VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

FACULTY OF ENVIRONMENTAL ENGINEERING

DEPARTMENT OF ROADS

Deivydas Jarukas

ANALYSIS OF DESIGN REGULATION FOR LOW VOLUME ROADS AND RECOMMENDATIONS FOR LITHUANIAN STATE ROAD NETWORK DEVELOPMENT

MAŽO INTENSYVUMO KELIŲ PROJEKTAVIMO REGLAMENTŲ ANALIZĖ IR REKOMENDACIJOS LIETUVOS KELIŲ PLĖTRAI

Master Thesis

Study programme of Innovative Road and Bridge Engineering, state code 628H20001

Road and Bridge specialisation

Study field of Civil Engineering

Vilnius, 2018

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
FACULTY OF ENVIRONMENTAL ENGINEERING
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Vilnius, 2018

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DECLARATION OF AUTHORSHIP IN THE FINAL DEGREE PROJECT

January 9, 2018

(Date)

I declare that my Final Degree Project entitled "Analysis of design regulation for low volume roads and recommendations for Lithuanian state road network development" is entirely my own work. The title was confirmed on November 14, 2017 by Faculty Dean's order No. 237ap. I have clearly signalled the presence of quoted or paraphrased material and referenced all sources.

The academic supervisor of my Final Degree Project is Virgaudas Puodžiukas.

No contribution of any other person was obtained, nor did I buy my Final Degree Project.

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2017 11 20
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OBJECTIVES FOR MASTER THESIS

2017-11-20 No. ....
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For student Deivydas Jarukas
(Name, Surname)

Master Thesis title: ***ANALYSIS OF DESIGN REGULATION FOR LOW VOLUME ROADS AND RECOMMENDATIONS FOR LITHUANIAN STATE ROAD NETWORK DEVELOPMENT (MAŽO INTENSYVUMO KELIŲ PROJEKTAVIMO REGLAMENTŲ ANALIZĖ IR REKOMENDACIJOS LIETUVOS KELIŲ PLĖTRAI)***

Approved on 14, November 2017 by Dean's decree No. 237 ap

The Final work has to be completed by 4 January, 2018

THE OBJECTIVES:

To revue the sructure of Lithuanian road network and accident data. To analyse low wolume roads on Lithuanian state road network and standard regulations for design of low wolume roads. To formulate the objectives and targets of research paper. To compare design regulations of developed countries like USA, Germany, The Netherlands and Lithuania. To analyse design documentation of several, selected low volume roads and design nimplementation practices in Lithuania. To analyse traffic volume, road geometric elements taking attention to the road function, design speed and level of services.

To propose the most favourable international experience for implementation in Lithuania. To delivere general conclusuions and recommendations for a practical application of new design standards recommendations for Lithuania.

....

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Antrosios pakopos studijų **Inovatyvių kelių ir tiltų inžinerijos** programos magistro baigiamasis darbas 3 (keliai ir tiltai).

Pavadinimas: **Mažo intensyvumo kelių projektavimo reglamentų analizė ir rekomendacijos Lietuvos kelių plėtrai**

Autorius **Deivydas Jarukas** Vadovas **Virgaudas Puodžiukas**

Kalba: anglų

Anotacija

Baigiamajame magistro darbe tiriamas mažo intensyvumo kelių tinklas ir projektavimo reglamaentai skirti projektuojant mažo intensyvumo kelius Lietuvoje. Apžvelgus Lietuvos ir kitų valstybių projektavimo normas ir rekomendacijas buvo suformuotas mokslinio darbo tyrimo tikslas. Tikslas išnagrinėti mažo intensyvumo kelių projektavimo reglamantus Lietuvoje ir užsienio valstybėse, bei pateigti rekomendacijas mažo intensyvumo kelių plėtrai. Šiam tikslui įgyvendinti buvo nagrinėjami rajoninių kelių žemės sankasos ir dangos pločiai, atlikta eismo intensyvumo analizė, išnagrinėti 5 žvirkelių asfaltavimo projektai. Darbe pateiktos bendrosios išvados ir rekomendacijos projektuojant mažo intensyvumo kelius.

Darbą sudaro: Įvadas, keturi skyriai, bendrosios išvados, bei priedai. Darbo apimtis – 87 p. teksto be priedų, 24 paveikslėliai, 37 lentelės. Rašant darbą remtasi 34 literatūros šaltiniais.

Paildomai pridedami darbo priedai.

Prasminiai žodžiai: dangos plotis, eismo intensyvumas, mažo intensyvumo kelias, projektavimas, žemės sankasa.

