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LOGISTICS AND TRANSPORT

Transport constructions 1

UNIVERSITY OF APPLIED SCIENCES UPPER AUSTRIA

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Inhalt

1. ROAD CONSTRUCTIONS – ROAD DESIGNING PRINCIPLES

1.1. Road construction project

A road construction project refers to a complex architectural, technical, economic and ecological solution of construction, including design and conditions for the implementation of construction. The project is processed in the scope and details needed for the zoning decision and the planning permission. In the Czech Republic, design offices or the project engineers themselves are guided by the relevant laws, standards and technical regulations when designing roads, in particular by:

- Act no. 13/1997 Coll., On the Road Network, as amended
- Act No. 361/2000 Coll., On Road Traffic, as amended
- Act No. 183/2006 Coll., On Town and Country Planning and Building Code (Building Act)
- ČSN 73 6101 Design of Highways and Motorways
- ČSN 73 6110 Design of Urban Roads
- ČSN 73 6102 Design of Intersections on Highways

Prior to designing a construction project, the client (investor) sets the basic conditions for routing, the category of road, especially on the basis of the prospective plans for the development of highways and motorways.

1.2. Basic materials

The main engineering data include:

- basic conditions for routing (proposed by the investor, i.e. the client);
- road category;
- current and prospective traffic volumes;
- design speed in relation to the area, the sections with speed limitation;
- the built-up area service requirements;
- technical infrastructure requirements (underground utilities);
- requirements for solution of intersections;
- the structure of traffic flow, the share of freight transport.

When developing a project, account must also be taken of hydrological (including groundwater), geological, soil, and climatic (especially snow) conditions, as well as the

protection of the agricultural and forest land resources. In doing so, the following aspects must be ensured: the highest achievable safety, efficiency and driving comfort at the determined design speeds; the economically efficient and technically correct road solution assessed from the point of view of aesthetics, its correct integration into the landscape, and creation and protection of the environment.
If the protection of the environment cannot be secured by more suitable placing of roads in the landscape, complying with relevant hygiene regulations during construction works must be ensured by appropriate technical and organizational means.

If the existing road is disrupted by construction works, the project must also include a proposal to provide alternative passage for road traffic during the construction. The proposed traffic measures (e.g. traffic lights management, detours, the creation of a temporary carriageway, etc.) must be documented by a technical and economic certificate confirming that they represent the most appropriate solution.

1.3. Design road categories

Design road categories according to the Czech technical standards (ČSN) – road category refers to its traffic-technical value. It is a summary of the technical parameters of a road with the same designation, cross-sectional arrangement and the same design speed.

Marking of design road categories includes the following characteristics:

- letters for the categories of roads: the roads of 1^{st}, 2^{nd} and 3^{rd} classes (S), motorways (D) and expressways (R), local roads (M) and field paths (P),
- the width of a road in metres,
- the design speed in km/h.

For example, R 25.5/80 denotes a road classified as an expressway with the width of 25.5 m and the design speed of 80km/h.

Design speed - it serves to determine the minimum design features of a road and refers to the maximum safe speed of an average vehicle travelling through any section of a road in normal atmospheric conditions without affecting the other traffic. The design speed can be lower than the maximum allowed speed on a specified section of a road. One vehicle must be allowed to travel on a road at the design speed in the specified conditions throughout a homogeneous road section.

The design speed is determined by the economic and transport significance of a communication with respect to the actual local and, in particular, land conditions. From the point of view of the economic and transport significance of the road, the necessary quality of the traffic flow movement must be achieved, which is expressed by the corresponding values of the required travel speed.

Traffic flow volume – the number of vehicles passing through a specified road profile per unit of time (e.g. per 1000 vehicles/hour).

Road capacity – the maximum volume or the maximum number of vehicles that can pass through a specified profile or section of a road per unit of time.

The required travel speed and design volume, and the ability of the road to transport traffic loads are assessed at junctions as well as at sections between intersections. At junctions, the capacity conditions of the main, connecting and crossing traffic flows are assessed.

The sections between junctions are evaluated separately by characteristic sections with

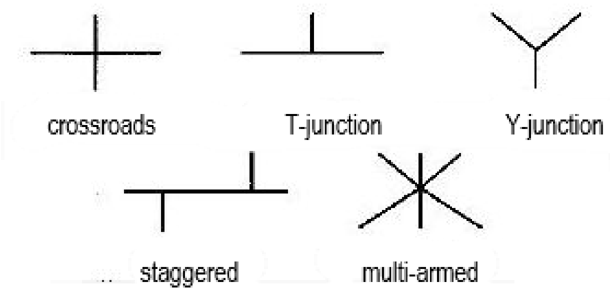
homogeneous building and traffic conditions:

- Building conditions, road grade and sight distance in case of two lanes,
- Traffic conditions with varying volumes and composition of traffic flow over time.

2. ROAD CONSTRUCTIONS – COMPONENTS OF ROADS

2.1 Road crossing

According to ČSN 73 6102 entitled "Design of intersections on highways", a crossing is a place where roads intersect or meet in the ground plan projection and at least two of them are interconnected. The following are not considered as crossings: the connection of forest roads and field paths, roads leading to real-estates, and the connection of service transport facilities. From structural point of view, according to the way of junction (crossing) of two roads, intersections are divided into **fly-over junctions** (interchanges) and **at-grade junctions** (intersections). The main types of at-grade junctions include:



Source: The author
Figure 1 – The main types of at-grade junctions (intersections)

Figure 1 does not show one of the important types of at-grade junctions, and this is **roundabout**. Building of roundabouts has its reasons especially at the boundaries of built-up and non-urban areas (from a psychological point of view, when a driver has to slow down at the entrance to a built-up area) and in places with a higher number of accidents at normal intersections, at multi-armed junctions or at fork junctions with a small angle of crossing.

Traffic flow volume – the number of vehicles passing through a specified road profile per unit of time (e.g. per 1000 vehicles/hour).

Road capacity – the maximum volume or the maximum number of vehicles that can pass through a specified profile or section of a road per unit of time.

2.2 Objects on roads

Objects on roads include artificial structures allowing or protecting the route:

- Bridges, culverts;
- Tunnels;
- Retaining walls, gabions, galleries, etc.

Road equipment includes crash barriers, road lighting, traffic signs, horizontal road signs and the like.

Drainage of roads

2.3 Road drainage

Road drainage is provided by **road equipment** and is another important part of the road as the water element can cause damage to building components in case of improper design of drainage system along the road. The body of road (mainly the active bedrock) and the adjacent land must be protected against the harmful effects of groundwater and rainwater from the surface runoff. Drainage equipment used to collect and drain such waters include:

- **surface equipment** (ditches, rigols, slopes, cascades, pits) and/or
- **sub-surface equipment** (dry wells, drainage piping).

