropriate to add a grooved profile which makes it possible to lay the tracks on the roadway, particularly in ports.

All these profiles have the following elements in common : at the upper part the mushroom which supports the wheel contacts, the core, middle part ; the skate, lower part ; the joint surfaces, inclined parts of the mushroom and the shoe which allow the tightening of the joint plates. The mushroom of the grooved profile also includes the equivalent of a counter rail which allows the wheel flanges to travel on the roadway.

Figure 4 : Example of a rail

2.3.1.2 Efforts applied

The rail supports and guides the wheel of the rolling stock, it is therefore the essential element of track safety. The rails directly receive the forces exerted on the track; these efforts are vertical, transversal and longitudinal. The following diagram shows the forces applied to a rail.

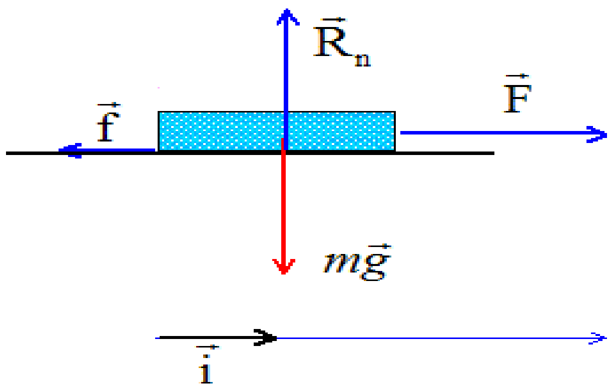


Figure 5 : The forces applied to the rails

2.3.1.2.1 Vertical forces

These are the static forces due to the load of the vehicle wheels. These static forces can increase considerably due to the dynamic effect of very high speeds.

Cv = 1+ (V2/30000)

With V in Km/h

Examples : a speed equal to 110km/h ⇒ Cv = 1.41

120km/h ⇒ Cv= 1.48

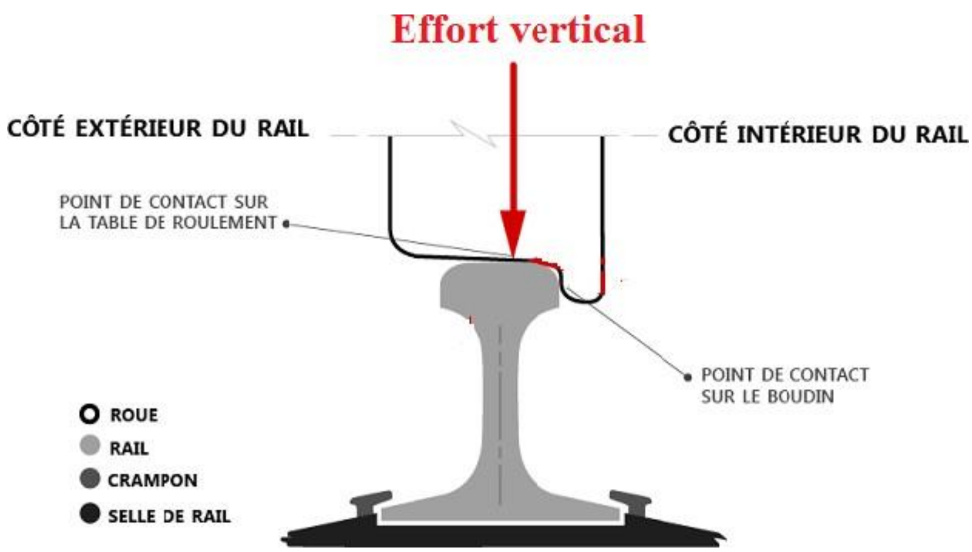


Figure 6 : Vertical forces on the rails.

2.3.1.2.2 Transverse forces

These efforts are caused by curved traffic including the progressive orientation movement in curves. The front wheel of the locomotive attacks the outer rail of the curve. It is therefore the impacts which are the most dangerous because they are exerted at the top of the rail and tend to overturn it, they force the fasteners, they can also cause the track to shift.

The following figure shows the transverse forces that apply to the side of the rail as mentioned previously.

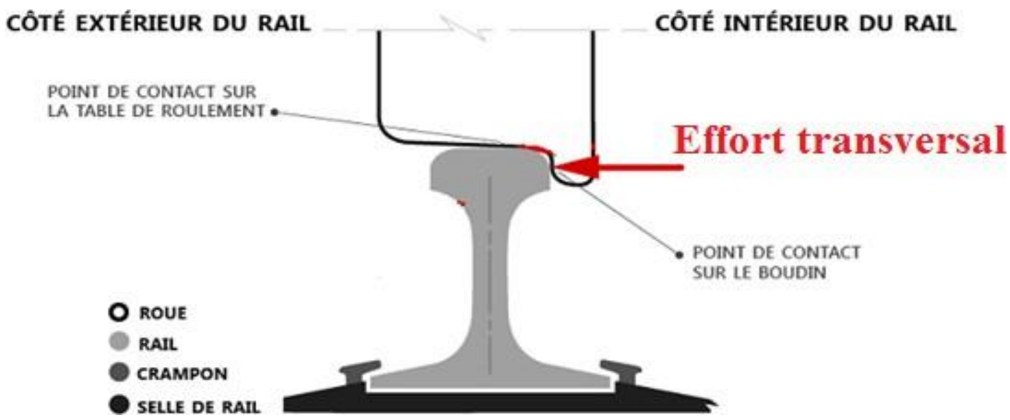


Figure 7 : Transverse forces on the rails.

2.3.1.2.3 Longitudinal forces

The forward movement of the locomotive obtained by the grip of the driving wheels on the rail causes a reaction which tends to make the rail move in the opposite direction of movement. At the joints, the impacts of all the wheels of the train on the end of the rails tend, on the contrary, to move the rail forward. Finally, the expansion forces are also exerted in the longitudinal direction.

We must therefore take into account all these requests to study :

- The profile of the rail.

- The nature of metal.

- The number of sleepers and their surfaces.

- The methods of attaching the sleepers.