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Master Degree Studies **Innovative Road and Bridge Engineering** study programme Master Graduation Thesis 3 (Roads and Bridges).

Title: **Analysis of design regulation for low volume roads and recommendations for Lithuanian state road network development**

Author **Deivydas Jarukas** Academic supervisor **Virgaudas Puodžiukas**

Thesis language: English

Annotation

The final Master Thesis analyses the network of low volume roads and design regulations applied to the design of low volume roads in Lithuania. Having reviewed design standards and recommedations of Lithuania and other countries, the objective of the scientific research has been formulated. The objective was to examine regulations on the design of low volume roads in Lithuania and foreign countries and to provide recommendations for the development of low volume roads. To achieve the objectives, the widths of road and carriageway of regional roads have been studied, traffic volume analysis has been performed and five gravel road paving project documentations have been investigated. The thesis presents general conclusions and recommendations for the design regulations of low volume roads.

The work consists of: the introduction, four chapters, general conclusions, and annexes. The volume of the written paper is 87 pgs of text without annexes, 24 figures, 37 tables. 34 literature sources have been used when preparing the thesis.

Keywords: carriageway width, traffic volume, low volume road, designing, road width.

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ABBREVIATIONS

AADT– Average Annual Daily Traffic

AASHTO – American Association of State Highway and Transportation Officials

GDP – Gross Domestic Product

HCM – Highway Capacity Manual

HDM – Highway Development and Management

KM – Kilometers

LOS – Level of Service

LRA – Lithuanian Road Administration

TEN-T – Trans European Network Transport

INTRODUCTION

Road is an engineering structure designed for vehicular and pedestrian traffic. Roads are inseparable part of the complex transport system which receives large amounts of financial resources every year. These resources are used to maintain and repair existing roads, and to design as well as construct new ones. One of the most important phases of building road infrastructure is road design process, since road structure, parameters, construction technologies, road operational lifetime, and price depend on it. Proper design activity work allow rational use of the allocated funds and contribute to ensuring a high level of safety on roads. However, in order the design works went smoothly, certain background for it must be established, the quality of legislation regulating road design and its renewal being of utmost importance.

Presently, the design of the roads in Lithuania is carried out according to regulations on road design which are updated from time to time. Nevertheless, these updates are not sufficient to permit a satisfactory improvement of the safety of road users. According to the Lithuanian Road Administration, 3280 traffic accidents (with fatal consequences or resulting in injuries) occurred in 2016 leading to 188 deaths and 3875 injured persons. About 32 percent of traffic accidents on roads of national sinificance occurred on regional roads.

In Lithuania regional roads constitute the main part of the road network of national significance. The majority of these roads are attributed to low volume roads. A low volume road is an engineering structure intended for traffic volumes not exceeding 400 vehicles per day. However, in terms of designing, the category of low volume roads is not distinguished in Lithuania – there are no specific design standards or recommendations applied. Therefore, these roads are designed in line with general requirements. Low volume roads have been discussed by Žilionienė D., Čygas D., Juzėnas A. [31], Vorobjovas V. [32] and Jerome W. Hall, Elizabeth W. Rutman, James D. Brogan [33] in their articles.

This thesis aims at analysing foreign literature on low volume road designing, and at comparing road design standards applied in Lithuania and other countries, as well as at examining low volume road projects intended for asphalt works of gravel roads. This thesis also suggests recommendations for the development of Lithuanian roads, the designing of low volume roads being an element of this development.

The subject of the thesis – analysis of low volume roads.

Scientific novelty of the work – low volume roads in the network of the Lithuanian national roads have not yet been investigated.

The objective of the work – to analyse design regulations on low volume road design in Lithuania and in foreign countries and to provide recommendations for the innovative development of low volume roads.

In order to achieve the objective of the thesis the following **task** have been set:

- to carry out an analysis of the Lithuanian road system;
- to perform an analysis of road accidents which occurred on the national roads of Lithuania during 2013–2016;
- to analyse legal acts regulating road design procedures and recommendations on road design applied in Lithuania and other countries, such as the United States of America, Germany, and the Netherlands;
- to compare the differences of road design standards;
- to investigate projects intended for road paving works of gravel roads by analysing the traffic volumes, longitudinal profiles, horizontal road alignment, and cross section profile of the designed road sections;
- to analyse annual traffic volumes, carriageway widths, and road widths of regional roads of national significance;
- to perform economic justification of the solutions suggested for design regulations of low volume roads;
- to provide recommendations for the design of low volume roads in Lithuania based on the problems identified and of the research results.