3.PLANNING, TECHNICAL AND DESIGN CHARACTERISTICS OF ROADS

3.1 Road route design

A road route is a spatial line that determines the horizontal and vertical course of a designed road within the landscape (terrain). **Planning** is the activity that seeks and determines the most appropriate course of the route of a road in the horizontal and vertical design. When planning, it is necessary to take into account the economic, environmental, climatic, and aesthetic aspects, and especially the safety and fluidity of traffic.

A design is made in two perpendicular projections:

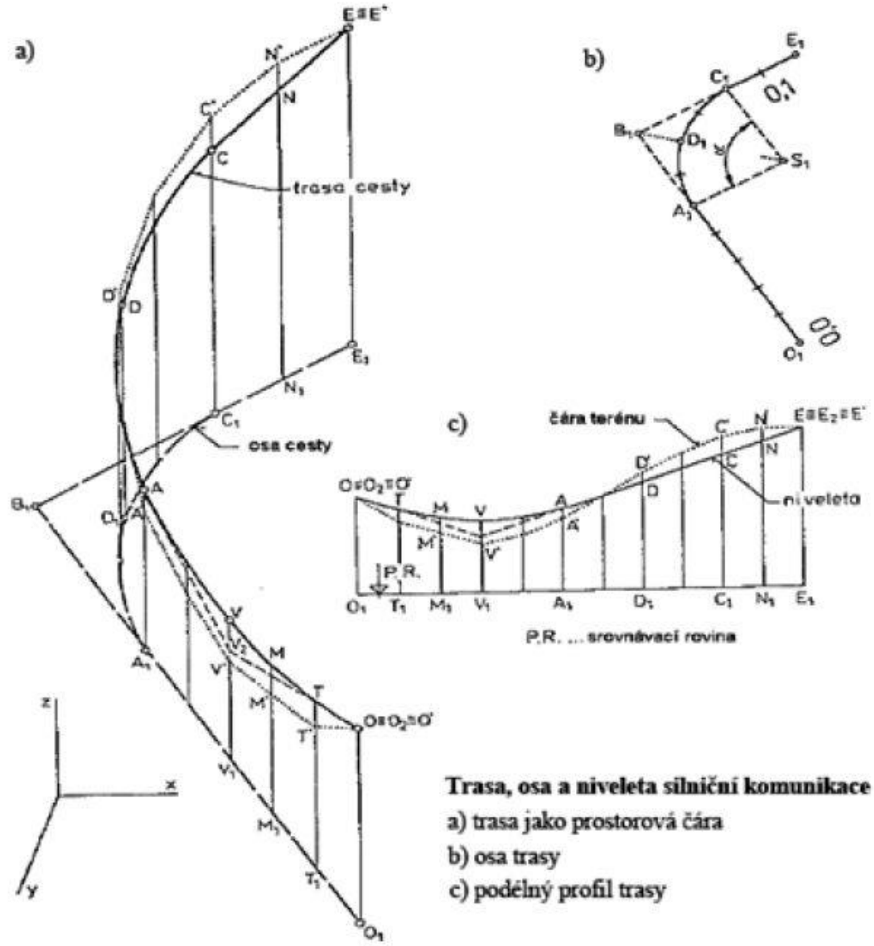
- Situation - a map with altimetry, a ground plan, a route (axis) of the road projected to horizontal plane; determines the **situation and direction of the road**.

- Longitudinal profile - an unfolded horizontal route projection to vertical plane, the road level; **determines the height position and height conditions of the road** (sometimes referred to as the longitudinal section of the road).

Preparatory works make use of medium scale maps (1: 10,000; 1: 25,000), whereas projects work with large-scale maps (1: 500, 1: 1,000 and 1: 2,000) with contours that determine the height of terrain. The most important route planning requirements are:

- Traffic connection efficiency,
- Minimizing the volume of earthworks,
- Taking into account geological conditions in the area, climatic conditions and properties of building materials,
- Spatial route effect (avoiding the barrier effect),
- Route aesthetics by incorporating it into the terrain by combining horizontal and vertical elements.

In practice, however, road sections in the combination of vertical and horizontal curves (composite curves) are designed as well. The schematic representation is shown in Figure 2.



Source: ČSN 73 6101 – Design of highways and motorways
Figure 2 – Horizontal and vertical solution of a road route

3.2 Design elements

The design elements listed in ČSN 73 6101 are given at the lowest or highest admissible values. When designing road communications, design elements should be appropriately increased (e.g. the radii of curves, the length of sight distance, etc.) or reduced (e.g. longitudinal slopes, etc.) in order to ensure the best possible conditions on roads.

The basic design elements include the design speed that, by means of formulas specified in the technical standards (ČSN), enables the calculation of **derived design elements**, for example:

- R_O – horizontal curve radius
- R_V – crest curve radius
- R_U – sag curve radius
- D_z – minimum stopping sight distance
- D_p – minimum overtaking sight distance
- p – cross slope

3.3 Sight conditions

A required **stopping sight distance** in front of obstructing objects on the carriageway must be ensured on the entire length of all roads. **Overtaking sight distance** is only available on the longest possible length on two-lane two-way roads. Four- and multi-lane roads are provided only with stopping sight distances. The values of the lengths of the stopping sight distances and overtaking sight distances are listed in the technical standards.

4. HORIZONTAL CHARACTERISTICS OF ROAD - CURVES

4.1 Horizontal curves

A smooth change in the road axis direction is carried out by the following types of curves:

- simple circular curve,
- circular curve with transitions,
- transition curve,
- composite curve.

Circular curve with transitions is the most common horizonatal curve solution. It consists of a circular part and two-sided clothoid transitions.

Transition curve can be designed where, for reasons of proper incorporation in the landscape, a complete elimination of the circular part of the curve between the transitions is more suitable.