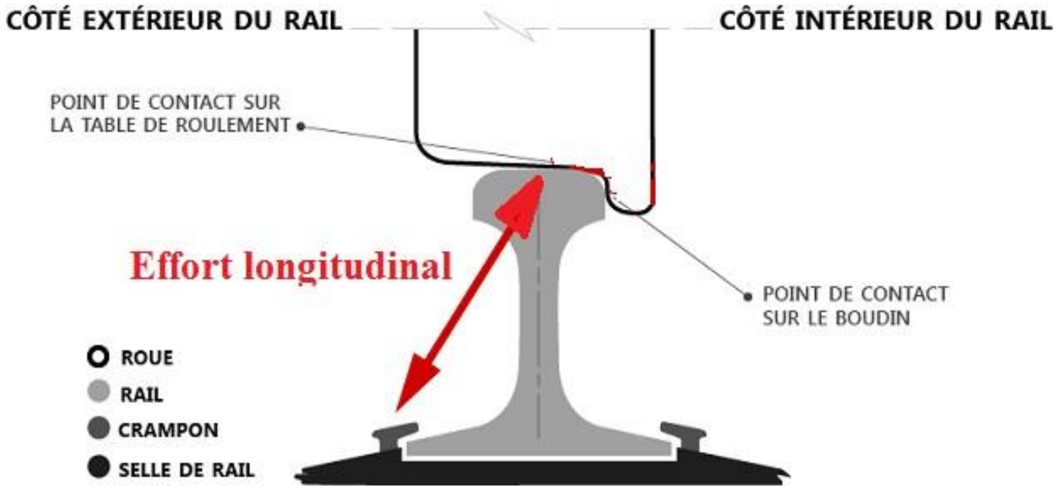


Figure 8 : Longitudinal forces on the rails.

2.3.1.2.4 Air resistance

It is generally accepted that this resistance is given by the following formula :

$R = V_{2S}/170$

With V designating the speed in km/h of the train relative to the air (which may be moving if there is wind) and S the surface in m² of the largest cross-section of the train perpendicular to the axis of the track, what is called in navigation the master torque. This formula, applicable only in the case of headwind which was confirmed in the “Berlin-Zossen” experiments up to a speed of 200 km/h. knowing that the train has a surface S of around 9 m².

2.3.1.3 Rail profile

There are 3 main shapes of rail :

- The shoe rail called Vignole rail.

- The rail has a double bead or bull headed.

- The rutted rail generally used in tram tracks.

2.3.1.3.1 The shoe rail

The shoe rail is the most used worldwide for railway tracks, it is made up of 3 parts:

- The bead

- Blade
- Skate.

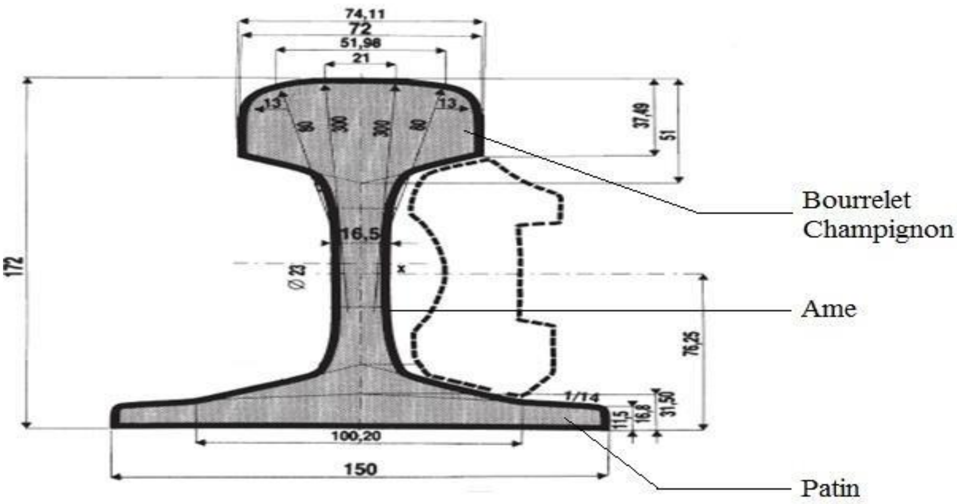


Figure 9 : Cross section of a shoe rail

Table 1 : Characteristics of a slider rail

Theoretical linear mass	60.21	Kg/ml
Moment of inertia Ix	3038.3	cm^4
Module of inertia Ix/v	335.6	cm^3
Section	76.7	Cm^2
Tensile strength	880	N/mm^2

- **The bead**

The profile of the rail bead and that of the wheel tire are studied with a view to achieving the best rolling conditions and ensuring the most satisfactory guidance of the wheel pin.

On a curve, when the wear on one side of the rail has reached the permitted limit, the rail can be turned over end to end.

- **The core and the shoe**

The ratio between the height of the web and the width of the shoe plays a very important role in its stability. Refer to figure 9.

2.3.1.3.2 The double beaded rail

Originally this profile is made up of 2 beads connected by a completely symmetrical core. This design was inspired by the desire to be able to turn the rail upside down and thus double its lifespan.

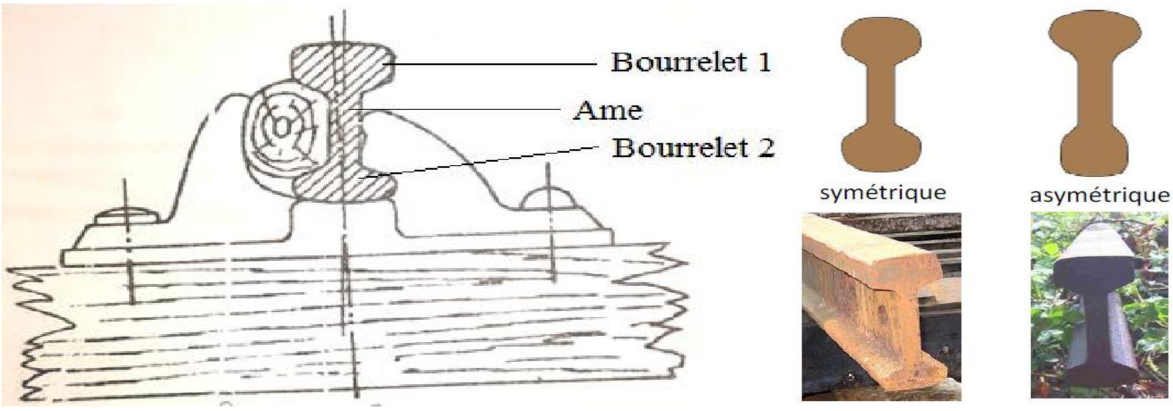


Figure 10 : Cross section of a double beaded rail.

2.3.1.3.3 Grooved rail

This type of rail is generally used for tracks embedded in road surfaces, particularly for industrial installations and tram lines.