1. ANALYSIS OF LITHUANIAN ROAD NETWORK

1.1. The structure of Lithuanian road network

The total length of the Lithuanian road network is 70 thousand kilometers. The roads of national significance falling under the responsibility of the Lithuanian Road Administration under the Ministry of Transport and Communications are 21.3 thousand kilometers long, while the total length of secondary roads is 59.7 kilometers, which is about 3 times more than the roads of national significance.

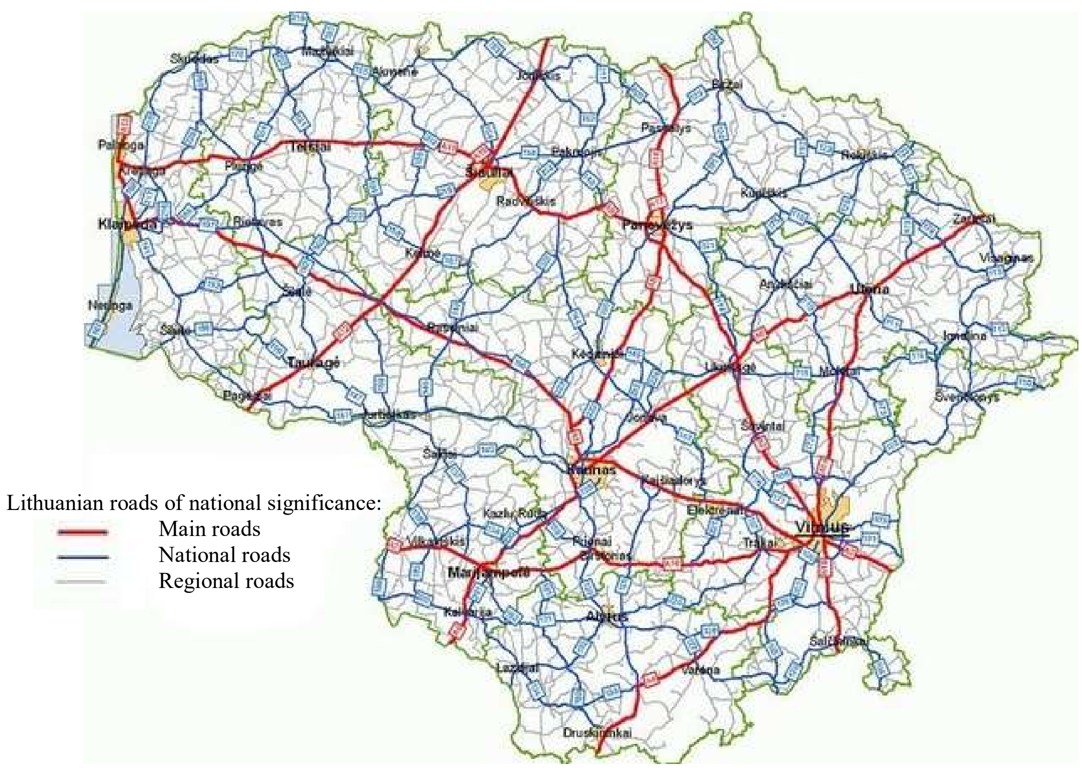


Figure 1.1 Lithuanian road network

The structure of the Lithuanian road network of national significance is the following:

- **Main** roads are the major Lithuanian roads. The most important of them, which by a decision of the United Nations Economic Commission for Europe are included into the international road network, are marked with index E with a corresponding number and later maintenance as TENT road network.

- **National** roads are roads connecting the motorways, centers of administrative units of the territory of the Republic of Lithuania, or interconnected with each other.
- **Regional** roads are roads connecting cities, major rural areas and motorways as well as national roads.
- **Local** roads are roads connecting regional roads, villages, and other roads used for local traffic, including public roads such as: forest roads, national park roads, roads in protected areas, border roads, quarry roads, roads used for hydraulic equipment access, roads in restricted areas, courtyards, and all other roads not classified as public roads, that are used by legal entities and natural persons.

According to certain parameters, traffic conditions, and traffic volumes, roads of national significance are classified as AM (motorways) and roads of I-V categories. AM category motorways are roads specifically intended for high-speed driving, having intersections of different levels with other roads and railways, pedestrian and bicycle tracks, and cattlepassages. At intersections the traffic flows of the vehicles entering and exiting motorways should not intersect on the same level. Opposing traffic flows on motorways have separate carriageways with dividing lanes.

Roads of category I are intended for high traffic volumes, however, the level of comfort and service on them is lower than on motorways. Opposing traffic is separated by dividing lanes. Technically and economically, crossroads and intersections with bicycle tracks and pedestrian walkways may be on the same level. Phasic construction of crossroads is allowed.

Roads of category II form the network of main and national roads.