Composite curve can be designed where the solution is demonstrably less suitable for reasons of proper integration into the terrain or for aesthetic reasons. It can be composed of:

- alternating circular, outer and intermediate transition sections,
- or exceptionally, of circular curves of different radii - usually with outer transitions

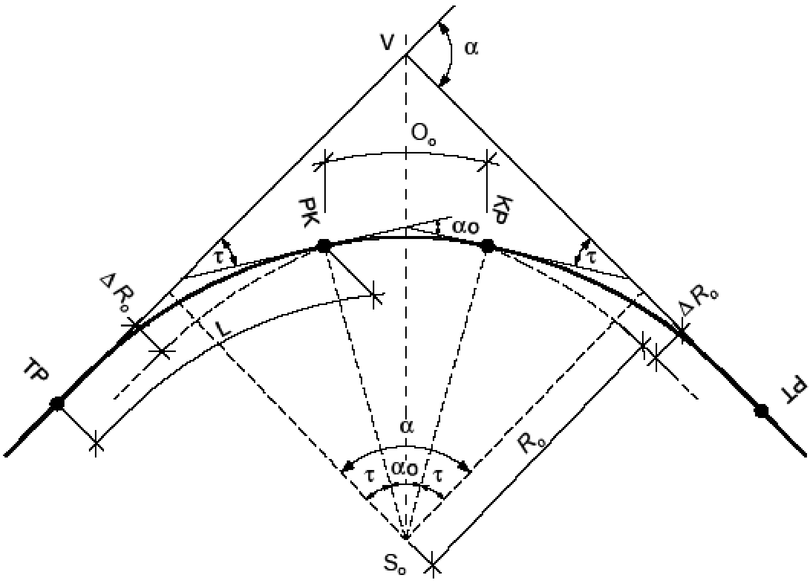
The magnitude of the minimum radius of horizontal curve R*o* is calculated according to the relevant formula given in the ČSN standard, where the smallest allowed radii of horizontal curves can be found in relation to the design speed and the centripedal slope.

4.2 Vertical curves

The vertical solution also consists of straight sections and curves, but these are formed by a second-degree parabola with vertical axis. The vertical solution is to be designed as smooth as possible with the highest possible radius of the curves (mainly due to better sight conditions on horizons). Requirements for minimum and maximum longitudinal slopes are given in the relevant technical standards (ČSN). There are two types of vertical curves: **crest curves** and **sag curves**.

4.3 Transition curves

Transition curves are designed to reduce the jump transition between a straight section and circle, in particular by means of the clothoid shape. Transition curves are inserted either between the tangent
and circular curves, or between two same-way circular curves of different radii. For aesthetic reasons, transition curve length *L* [m] (see Fig. 3) should be designed depending on the radius of the circular curve in the values given by a specific table in the technical standards (ČSN).



Source: http://www.fce.vutbr.cz/PKO/0M2/PREDN3/predn3.htm
Figure 1 – Circular curve O_o with transitions L

4.4 Cross slope

For highways and motorways, the basic cross slope of the roadway in both straight sections and curves is commonly 2.5% or more in curves. **Normal crown** (or roof slope) is usually designed on straight sections. For reasons of easier drainage, it may also be designed as one-sided slope on less important roads, in the areas of at-grade intersections, and in suitable terrain conditions. The transition from the normal crown to the one-sided slope must be carried out smoothly.

4.5 Road camber

Road camber is made in the curve of a road. The non-zero cross slope of the roadway is required, first, because of its necessary drainage with respect to road safety and roadway life, and, second, in order to eliminate centrifugal force in horizontal curves. The camber of the roadway is carried out in the space of the transition curve so that a full **centripetal slope** should be reached before the beginning of the circular part of the curve. The camber is often done over the entire length of the transition. On directionally segmented roads (motorways and highways), the camber is made on each carriageway separately.

The required centripetal slope of a road is achieved by turning the considered part of the cross section around:

- the carriageway axis (see Fig. 4),
- or the outer edge of the marginal strip.

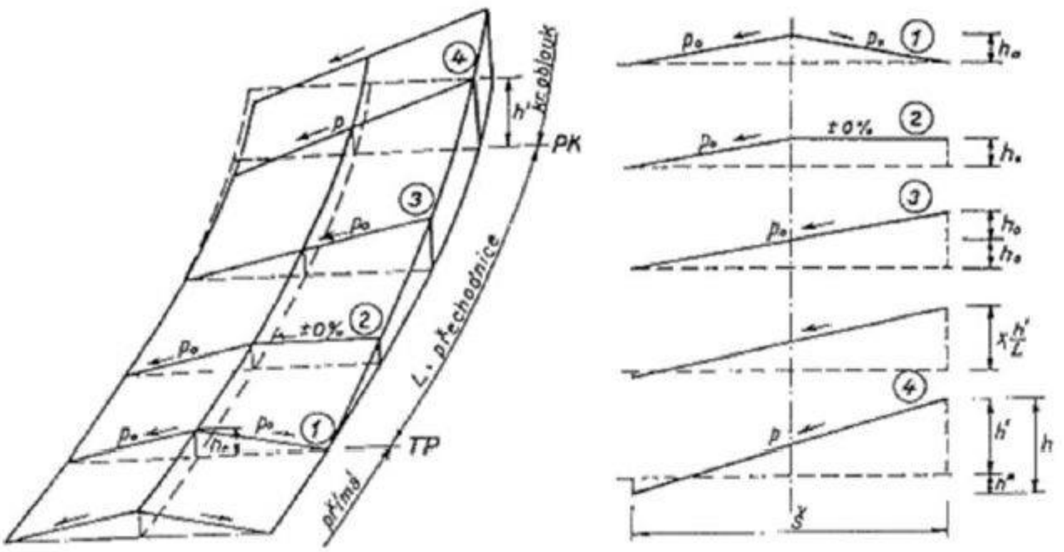


Figure 2 – Road camber around the carriageway axis
Source: ČSN 73 6101 – Design of highways and motorways

According to the relevant ČSN standards, carriageway extensions are also done in horizontal curves for safety reasons in addition to the camber of the road.

5. CATEGORIZATION OF ROADS, COMPOSITION OF ROADWAYS (ROAD ELEMENTS)

5.1 Road categories

According to **Act No. 13/1997 Coll., On the Road Network**, as amended, roads in the Czech Republic are divided into the following categories:

- **Motorway** – a road designed for fast long-distance and international transport by motor vehicles that is built with fly-over crossings, with separate entry and exit points, and which has directionally separated carriageways.

- **Highway/road** – a publicly accessible road designated for use by road and other vehicles and pedestrians. Highways form a road network and are divided into the following classes according to their purpose and transport significance:

  - **1st class roads**, which are intended particularly for long-distance and international transport. This category includes expressways, which have four-lanes and are directionally segmented. They have similar parameters to motorways and are marked with the letter R;
  - **2nd class roads**, which are mainly designated for inter-district traffic;
  - **3rd class roads**, which are designated to connect municipalities or serve as connections to other roads.

- **Urban road** – a publicly accessible road that serves predominantly to local transport within a municipality. Urban roads are further divided according to their transport significance, designation and construction equipment into the following categories:

  - 1st class urbanl roads, which mainly refer to **local expressways**;
  - 2nd class urban roads, which are **collector roads** with a limitation of the direct connection of neighboring properties;
  - 3rd class urban roads, which refer to **service roads**;
  - 4th class urban roads, which refer to **roads inaccessible to road motor vehicles or where mixed traffic is allowed**.

- **Special-purpose road** – is a road that serves to connect individual properties for the needs of the owners of these properties or to connect these properties to other roads or to cultivate agricultural or forest lands.