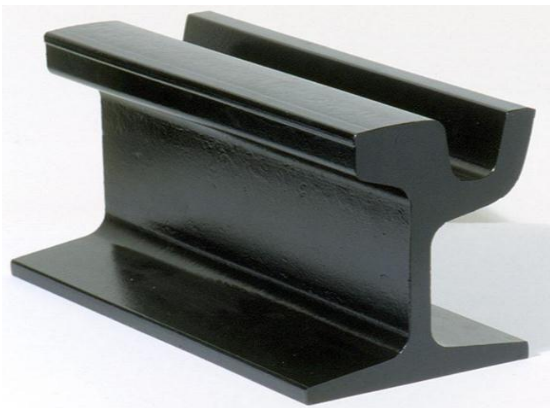


Figure 11 : Cross section of a flange rail.

2.3.2 Sleepers

A sleeper is a fundamental element of the railway track. It is a part placed across the track, under the rails, to maintain the gauge and inclination, and transmit the loads of vehicles traveling on the rails to the ballast. We mainly use wooden, metal or concrete sleepers.

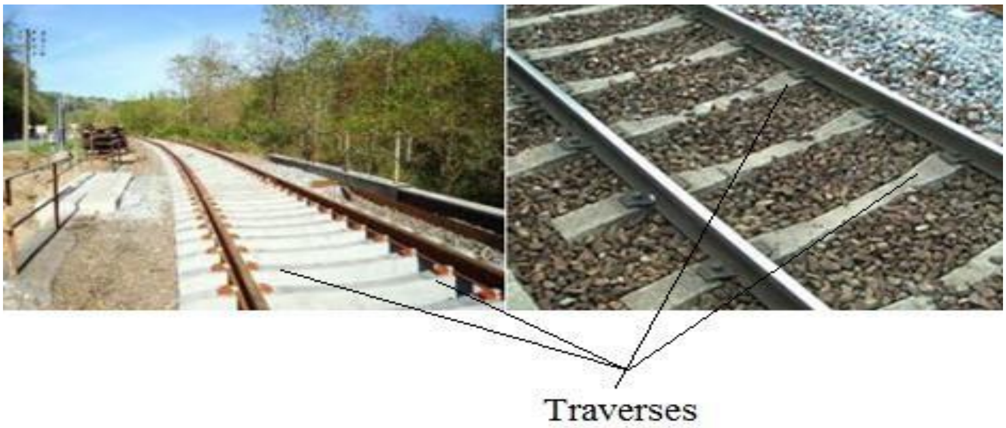


Figure 12 : examples of different types of sleepers.

2.3.2.1 Role of sleepers

The role of the sleepers is to maintain the rails at the normal gauge and to distribute the load that the rails receive from the axles onto the ballast. For this it is necessary that :

- Their length and width dimensions provide sufficient support surface so that the unit pressure remains within certain limits.

- Their thickness gives them the necessary rigidity while leaving a certain elasticity.

- Which resists atmospheric agents.

- That through their shapes the sleepers effectively resist longitudinal and transverse movements.

- Which allow the use of a durable attachment system.

Noticed :

A crosspiece that is too long tends to bend downwards, a crosspiece that is too short tends to bend upwards.

There are currently 3 types of sleepers :

- Wooden sleepers

- Metal sleepers

- Reinforced concrete sleepers.

2.3.2.2 Type of sleepers

- **Wooden sleepers**

Figure 13 : Model of a wooden sleeper.

- *** Dimensions**

The wooden sleepers generally measure 2.6 m long, 0.28 m wide and 0.14 m thick.

The surface S is of the order of $S=28*260=7280\ cm^2$ in order to calculate a given constraint.

- **Attachment**

The skid rails are fixed to the wooden sleepers by crampons or by lag screws with or without the interposition of a metal one.

The lag screw is a large screw that is put in place using a wrench, for this purpose the head ends up with a square shape.

Figure 14 : Dimensions of a crampon.

Figure 15 : Example of lag screw

- **Metal sleepers**

Figure 16 : Model of a metal sleeper.

They have the shape of an inverted trough, this shape is obtained by rolling which provides the rails with a good supporting surface and grips well in the ballast. The metal sleepers measure 2.5 m long, 0.26 m wide and 0.09 m thick ; with a table width of around 0.13m. This shape allows it to anchor well in the ballast and prevents transverse and longitudinal movements. In order to be able to attach the rail to the crosspiece, rectangular holes with rounded corners are provided. The method of attachment is not bolt.

- **The ties**

The weak point of the metal sleeper is the presence of the holes necessary for the fasteners attaching the rail to the sleeper. These rectangular holes, despite their rounded corners, constituted the beginnings of cracks which formed in the corners and which, developing, led after a certain time to deformation. The rail shoe is held by two clamps tightened by flat head bolts.

Figure 17 : Top view of the head of a crampon with a rounded section.

2.3.2.3 Dimensions of metal sleepers

Table 2 : Summary of dimensions for metal sleepers.

	S.N.C.B[1]* Germany	S.N.C.B*[2] Belgian
Length of the traverse	2.550 m	2.500 m
Height	10 cm (Angleur) 9.5 cm (Ougrée)	10 cm
Base width	26.6 cm (Angleur)	26 cm

	26 cm (Ougrée)	
Table width	13.5 cm (Angleur) 13 cm (Ougrée)	13.5 cm
Wing thickness	8 mm (Angleur) 11 mm (Ougrée)	9 mm
Wing thickness	8 mm	9 mm

*[1] S.N.C.B Germany

*[2] Belgian national railway company

2.3.2.4 Reinforced concrete sleepers

The very numerous types can be linked to three very distinct conceptions :

First system : One-piece sleepers : the sleeper is a beam which in its shape recalls the prismatic wooden sleeper, these are the Calot, Orion sleepers, etc.

Second system : Mixed sleepers : the sleeper is made up of two supports with a wide wheelbase, the spacing of which is maintained by a spacer.

Third system : Prestressed concrete sleeper.

2.3.2.5 Reinforced concrete one-piece prismatic sleepers

a) Calot sleepers

The crosspiece is provided with hollow thread hole molding. In these holes, we screw tree-nails made of creosote hornbeam wood, provided with external threads.

When the lag screw is screwed into the tree-nails, smooth internally, the external threads of the tree-nail apply against the hollow threads of the concrete and we thus obtain the desired resistance to tearing. Its length is currently around 2.4m.