Roads of category III form the network of national roads.

Roads of categories IV and V form the main network of regional roads.

Roads of category Iv connect the roads of national significance and rural areas, objects of infrastructure.

Roads of category IIv connect villages, interconnect with each other or with roads of higher categories.

Roads of category IIIv are local roads; they interconnect with each other or with roads of higher categories; they are access roads to hydraulic equipment or rarely visited objects of cultural and national heritage, forest roads and national park roads. [18]

1.2. Accident rate on the roads of Lithuania

Although the accident rate in Lithuania is decreasing, 3000 road traffic accidents still occur each year being a consequence for about 4000 victims. During the last ten years the number of road traffic accidents has reduced by half. However, during the last six years this number has basically remained stable.

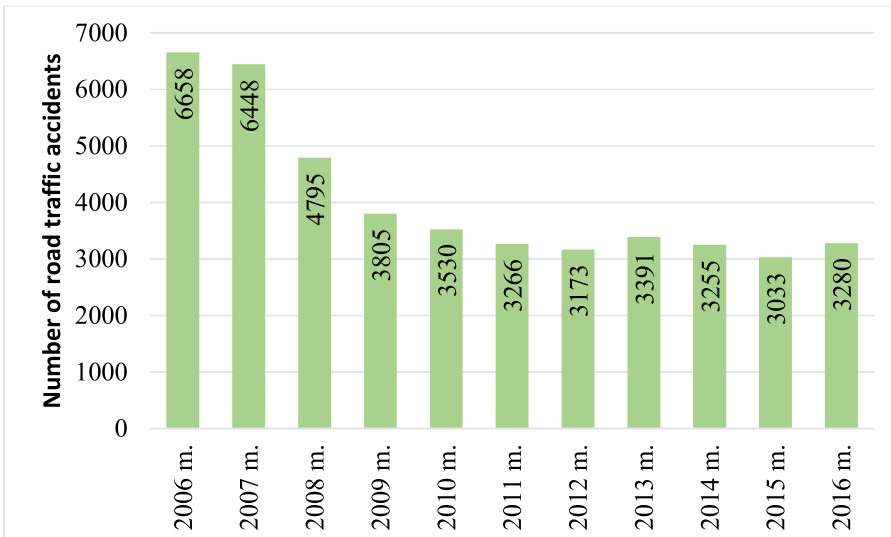


Figure 1.2 Change the number of road traffic accidents during the period of 2006–2016 (prepared by the author)

Although each year more new roads are built, existing roads are repaired, and the latest traffic safety measures are introduced, these measures are not sufficient to decrease the accident rate on roads.

As a rule, the victims of road traffic accidents are road users. During the last four years the number of injuries have not decreased and the number of deaths on roads decreased only by 0.73 times. Such change of the number of injured and killed people is minor.

Table 1.1 Distribution of road accidents and accident victims by seasons during 2013–2016 (prepared by the author, based on LRA data)

2013			2014			2015			2016		
Road accidents	**Deaths**	**Injuries**	**Road accidents**	**Deaths**	**Injuries**	**Road accidents**	**Deaths**	**Injuries**	**Road accidents**	**Deaths**	**Injuries**
3391	256	4007	3255	267	3785	3033	242	3594	3280	188	3875

In 2016, 30.76% of the total number of road traffic accidents occurred on roads of national significance, however, due to higher permissible speeds and less infrastructure adapted to most vulnerable road users, the number of deaths on these roads made up 63.83% of the total number of deaths on roads.

Table 1.2 below describes the change dynamics of the number of road traffic accidents and accident victims on roads of national significance in Lithuania in 2013–2016.

Table 1.2 Road traffic accidents and accident victims on roads of national significance in 2013–2016 (prepared by the author, based on LRA data)

Road category	2013			2014			2015			2016		
	Accidents	Deaths	Injuries	Accidents	Deaths	Injuries	Accidents	Deaths	Injuries	Accidents	Deaths	Injuries
Main	249	49	328	260	49	317	227	51	295	264	43	352
National	434	79	572	419	60	539	449	74	592	420	43	564
Regional	350	45	431	349	62	433	342	49	437	325	34	395
Total	**1033**	**173**	**1331**	**1028**	**171**	**1289**	**1018**	**174**	**1324**	**1009**	**120**	**1311**

In 2016 the total length of the roads of national significance was 21 244.407 km, out of this number the length of main roads was 1 750.719 km, national roads made up 4 925.491 km, and regional roads were 14 568.197 km long [14]. The main part of these roads consists of regional roads, where in 2016 there occurred 32.21% of all road traffic accidents occurring on the roads of national significance, and 9.91% of all road traffic accidents occuring in the country.