Ownership of roads

Roads are managed and developed by their owner, who is different for each road category and class. The owner of motorways and highways (including expressways) is the state and these roads are
managed by the Road and Motorway Directorate of the Czech Republic (ŘSD). The owner of the 2nd and 3rd class roads is the region on whose territory the roads are located (since 1 October 2001). The owner of urban communications is the municipality on whose territory the local roads are located. The owner of special-purpose roads is a legal or natural person.

5.2 Road elements in non-urban areas

The summary of the composite elements of a road shows us the width organization of crown. The crown consists of the following elements (see Fig. 5):

- **On directionally undivided roads:**
    - two-way carriageway (a lane in both directions *a*),
    - additional lanes,
    - marginal strips *v*,
    - shoulder (sealed *c* and unsealed *e*),
    - lateral dividing ways
    - associated lanes or ways,
    - short emergency lanes,
- **on directionally divided roads:**
    - two one-way carriageways (each carriageway consists of two or more lanes a),
    - additional lanes,
    - marginal strips v,
    - central reservation,
    - shoulder (sealed c and unsealed e),
    - lateral dividing ways,
    - associated lanes or ways,
    - short emergency lanes.

The widths of the individual composite elements can be found in the relevant technical standards. The lane width is usually in the range of 2.75 m to 3.75 m according to the category of a road.

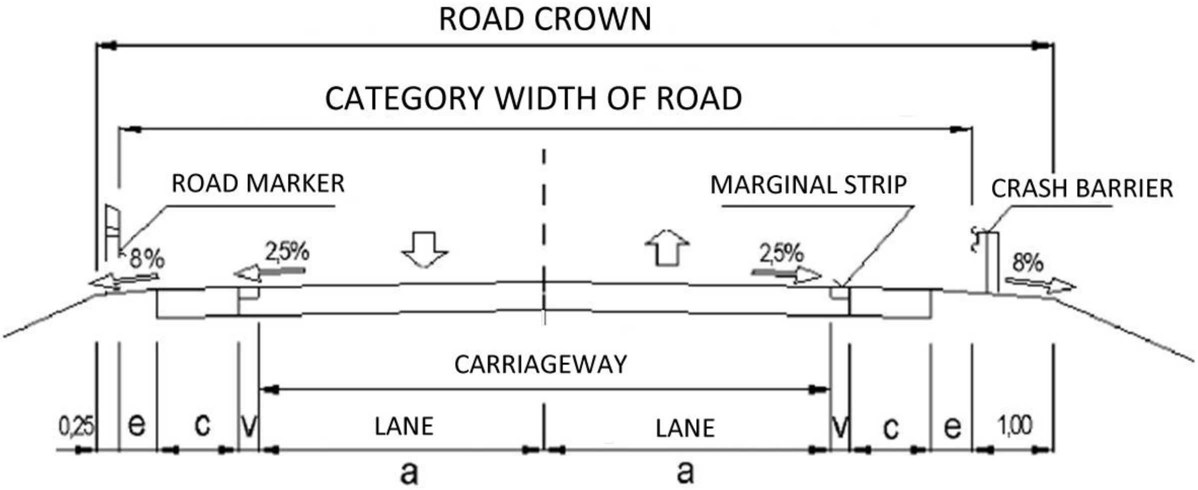


Figure 3 – A cross-section of a directionally undivided road and its composite elements
Source: http://www.czrso.cz/clanky/kategorie-pozemnich-komunikaci-dle-csn/

6. CONSTRUCTION MATERIALS AND STRUCTURAL LAYERS OF ROADS

6.1 Construction material and structural layers of roads

A road consists of:

- roadway,
- base course,
- sub-base.

The building material used for the construction of the road can be divided into aggregate and binder. Thanks to these materials and their mixtures, the individual structural layers are formed on the subgrade (the construction surface of the base course). Aggregate refers to typical crushed stone with the appropriate grain size, but recycled artificial materials can also be used. Binders can be divided into:

- hydraulic (lime, cement, fly ash, etc.)
- bitumenuous (natural, petroleum such as asphalt, tar, etc.)

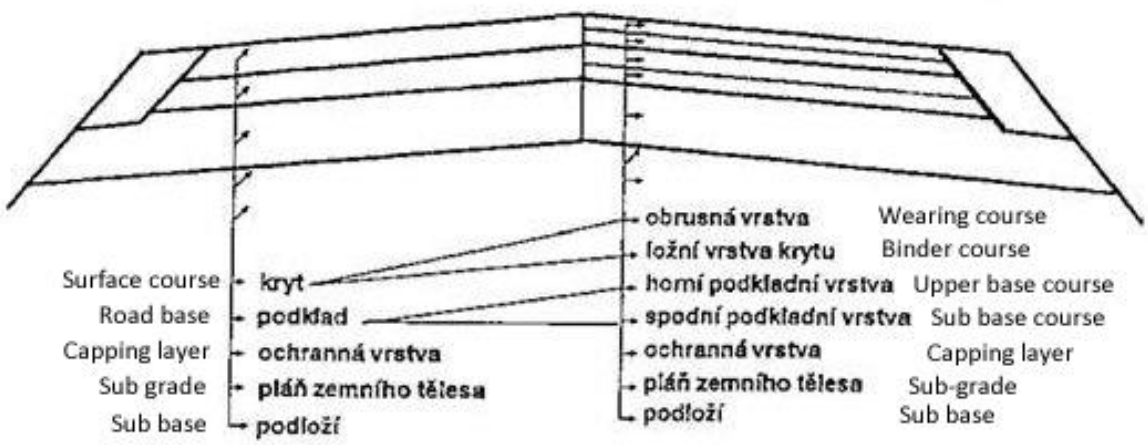


Figure 6 – Structural layers of a road
Source: Mahdalová 2010

Roadway is the paved part of a road designed for movement of vehicles which enables (owing to its load capacity and straight surface) economical and safe transport with the design speed throughout its service life. Typically, this is a multi-layered construction that usually consists of:

- surface,
- road base and
- capping layer.

It lies on a modified sub-base (the sub-grade), the upper layer of which is formed by an active zone of high-quality materials.

The surface forms the upper part of the roadway and is directly exposed to the effects of vehicle wheels, atmospheric influences and temperature changes. Its quality has an impact on transport costs and maintenance costs. That is why the surface is made of high-quality materials and good technological procedures must be taken when it is made. The surface has usually two layers (binder and wearing courses) on asphalt roads, whereas less loaded roads can have a single-layer surface. The cement-concrete pavement surface is made as a single-layer (180 to 300 mm thickness).

Depending on the use of construction material, the roadway surface can be divided into:

- asphalt,
- cement,
- paved,
- gravel,
- of stabilized soils,
- special.