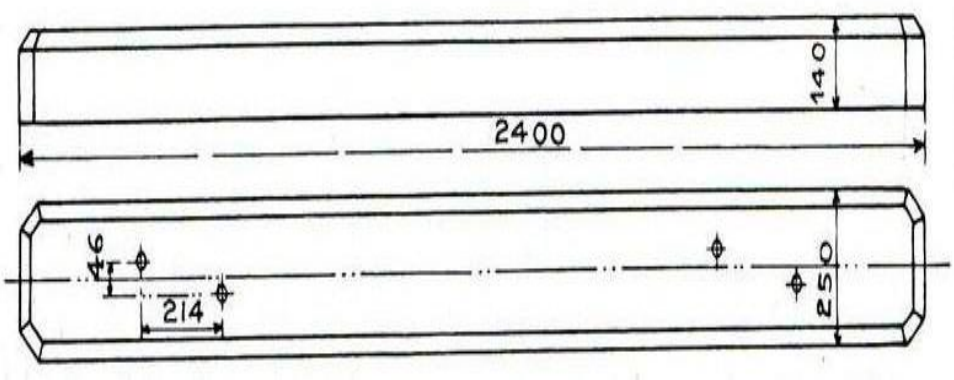


Figure 18 : Dimensions of the Calot system crossbar.

Figure 19 : Model of reinforced concrete sleepers.

b) Mixed sleepers in ordinary reinforced concrete

Crossing Vagneux

The vagneux sleeper is of the semi-rigid type, to counter the criticism leveled at prismatic sleepers, namely : accidental jamming of their central part can cause bending forces capable of cracking the concrete.

The central part is made up of a metal beam, with a double T profile, which fits into two large reinforced concrete heads.

The attachment consists of a lag screw screwed into a molded housing.

Figure 20 : Mixed ordinary concrete sleeper model.

The dimensions of all the components of the crossbar are mentioned in the following figure :

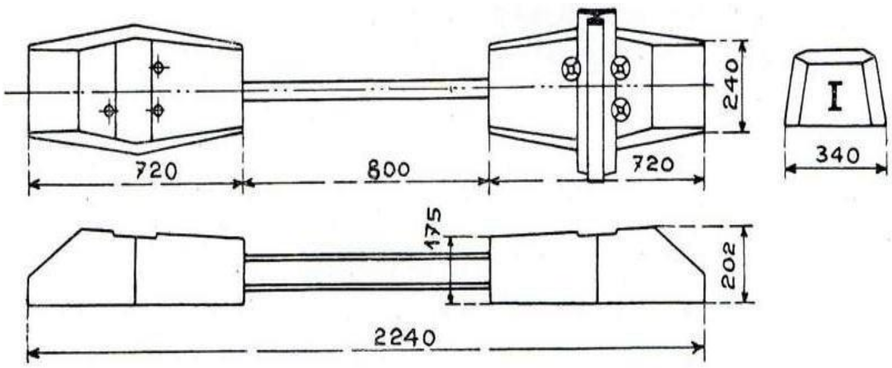


Figure 21 : Dimensions of the Vagneux system sleeper.

c) Prestressed concrete sleepers

The initial prestressing or compression results from the prior tensioning of the reinforcement tie rods (or wires) anchored at the ends, whether or not surrounded by sheaths.

The tension of the tie rods is transmitted to the concrete in the form of a compression equal to this tension so that the resistance to cracking is, in principle, equal to the prestressing tension.

When concreting, it is necessary to vibrate the concrete to ensure its perfect homogeneity.

Applied to railway sleepers, the main purpose of prestressing is to combat concrete cracking. Many networks are interested in the question, but we are still at the experimental stage.

Regarding the fastening of concrete sleepers, the use of lag screws is widely used to fix the rail to the concrete sleepers.

Figure 22 : Example of a prestressed concrete sleeper.

The fixing of prestressed concrete sleepers to the rails is done in almost the same way as the other types, the fixing systems are as follows :

Figure 23 : Steel clips for fixing concrete sleepers.

Figure 24 : System for fixing rails to wooden sleepers.

Figure 25 : System for fixing rails to metal sleepers.

2.3.3 The ballast

Ballast is a bed of gravel or stones on which a railway track rests.

It is therefore an unstable pile of stones. However, nothing better has been found to stabilize the railway tracks and offer optimal comfort to passengers. Pebbles are easily available and do not pollute. Thus, the rails have always rested on ballast, a compact thickness of hard and crushed stones, with angular shapes. The rails are also placed on the sleepers, these parts which make it possible to maintain the gauge of the rails. The dimensions of these stones are of the order of a few centimeters.

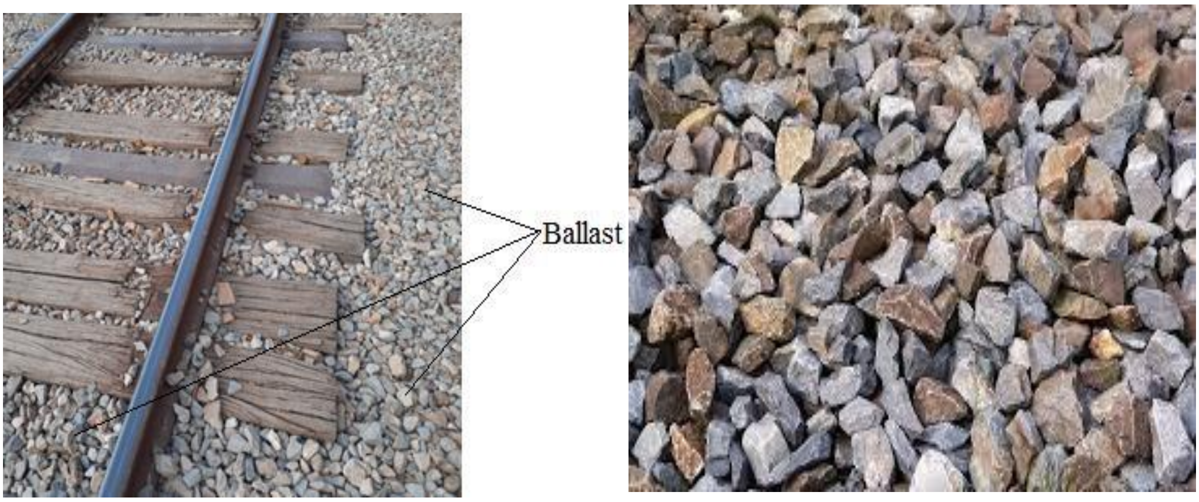


Figure 26 : Example of ballast.

2.3.3.1 Role of the ballast

If the sleepers rested directly on the platform, they would sink more or less into the natural ground, the strength of which is generally insufficient to support the load transmitted by the sleepers.

This drawback is avoided by interposing between the sleepers and the platform a layer of ballast of sufficient height so that the pressure received by the sleepers, under the action of rolling loads, is distributed as uniformly as possible over a largest surface area of the platform.

Packing the ballast under the sleeper maintains the correct leveling of the track. It also slows down longitudinal and transverse movements.

The minimum thickness generally accepted for the ballast layer between the platform and the inside face of the sleepers is 30 centimeters.