Depending on the position of the level of road sub-grade relative to the surface of the area, the types of base course routing are as follows (see Fig. 7):

- base course in the embankment (section 1);
- base course in the notch (section 2);
- base course in the cut - partly in the notch and partly in the embankment (section 3);
- base course on the surface of the area (section 4).

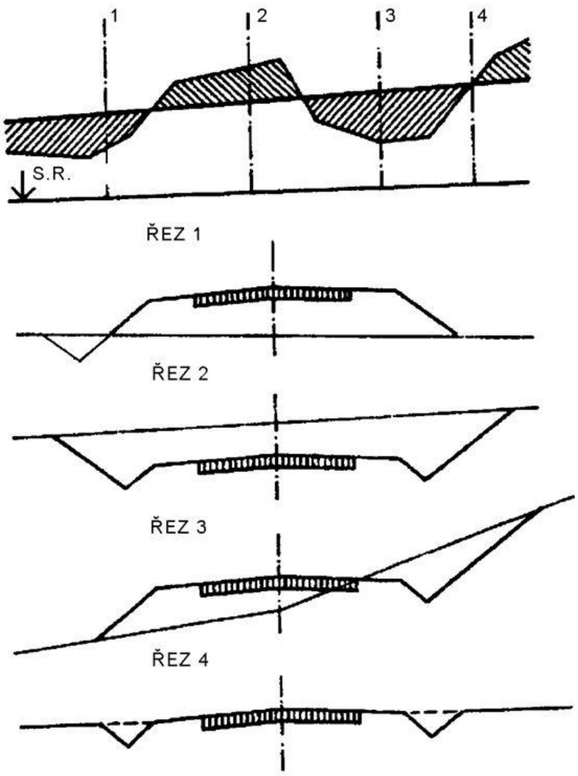


Figure 7 – Possible ways of building a base course depending on the terrain
Share:
http://share.pdfonline.com/0f164f37e4d148408f55dbd18aca9235/Dopravn%C3%AD%20stavby.htm

7. URBAN ROADS – ROADS WITHIN THE TOWNS

7.1 Classification of urban roads

Classification of urban roads (according to ČSN 73 6110)

According to a urban-traffic function, urban roads are divided into the following functional groups:

- A - **express**, they have only a traffic function, they are structurally and organizationally separated from the housing development in a city (divided into groups A1 and A2);

- B - **collector**, with a traffic-service function, are connected to express roads and thus divert traffic from urban areas to higher roads (further differentiated into groups B1 and B2);

- C - **service**, where the service function predominates over traffic one, they refer to individual streets in residential or industrial parts of cities (further differentiated into C1, C2 and C3).

- D - **mixed** traffic roads and roads with the exclusion of motor traffic - these communications of functional group D are marked by the subgroups:

  - D1 – mixed traffic roads (e.g. residential area or pedestrian zone);
  - D2 – roads inaccessible to road motor vehicles (e.g. pedestrian lane or bicycle lane).

The nature of the functional groups and classes of roads must be in accordance not only with the design elements of horizontal, vertical and width solutions, but the planning of roads and their interconnection must be designed to naturally fulfill the function to which they were designated. Traffic is to be directed and routed from a fine and dense network of service roads to a higher level of collector roads, and further (in the case of a larger source and destination distance) to the level of express communications. In any case, horizontal and width solution of service roads should not attract or even allow transit traffic.

7.2 Differences of urban roads

Local, urban roads are naturally included in the field of roads together with highways and motorways, they are naturally linked to them and create a transport network with them; however, they are characterized by many features that make them distinct from highways and motorways. Urban roads require a wider range of traffic-engineering knowledge and also urge the urban transport expert to take into account a much greater number of influences and requirements. This also means that a city transport specialist will not work independently but will coordinate his activity and consult other experts such as urban planners, architects, environmentalists, network administrators and, last but
not least, politicians, especially local ones, who should pass a so-called social demand to experts.
The basic difference between urban and other types of roads is in the environment in which they are situated. Highways and motorways lie in **non-urban area**, which is a free landscape outside a built-up area of a municipality. Urban roads are located in **built-up area**, i.e. in the territory of a residential unit that is built-up or intended to be built-up.

This results in a difference in spatial constraints. Urban roads are set in urban environment that, with the buildings and other constructions, leaves only a limited space. Urban roads are situated in the urban structure, which has, for the most part (at least in the case of Central European cities) gradually evolved over centuries. Urban and transport structures are closely related and developed together. The current problem is, in particular, that transport requirements are rapidly expanding over the course of the century, and requirements for the transport structure strongly outweigh the possibilities of urban structure.

Urban roads have significantly different functions compared to highways. Urban street is definitely not just a space for transportation, but it has a residential and social function, and creates urban space as a place suitable for life of a large number of people.

7.3 Urban road area

A **urban road area** is the part of a road that serves public traffic (cars and pedestrians) or residence, as well as static and dynamic traffic including green ways. It is divided into main traffic area and associated traffic area. As far as the communications of the functional subcategory D1 is concerned, it is divided into traffic area and residence area. The functional subcategory D2 has only a traffic area. The area of a urban road is defined either by the street line (objects, fencing) or by the outer edge of the pedestrian lane or a similar surface.

The **main traffic area** is a part of a urban road area that is bounded by the outer edge of the safety distance for the road categories A, B and C with side curbs, by the width between the marginal or safety device for communications without side curbs, and by the width of the crown for communications without such devices. The central reservation up to a width of 20 m, or central elevated tramway with all included devices (crash barriers, poles, etc.) and associated lanes are also parts of the main traffic area.

Traffic area is the part of a urban road area of the functional subgroup D1 which serves mixed traffic.

Associated traffic area is the part of a urban road area between the main traffic area and the outer edge of the local road area. It is used by both static and dynamic traffic. It is a space above the associated lanes or ways or pavements including greenery.

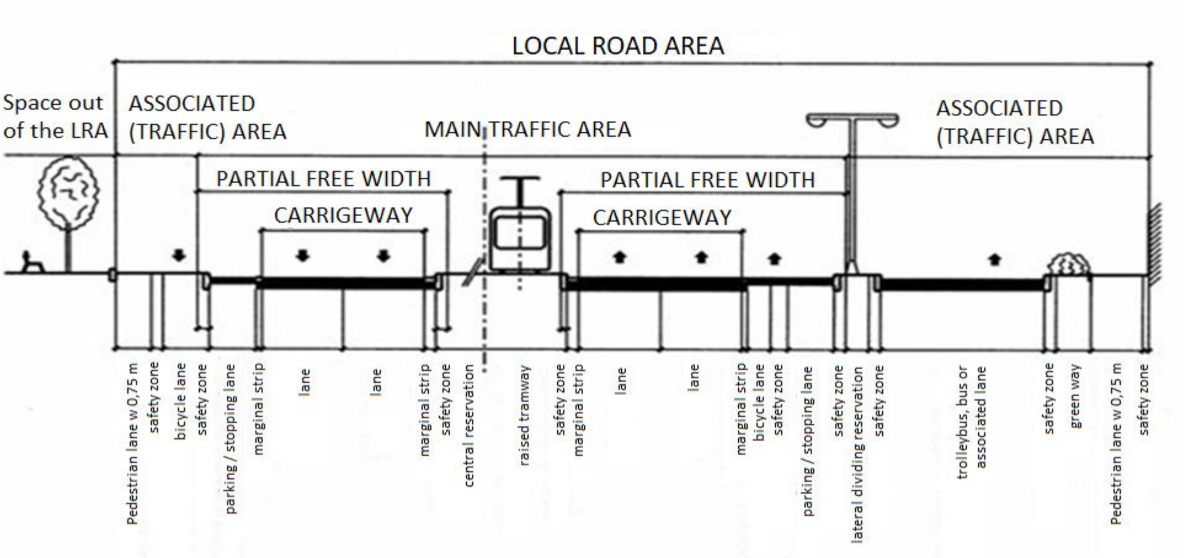


Figure 8 - Cross section of a urban (local) road area
Source: http://kds.vsb.cz/mkk/

8. DESIGNING OF URBAN ROADS AND PARKING AREAS IN CITIES

8.1 Design categories of urban roads

Design categories are, similarly to roads in non-urban area, marked with a letter and numeric designation which gives us the operational and technical parameters and the structural parameters of the building character and the functional classification of an urban road. The symbolics for identifying the type of a urban road is more complex than for non-urban roads, as there are more elements to be found, and it is created as follows:

- **M** – urban road (always at the beginning)
  - **R** – express, **S** – collector, **O** – service
    - **number** – gives the number of lanes
      - **letter** – indicates structural elements of a urban road (e.g. **c** – sealed shoulder, **T** – tramway, **p** – parking lane, **a** – bicycle lane, **b** – bus and trolleybus lane, **d** – directionally divided road, etc.)
        - **the width of a urban road area** in metres
          - **the width of the main traffic area (free width)** in metres
            - **design speed** in km/h

8.2 Structural elements of urban roads

Depending on the functional groups of urban roads, according to the design volumes and the desired supply needs for the various traffic participants, the relevant structural elements are used and the number of individual lanes is determined. The smallest permissible values of the individual elements can be found in the relevant technical standards (ČSN). When designing a transverse arrangement of urban roads, combinations of the smallest values of the structural elements are not allowed, and combinations of the largest values are not suitable either. In most cases, the elements are designed to maintain a certain safety zone and, in this way, designing also takes into account the vehicles of rescue integrated system, in particular firefighters.

- *a* – travel lane;
- *e* – unsealed shoulder;
- *c* – sealed shoulder;
- c_p – parking and stopping lane;
- c_z – green way;
- a_t , a_b – tramway (raised or not raised) and bus or trolleybus lane;
- a_c , a_{ch} – bicycle lane, pedestrian lane;
- *d* , d_p – central reservation and lateral reservation;
- *v* , v_d – marginal and dividing strip;
- b_o – safety zone.

8.3 Parking spaces

The design of parking and emergency spaces is governed by ČSN 73 6056 Parking areas for road vehicles and by ČSN 73 6110 Design of urban roads.

Parking of a vehicle means locating a vehicle outside road travel lanes usually for the time of shopping, making a visit, doing one's job, loading and unloading goods.

Long-term parking means locating a vehicle outside road travel lanes usually in the place of residence, or at the seat of the vehicle keeper while the vehicle is not used.

An area designed to park a vehicle is called a **parking space**. Parking spaces can either be separate, or they create **parking bays** along carriageways and **car parks** that are spaces for parking vehicles on a separate area outside the main traffic area.

Depending on how the vehicle is parked (parking space dimensions are based on the above mentioned ČSN standards), parking spaces along lanes include:

- perpendicular order of parking spaces;
- parallel order of parking spaces;
- angle order of parking spaces (at an angle of 45° or 60°)

9. RAILROAD CONSTRUCTIONS – RAILWAY CATEGORIES IN THE CZECH REPUBLIC

9.1 Railway categories in the Czech Republic

Railway tracks in the Czech Republic, pursuant to **Act No. 266/1994 Coll., On Rail Systems**, as amended, are classified into categories according to the meaning, purpose and technical conditions laid down by the implementing regulation. The abovementioned act defines individual tracks (rail transport):

- Railway tracks;
- Tramway tracks;
- Trolleybus tracks;
- Cableways and industrial tracks.

The railway tracks include:

- a **national railway** serving international and national public rail transport;
- a **regional railway**, which refers to a regional or local railroad that serves public rail transport and is fed into a national or other regional railway;
- a **siding**, which is a track that serves the operator's or other entrepreneur's needs and is fed into a national or regional railway or other siding;
- a **special railway**, which serves mainly to ensure the transport service of a municipality (e.g. the underground in Prague)

The resulting state of categorization of the railway network in the Czech Republic is based on the current state of the railway network and the concept of its development in the years to come. In relation to the European Union, most national railways are integrated into the TEN-T network, which is the concept of the trans-European transport network. Upon the Czech Republic accession to the European Union it was also decided about the modernization of selected railway lines, which led to the creation of international rail corridors in our country. The modernization of these lines mainly deals with increasing the load class, increasing track speeds in some sections to 160 km/h, electrifying and doubling the tracks, minimizing level crossings with roads, using the modern and uniform (in the framework of rail interoperability) equipment with automatic block etc. So far, most sections of railway corridors have been built or modernized:

- **transit corridor**: Děčín (national border with Germany) – railway station in Prague-Holešovice - Pardubice - Brno main station- Břeclav (national border with Slovakia)

- **transit corridor**: Petrovice u Karviné (national border with Poland) - Ostrava main station - Přerov - Břeclav (national border with Austria)
- **Itransit corridor**: Mosty u Jablunkova (national border with Slovakia) - Ostrava main station - Přerov - Prague - Plzeň - Cheb (national border with Germany)
- **transit corridor**: Děčín (national border with Germany) - Prague - České Budějovice - Horní Dvořiště (national border with Austria)

9.2 Characteristics of the railway network in the Czech Republic

The current construction length of the tracks in the Czech Republic is 9430 km. Our country is among the countries with the highest density of railway network. Most railway tracks have a **normal gauge** (1435 mm), but there are narrow gauge tracks (e.g. Jindřichův Hradec - Nová Bystřice), where 760 mm gauge is used. The vast majority of railways are single-track, some of the major national railways are double and multi-track. Double-track (and multi-track) railways increase **track capacity**, i.e. the maximum number of trainsets that are able to pass through a given section of the railway track for a time period.