2.3.3.2 Required quality

A good ballast must have the following qualities : permeability, elasticity, solidity, lend itself to jams, not be frost-resistant, not disintegrate under the influence of atmospheric agents.

Permeability : The ballast must ensure good water flow because the water that remains in the ballast ultimately forms mud, the sleepers that rest on it are poorly seated (muddy or dancing sleepers); this water freezes in winter, causing the ballast to swell and the track to rise. And then, the frozen track loses its elasticity.

Elasticity : This characteristic derives from the relative mobility of the elements constituting the ballast. For it to be good, the stones must be large enough and be well calibrated.

The ballast must retain its elasticity and not form a compact mass under the sleepers, compressed under the weight of the trains and not “returning” when the load has disappeared.

Strength : The ballast must be hard enough to resist shocks caused by rolling loads and to withstand the destructive action of tamping tools. Soft or porous ballast disintegrates quickly, it absorbs humidity which retains dust and foreign bodies. All things being equal, the ballast may be finer the harder it is.

The choice of ballast is conditioned by

- Local resources.

- The price you have to pay for a good ballast.

2.3.3.3 Dimensions of elements

The ballast is theoretically supplied in caliber 40x60 mm (the length being measured diagonally). When the dimension exceeds 60 mm, tamping becomes difficult.

To obtain maximum permeability, the dimensions must be as uniform as possible, otherwise the smaller elements would fill the gaps left between the larger ones. This uniformity gives compactness to the ballast and promotes a regular distribution of pressure on the platform. The weight of a cubic meter of 40x60 mm or 20x40 mm ballast is on average 1400 kg.

2.4 Installation of the sides

A railway fishplate is a metal part used to connect two consecutive rails of a railway track. The sides are attached in pairs, using bolts or tightening “Cs” (metal parts whose shape is reminiscent of the letter “C”).

Fishplates are often used near switches or other track devices : on the track, the junction between two rails will be made by welding, for example using the long welded rail technique.

Figure 27 : Example of joint joint

The fishplates connect two rail ends by resting under the head and on the inclined part of the shoe and are tightened by 4 or 6 bolts. They have a symmetrical or almost symmetrical profile and contain on their exterior face two longitudinal ribs preventing the rotation of the bolt heads. Some 6-hole splints have a vertical corrugation and possibly horizontal corrugations to reinforce their rigidity.

Chapter 3 : Behavior and dimensioning of railway tracks

3.1 Introduction

The infrastructure of the railway track is the foundation of a track, in other words, it is the lower part on which this track rests. It is used to distribute the loads exerted by the sleepers on the platform and to dampen the vibrations of the superstructure, in addition it contributes to the longitudinal and lateral stabilization of the track. It therefore makes it possible to a large extent to ensure, by its nature and its thickness, the correct behavior of the railway track from the point of view of rigidity, strength and drainage.

The railway track is the base for any rail infrastructure ; it decides the directions in which the train will travel. It plays a great role in the safe and economical transportation of people and goods over long distances. Proper alignment, as part of the track, ensures comprehensive maintenance, allowing trains to move at high speed with full load. Not all railway tracks are the same, though. They can vary according to several factors and are relevant for understanding how the different rail systems work. In this blog post, we will go on to understand different kinds of railway tracks concerning four major criteria : gauge, purpose/usage, construction type, and operational capacity. Each of these characteristics offers another dimension in which the tracks can be classified within the categories of rail width, utilization of the track, construction method, and even the number of trains supported at one time.

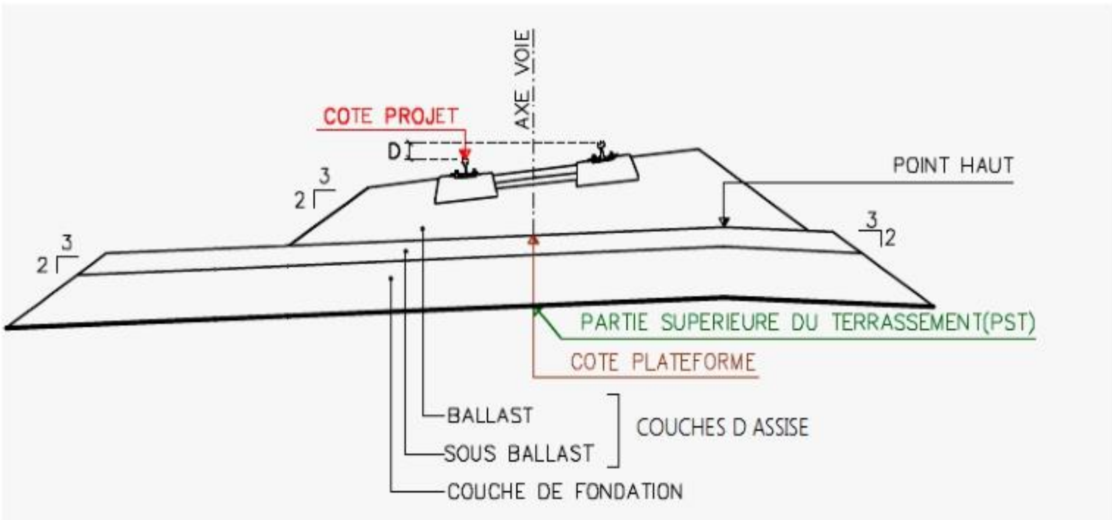


Figure 28 : Diagram of a railway track showing the main elements and how they provide support and protection to the track system.

3.2 Construction of a railway

The railway is made up of two parts, the superstructure and the infrastructure. The infrastructure is composed of either the platform ; interface between the track itself and the ground or the engineering structure on which the superstructure is placed.

The superstructure of the railway is made up of various components : rails plus attachment and fixing accessories, sleepers, a base layer made up of ballast, an underlay (under ballast), devices various tracks and level crossings, etc.

3.3 Sizing of seat structures

3.3.1 General

By definition, the base layer includes the ballast layer and the sub-layer (under ballast). Their main roles are :

• Damping of significant vibrations coming from Rails - Wheel contact

• The distribution of loads from the crossings in an almost uniform manner on the platform ;

• The contribution to the longitudinal and transverse stability of the railway track ;

• Evacuation of runoff water through drainage

3.3.2 Ballast layé

Ballast is the bed of stones or gravel on which a railway track rests, ballast is made up of crushed hard rocks (generally, these are eruptive rocks : granite, rhyolite, quartzite, etc.) of grain size varying between 20mm and 63mm, which must resist attrition, which dulls the angles. The thickness of the ballast depends on the load and the intensity of traffic ; the minimum thickness generally accepted for the layer of ballast between the platform and the underside of the sleepers is 30 centimeters.