The electrified tracks use different power systems. In the Czech Republic the following systems are used:

- Alternating voltage 25 kV, 50 Hz (mainly the south of the Czech Republic);
- DC voltage 3 kV (mainly the north of the Czech Republic);
- DC voltage 1,5 kV (mainly the track Tábor – Bechyně).

10. RAILROAD CONSTRUCTIONS – RAILWAY OPERATION POINTS AND TRANSPORT STATIONS

10.1 Basic concepts

Operation point is a place on a railway track designed for the management of rail transport (train management). They are divided into:

- **operation points with track branching** - railway stations, passing loops and branches
- **operation points without track branching** - watchtowers, signal boxes and railway signals of the automatic block, and automatic signal boxes

Transport station is a place on a railway track, which serves only for getting off and boarding of passengers, unloading and loading of goods. It refers to stops and cargo spaces.

Railway signal is a device which indicates individual signals (signals or instructions). The signals are marked depending on what they are used for (what signal they indicate), for example, entrance signal, alignment signal, partition signal etc.

Broad track refers to track section between two adjacent stations or a track section between a station and the end of s track at s stop or a station. The boundary between a station and a broad track is the **entrance signal**. The broad track is further divided into separate sections (separated by signals):

- space section;
- interstation section;
- track section.

10.2 Railway stations

An operation point with railway branching that enables overtaking and cruising of trains, passenger transport, sale and dispatch of goods, and (in the case of larger rail equipment) sorting and assembling of trains. Depending on the purpose and nature of work, we can distinguish between **freight**, **passenger** and **mixed stations**. Depending on the track arrangement, we distinguish between **head**, **drive-through** and **mixed stations**.

Depending on the position in a railway network, there are the following types of stations:

- starting;
- intermediate;
- connecting;
- branch;
- crossroads;
- contact;
- node;

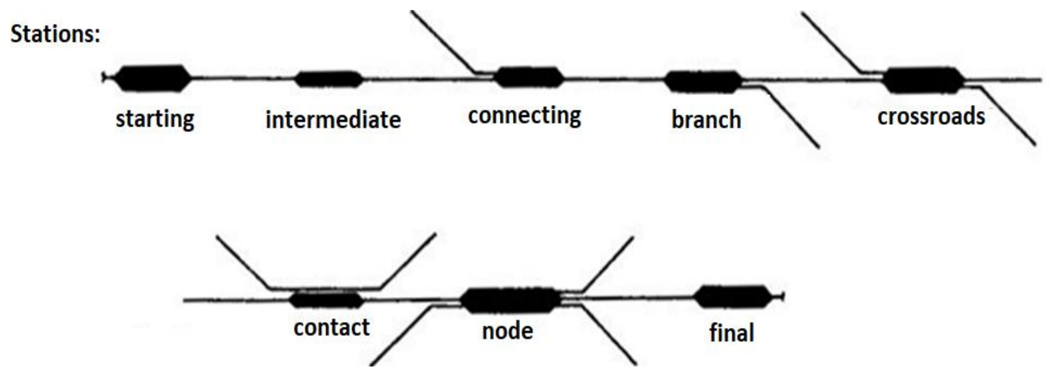


Figure 4 – The classification of stations according to their location in a railway network
Source: The author

At the station we divide railway tracks from the point of view of their use into transport and handling tracks. **Transport tracks** are used for entering, departing or passing of trains and their cruising or overtaking. These are further divided into:

- **Main**
- **Overtaking** (overtaking and cruising of trains);
- **Other** (parking, beginning of a train movement after its assembly, etc.)

Handling tracks are used to move the vehicles in a station or to deliver to the point of unloading or loading. Further, they are divided into parking, extraction, marshalling, connecting, etc.

Platform at a railway station is a part of the railway substructure (traffic area and communications) intended for boarding of passengers and their getting off and for handling of small consignments. By the type of layout, platforms are divided into:

- **Peronization** (a platform with an extra-level access);
- **Half-peronization** (one rail group of platform has an extra-level access, whereas the other group of platform is with level access);
- **Level platform**.

Station building is a ground building, which forms the transition between a railroad and pre-station area, and consists of publicly accessible and inaccessible spaces. There are facilities for passengers, carriers, operators of the railway. They primarily provide services for railway passengers, but they also serve as a base for public transport passengers at transfer points. Their disposition is based on the frequency of the passengers at a specified railway station.

Space around the station is the area before the station building. It may include other public transport stops, parking lots, taxi stands, bicycle storage facilities, or various shops or services.
It is a kind of gateway to the city, there should be no traffic road in front of the building, but it should create an architecturally dignified area along with the connection to other types of public transport. Therefore, it is often advisable to create public transport hubs in the area in front of a station, which would guarantee a good and convenient transfer of passengers from regional rail lines to public transport or regional bus lines.

11. GEOMETRIC PARAMETRES OF TRACKS - BASIC DATA

The geometric position of a track is its spatial position given by:

- track gauge;
- relative height position of rail ways;
- horizontal planning of tracks;
- vertical planning of tracks.

11.1 Track gauge

The track gauge is the distance of the trailing edges of the rails, measured at a cross sectional plane of 14 mm below the rail crown (in the case of wide rails). A normal track gauge is 1435 mm. In addition to the normal gauge, there are different types of narrow and wide gauge (e.g. Russian gauge used in Russia and other states of the former Soviet bloc is 1520 mm).

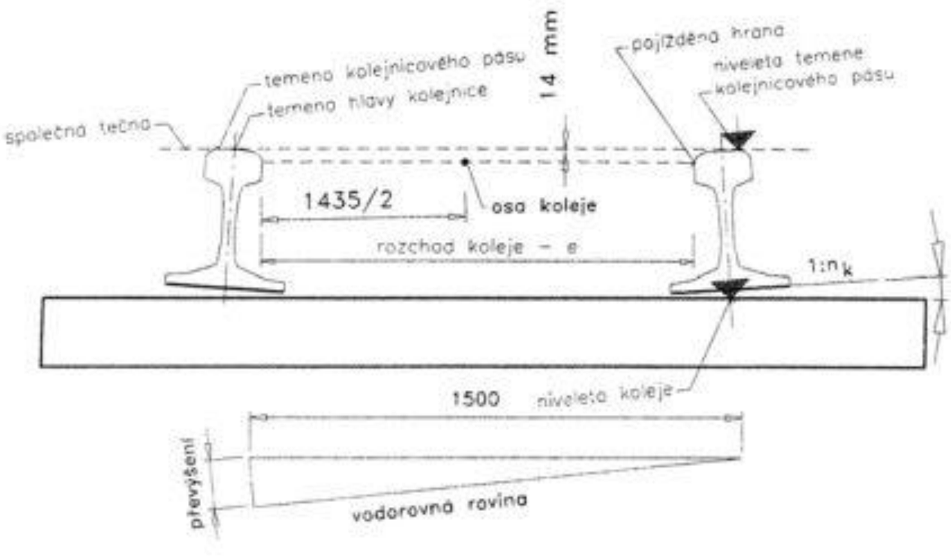


Figure 5 – Graphical representation of track gauge
Source: http://telegrafroad.sweb.cz/legislativa/zeleznice_stavitelstvi.pdf

Tracks are widened in curves for a safe and smooth passage of railway vehicles, allowing the gears of the railway vehicles to move in the transverse direction. This is called **gauge extension** and is realized by moving the inner rail into the center of the circular curve. The extension value is calculated by an appropriate formula, with the maximum admissible extension being 16 mm.