3.3.2.1 Role

• The transmission of the forces generated by the passage of trains on the ground, without it does not deform by compaction.

• Embed the sleepers to ensure resistance to longitudinal deformation, particularly important for the technique of long welded rails.

• Ensure, due to its particular granularity, the drainage and evacuation of water superficial ;

• Constitutes a very effective vibration absorber thanks to its rheological properties (dissipation of vibrational energy by attrition of ballast elements).

• Allow, by means of mechanized tamping-straightening, the very rapid rectification of the leveling and tracing.

• The upper layer, called the padding layer, whose main role is to allow the sleepers to be properly wedged, must be made of angular materials ; it is enough for it to be 0.15 m to 0.20 m thick below the lower face of the sleepers. Round stones, which are difficult to pack, must be eliminated.

Required qualities of Ballast

A good ballast must have the following qualities : permeability, elasticity, solidity, lend itself to tamping, not be frost-resistant, not disintegrate under the influence of atmospheric agents ;

3.3.2.2 Permeability : The ballast must ensure good water flow because the water that remains in the ballast ultimately forms mud, the sleepers that rest on it are poorly seated (muddy or dancing sleepers) ; this water freezes in winter, causing the ballast to swell and the track to rise. In addition, the frozen track loses its elasticity.

3.3.2.3 Elasticity : This derives from the relative mobility of the elements constituting the ballast. For it to be good, the stones must be large enough and be well calibrated. The ballast must retain its elasticity and not form a compact mass under the sleepers, compressed under the weight of the trains and not “returning” when the load has disappeared.

Strength: The ballast must be hard enough to resist shocks caused by rolling loads (crushing) and to withstand the destructive action of tamping tools (crumbling). Soft or porous ballast disintegrates quickly, it absorbs humidity which retains dust and foreign bodies. All things being equal, the ballast may be finer the harder it is.

3.3.2.4 Material

Generally we use crushed stone, with a grain size varying between 20 mm and 63 mm, of different types :

 Any sand or gravel, from rivers or quarries.

 Broken stone, granite, siliceous or limestone (in this case, it must be hard and frost-proof).

 Pebbles.

 Blast furnace slag

The quarries where these materials are extracted and transformed are ballast pits. The ballast elements must fit together to form a compact but permeable mass.

The quality of the ballast is defined by a “quality coefficient” which specifies the resistance to wear, friction and moderate shocks, determined from classic tests :

• Wear resistance test (Deval or micro-Deval test) ;

• Fragmentation resistance test (Los Angles test)

• Compressive strength test Normative reference : NF EN 13450 Aggregates for railway ballasts.

The ballast used on railways must have at least the following qualities :

• Simple compressive strength Rc ≥ 1200 kg/cm^2

• Micro Deval MDE coefficient ≤ 15 to 20

• Los Angles coefficient sec LA ≤ 20 to 25

• Or : - LA + MDE < 40 for v ≥ 160 km/h.

- LA + MDE < 50 for v < 160 km/h

• Category A of table 1 of standard EN 13450 is required (ballast 3 1.5/50)2.

- **DRG overall hardness**

This is one of the important parameters to characterize a ballast, it must have a hardness global at least equal to 12.

This hardness coefficient DR and for each sample is determined from the chart below, by combining the coefficients DEVAL dry (DS), DEVAL wet (DH), Micro Deval in the presence of water (MDE) and Los Angeles (THERE).

These coefficients are determined as follows :

Determination of the hardness coefficient DR of a sample according to the coefficients : “Los Angeles” and “Deval” or “Microdeval” the DS, DH and MDE tests characterize the wear resistance of the stone.

For the use of the chart, we will use the lowest of the 3 values obtained for the sample considered.

- **Calculation of overall hardness DRG**

The overall DRG hardness is equal to the lower of the following values :

 DR – 0.5,

 DR (mean - standard deviation),

 DRmini + 2 (lowest value + 2) calculated on a minimum of 5 samples.

Category	Ballast (d/D)	Granularity Percentage of passing mass							
NF EN 13450		80	63	50	40	31,5	22,4*	31,5 à 50	31.5 à 63
A	31,5/50	100	100	70 à 99	30 à 65	1 à 25	0 à 3	≥ 50	-

* It is permitted to use a 25 mm sieve instead of the 22.4 mm sieve with a tolerance of 0 to 5.