11.2 Curve superelevation

The vertical position of tracks is in one level in straight sections. The change of the height level of the
two rails is designed in the horizontal curve in order to exclude or mitigate the adverse effects of the centrifugal force during rail vehicles passage in a curve. The superelevation *p* is designed in a way that the outer rail is raised relative to the inner rail by a calculated value according to a specified formula, the level of the track being determined by the height position of the inner (non-raised) rail. Track superelevation is determined according to certain track sections and the respective track speed. A so-called track theoretical superelevation p_t is determined on track sections:

$$p_t = \frac{11{,}8 \cdot v^2}{r},$$

where ***v*** is designed track speed in km/h;

r is the radius of a circular curve in metres;

$\boldsymbol{p_t}$ is theoretical superelevation in millimetres.

In the circular part of a curve, in which trains go at different speeds, a normal superelevation p_n is determined. The maximum value of superelevation is concidered to be 150 mm, but if the calculated superelevation value is less than 20 mm, a track in the curve without superelevation of rails will be designed.

A smooth and gradual transition from a non-raised track to a raised one is enabled by **ascendant**. Again, the ascendant is calculated according to appropriate formulas and can be:

- linear – straight, has the same slope along the entire length in a ratio of 1: n;
- non-linear – composite.

12. GEOMETRIC PARAMETRES OF TRACKS- HORIZONTAL AND VERTICAL GEOMETRY

12.1 Horizontal planning of tracks

When solving horizontal proportions, horizontal curves and their radii are designed as long as possible (but there is a table of curves radii provided by the ČSN standards) in order to allow a safe passage of vehicles through curves. Horizontal proportions are designed by means of horizontal elements: a straight section (control line), a transition and a horizontal curve.

Transition is a curve of transient curvature that enables a smooth horizontal transition between the straight section of a track and the track section lying in a circular curve. A cubic parabola is used on railway lines and is calculated according to a relevant formula given in the technical standards ČSN.

The radius of **horizontal circular curves** should be as long as possible (calculated according to appropriate formulas) so that the speed shoud not have to be limited in the curves, and they must satisfy the maximum allowable speed of the fastest train used on a specified track. Likewise, the smallest possible radii of curves must meet the following conditions:

- on main tracks of the nationwide railway: r_{min} = 500 m, exceptionally can be reduced to 300 m,
- on regional tracks with the speed of max. 50 km/h: r_{min} = 190 m is allowed,
- on sidings: r_{min} = 150 m.

12.2 Vertical planning of tracks

On tracks in more complex terrain where it is necessary to design longitudinal slopes, the slope ratios for each track section are determined by a distinctive dynamic calculation, which takes into account:

- the highest required train speed;
- train braking method;
- driving performance;
- required braking distances.

Longitudinal slopes are determined by thousands (the number of metres by which the height of the track increases at 1000 meters), which results in the division of tracks into adhesive (with longitudinal gradient less than 45 ‰) and non-adhesive (more than 45‰). The breaks of a track longitudinal slopes in longitudinal sections are rounded by second-degree parabolic curves. The radii of these curves are calculated according to specified formulas where the track speed and a constant are considered, and the smallest permitted radius should be 1000 m.

12.3 Gauge cross section

The gauge cross section is a common name for the contour lines of the gauge and the contour of a vehicle. The gauge cross section and its dimensions are determined in a cross section perpendicular to the axis of the track. It defines the distance of the buildings, equipment and objects on the railway line from the track axis and above the crown of rails, so that free space is created in the track axis for a safe passage of railway sets with their load. Spatial layout of tracks is derived from gauge cross section.

Figure 11 shows the gauge cross-section of a non-electrified railway track (for electrified tracks, the height of the gauge cross section is given by the height of the contact line):

- **the left side is for:**
    - track rails (also at stops),
    - main tracks at stations and passing loops,
    - main tracks in the handling rails of sidings,
    - rails for trains transporting passengers,
    - A-B for equipment and structures on the outer side of rails,
    - C-D for the equipment between rails,

- **the right side is for:**
    - other rails at stations and passing loops,
    - other tracks in the handling rails of sidings,
    - E-F for all structures and equipment.

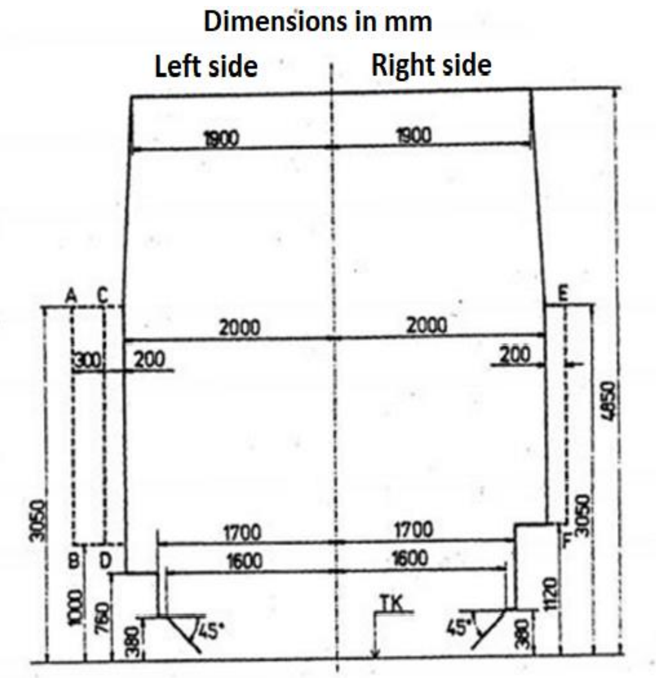


Figure 6 – gauge cross section of a non-electrified railway
Source: http://telegrafroad.sweb.cz/legislativa/zeleznice_stavitelstvi.pdf

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