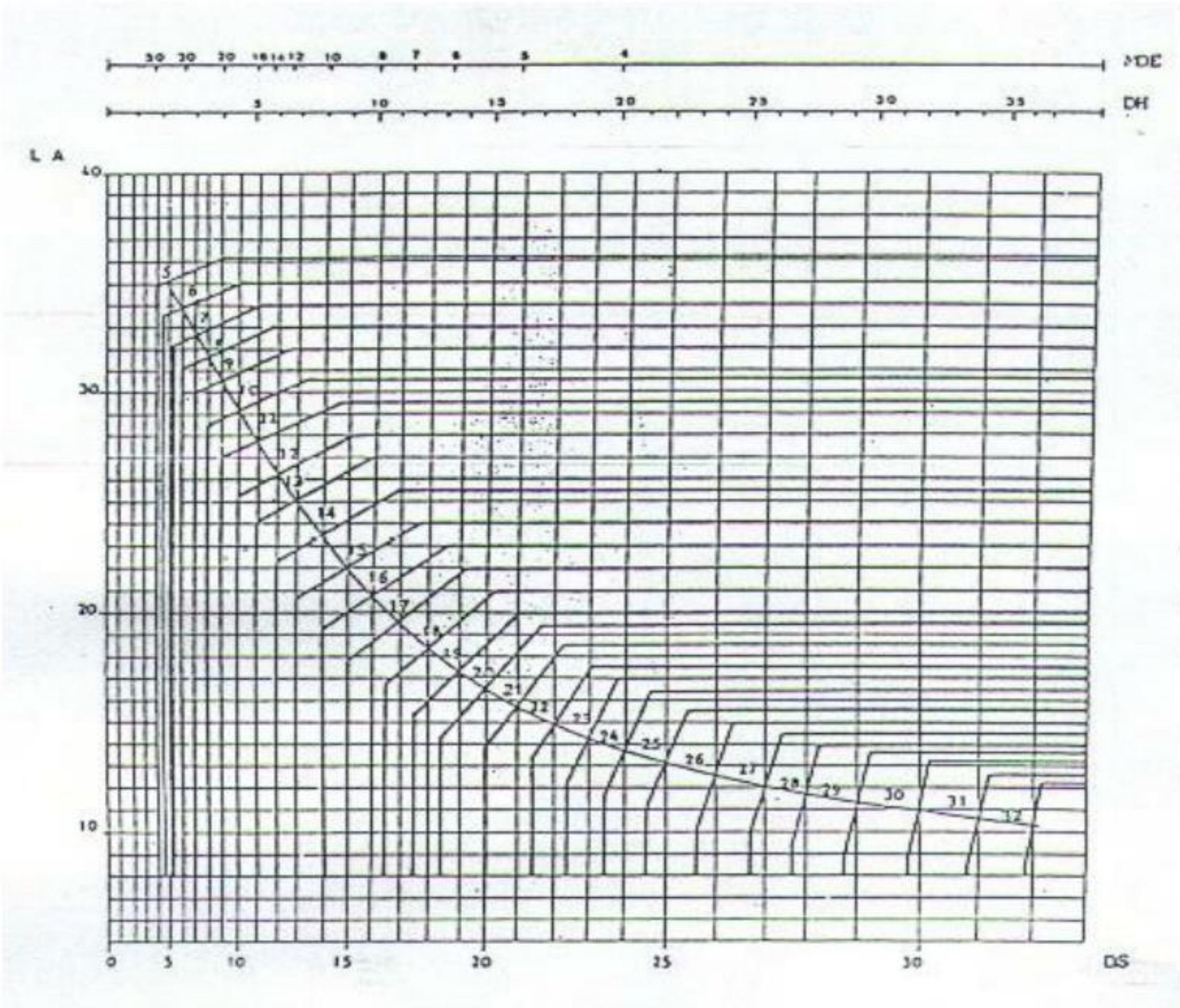


Figure 29 : Granulometry of double railway track base layers

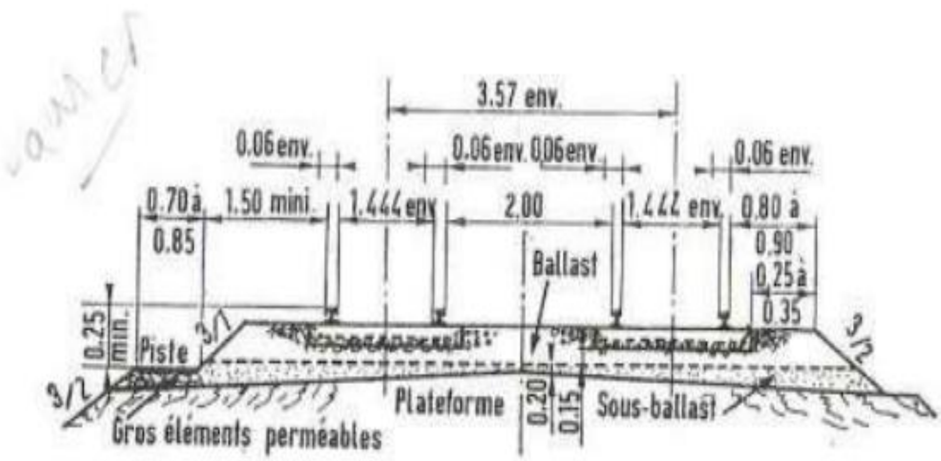


Figure 30 : Railway Platform Sizing

The overall hardnesses of the ballast are :

- Classic lines without passengers ; DRG =14.

- Classic lines with passengers and speeds below 200km/h ; DRG =17.

- High speed lines, above 200 km/h ; DRG =20.

Ballast profile

We ballast on an “uncovered floor”, meaning that the top of the sleepers is uncovered, resulting in better visibility of the fasteners, saving on ballast and making it easier to level the track.

Chapter 4. Sanitation works for a railway line

4.1 Introduction

One of the natural factors which causes numerous disorders affecting the performance of the railway track is water, it quickly contributes to the reduction of the lift which is manifested in particular by the alteration of the leveling, and therefore defects in the geometry roads. This water can be of meteoric (surface water) or internal (groundwater) origin. The drainage of railway platforms ensures the durability of the tracks and therefore the safety, reliability and maintenance costs of rail transport. In the railway sector, longitudinal drainage has two functions, surface drainage collecting runoff water from embankments or watersheds, and deep drainage ensuring the drawdown of the water table in the spoil.

4.2 Types and function of drainage

Drainage devices, along with the base structures and pathways, are part of the whole called infrastructure. They provide longitudinal linear drainage with a ten-year return time design, as well as transverse drainage (100-year return time design) using hydraulic crossing structures, which allow transit from one side to the other. of the platform, water from natural catchment areas and longitudinal drainage devices.

Figure 31 : Longitudinal and transverse drainage of railway tracks

Drainage devices combine the following functions :

- The collection and evacuation of meteoric water falling on the platform, the excavation slope, as well as the local watershed.

- Deep drainage of the platform to reduce the level of the water table to the necessary level to ensure the holding of the track.

In addition to their function, the types of drainage are distinguished

- by their position (cut or fill drainage),
- by their nature (open or buried drainage).

The terms "drainage" and "sanitation" are used to deal indifferently with the evacuation of runoff water or the drawdown of internal waters often joining common outlets.

4.2.1 Longitudinal drainage platform interaction

The drainage of railway platforms has a strategic role for the short and long term management of railway operations.

Indeed, the safety conditions for train movement on the superstructure are directly linked to the load-bearing capacity of the base layers, which itself depends on several factors including the quality of drainage.

Poor bearing capacity results in leveling defects, which leads to increased monitoring and maintenance costs, possible traffic slowdowns and can, in extreme cases, cause incidents or accidents.

4.2.2 The sustainability of the platform

Water is the main factor of disorder and degradation of infrastructure. The sustainability of the platform therefore depends largely on the quality of sanitation.

This quality is effective under three conditions :

- Good sizing through hydrological and hydrogeological studies during the project phase ;
- The creation of the platform according to the rules of the art during the works phase ;

After commissioning a drainage system, its quality will depend on maintenance.

4.2.3 Deep groundwater drainage

In the railway sector we distinguish between earthworks in embankment and in excavation, deep drainage can be provided mainly in the excavation.

4.2.4 Wet spoil

A cut is said to be wet when the maximum predictable piezometric level of the water table is located at least 2 m from point P (point of the upper surface of the sub-layer located in the axis of the platform).

In this case, the devices made are called deep drainage devices.

4.2.5 Devices used for deep drainage

The main devices commonly used for deep drainage of wet spoil are :

Open-air devices	Buried devices
1. Earth Ditches, Lined or not (FT, FTR)	3. Collectors – Draining (CD)
2. Prefabricated Concrete Ditches at Barbacanes (FBPB)	4. Slot Gutters (CF)

The choice of a type of structure results from taking into account the usage constraints specific to each device (impact, cost, etc.) and the general examination of the situation of the premises (evaluation of the flow rates to be evacuated, characteristics surrounding terrain, leveling of essential points, geometry of the platform, etc.).

Wet spoil areas generally require a drawdown of the water table by draining trenches on either side of the base structure.

The depth of the deep drainage wedging which ensures the drawdown of the water table to at least 1.5 m below point "P" was determined empirically based on feedback. It corresponds to the theoretical removal of water from the upper part of the ground, the thickness of which is approximately 1 m, and the base structure, the thickness of which is variable.

4.3 The main devices used in the deep drainage of wet spoil (open-air devices)

4.3.1 Earthen ditches (FT)

They are trapezoidal in shape with sides with a slope of 3/2 or 2/1 (base/height); In wet spoil, the creation of very deep ditches is the subject of a special study to ensure the alignment of the longitudinal profile (right-of-way) and the stability of the sides of the ditch.

When it is covered with concrete, the deep drainage function is ensured by the installation of barbicans. It is then called Barbacanes Coated Earth Ditch.

Figure 32 : Examples of earth ditch (ED)

4.3.2 Prefabricated concrete barbican ditches (FBPB)

The prefabricated elements have a length of 0.75 m or 1 m, with vertical sides pierced with holes (barbicans) of 80 mm in diameter.

Their use to drain wet spoil in common areas is subject to flow and slope conditions. Their capable flow rate is limited (around 60 l/s for a longitudinal profile slope of 0.002 m/m). If there is too much flow, they are replaced by earthen ditches, lined or not.

Only prefabricated type M ditches with two extensions can ensure deep drainage of the platform.

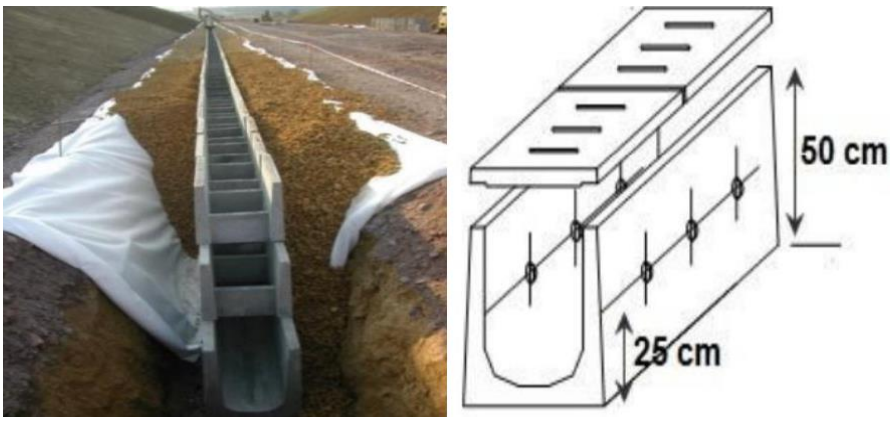


Figure 33 : Representation of a prefabricated concrete ditch with barbicans

4.3.3 Buried devices

Collectors – draining (CD) They are made up of pipes perforated in the upper part, placed on a bed of concrete and covered with draining materials. The CDs can be made of concrete or thermoplastic materials (PVC/HDPE) depending on the mechanical resistance.

CDs provide deep drainage in wet spoil. However, maintenance on this type of structure is difficult because there is only a manhole approximately every 80 m. In addition, the main problem is the clogging of the drain collector slots.

Figure 34 : Photo of a CD before installation of draining materials

4.3.4 Slotted gutters

Slotted gutters are made of reinforced concrete laid on a concrete bed and covered with geogrid then with drainage materials. They ensure deep drainage while presenting a high mechanical resistance.

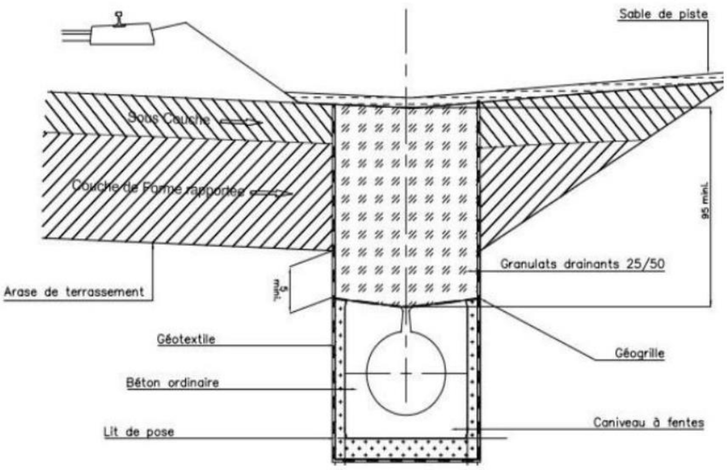


Figure 35 : Description of a slotted gutter

Conclusion

Through this chapter we understand the interest of water management on railways, we understand that water can be a danger from which railway equipment must be protected. Thus we see that the drainage and evacuation of water from railway infrastructures is fundamental for the maintenance of foundation structures and thus the maintenance of the track. In addition, we realize that the protection of the surrounding embankments is also important for the preservation of disorders that can affect the track.

Bibliographic references

[1] P. Alias. « Les cours de chemin de fer professés à l'Ecole des Ponts et Chaussées ». RHCP, 1996.

[2] Collections OPU, Algérie.

[3] Code UIC fiche N°719R « Union internationale de chemin de fer » 2eme édition 01/01/1994.

[4] Révision de la fiche N°703, « Caractéristiques de tracé des voies parcourues par des trains de voyageurs rapides ».

[5] Fiche N°703 (Compliment), « Installation fixes », Dresde, juin 1989.

[6] Railway Track and Structures (1970) AAR now has Recommended Track Standards, Vol. 66, N° 11, 28-31.

[7] Railway Gazette, (1970) Dynamics of Railway Track Systems and Their Economic Consequences, Vol. 126, No. 1, 19-24.

[8] Ahlf, R.E. (1975) Maintenance of way costs, how they are affected by Car Weights and Track Structure, Railway Track and Structures, Vol. 71 No. 3, p. 34.

[9] Fiche N° 719, Ouvrages en terre et couches d'assise ferroviaires, nouvelle édition, Gdansk, juin 1993.

[10] J. Alias. La voie ferrée. Eyrolles, 1977.

[11] A. Alaoui and T. Naciri. Les voies ballastées. Technical report, Rapport EUROBALT, CERAM, ENPC, 1995.

[12] V. Bodin. Comportement du ballast des voies ferrées soumises à un chargement vertical et latéral. PhD thesis, Ecole Nationale des Ponts et Chaussées, Juin 2001