During 2013–2016, the distribution of traffic accidents occurring on roads of national significance by type has had no significant change. The types of accidents on regional roads were various.

Two types of accidents, which occur most frequently, are the following:

1. Rollover, which is a type of an accident when a vehicle tips over on the carriageway or having run off the road;
2. Collision, which is a type of an accident when moving motor vehicles collide with one another, or a moving vehicle collide with a vehicle which had been moving in front of it and came to a stop.

In 2016 on regional roads of national significance most frequent types of road accidents were rollovers and collisions, 32.62% and 25.54% of the total number of road accidents, respectfully. In total these two types of accidents made up 58.16% of all traffic accidents which occurred on regional roads in 2016. The distribution of road traffic accidents by type on regional roads over the period of 2013–2016 is given in Table 1.3.

Table 1.3 Distribution of road traffic accidents on regional roads by type in 2013–2016 (prepared by the author, based on LRA data)

Types of accidents	**Number of accidents**							
	2013		**2014**		**2015**		**2016**	
Collision	74	21.14 %	71	20.34 %	81	23.68 %	83	25.54 %
Collision with motorcycle	1	0.29 %	4	1.15 %	6	1.75 %	1	0.31 %
Collision with moped	5	1.43 %	1	0.29 %	6	1.75 %	0	0.00 %
Collision with bike	30	8.57 %	33	9.46 %	22	6.43 %	30	9.23 %
Pedestrian run-over	59	16.86 %	48	13.75 %	47	13.74 %	41	12.62 %
Collision with obstacles	27	7.71 %	17	4.87 %	11	3.22 %	13	4.00 %
Animal run-over	2	0.57 %	0	0.00 %	0	0.00 %	1	0.31 %
Rollover	94	26.86 %	110	31.52 %	104	30.41 %	106	32.62 %
Collision with stationary vehicle	4	1.14 %	2	0.57 %	1	0.29 %	1	0.31 %
Collision with rail vehicle	2	0.57 %	1	0.29 %	1	0.29 %	0	0.00 %
Other accidents	52	14.86 %	62	17.77 %	63	18.42 %	49	15.08 %
Total	**350**	**100 %**	**349**	**100 %**	**342**	**100 %**	**325**	**100 %**

Having compared the numbers of traffic accidents in 2013 and in 2016, it can be noticed that the number of collisions with bikes has not decreased, which means that safe traffic of cyclists is not ensured on regional roads. Otherwise, a decrease in the number of collisions with motorcycles and mopeds is observed over the last four years.

2. COMPARISON OF ROAD DESIGN REGULATIONS

2.1 Introduction

When designing low volume roads, it is necessary to properly estimate the future traffic on them, it should be ensured that the service is comfortable and of good quality, and traffic safety level on them is as high as possible. A road should serve the needs of every road user. The designing of low volume roads has been rather widely discussed in foreign countries, such as United States, Germany, and the Netherlands. In Lithuania there are no adequate regulations on designing that could be applied for the designing of low volume roads.

For the purpose of a comprehensive review of technical regulations applied for low volume road designing in Lithuania, the Lithuanian designing standards were compared with the foreign ones.

2.1.1 Road function

The roads in Lithuania are classified according to their function and then divided into categories. Roads of the same significance may differ by their visual appearance, and for road users it is not always clear which is the significance of the road they are using. It is quite different in other ountries. One of the best illustrations of this phenomenon is the road system in the Netherlands, where roads are, first of all, classified according to their traffic function.

A sustainable safe road network has three traffic functions: [23]

- **flow function:** vehicle movement rapid and uninterrupted – through roads (national roads);
- **distributor function:** for the distribution and collection of traffic to and from different districts and residential areas – distributor roads (regional roads);
- **access function:** provide entrance: vehicles reach and depart from an individual dwelling, shop or company while ensuring the safety of the street as a meeting place, as for cyclists and pedestrians – access roads (local roads).

Presently, roads in the Netherlands often have more than one traffic function, which might pose a risk on traffic safety. The concept of sustainable, safe road transport comes down to the removal of all function combinations by making the road a mono-functional one, i. e. by creating categories of roads: pure through roads, pure distributor roads and pure access roads. Multi-functionality of the roads leads to not only contradictory design requirements, and also to higher accident risks.

The three road categories together make up a road network. Junctions are intended for switching traffic from one road to another. Road links are intended for the traffic flow to access main roads. An exception to this is the road link in access roads, where stopping and turning is allowed. Through roads should not have junctions, but split level interchanges to guarantee a continuous flow function [23].

Besides a traffic function, streets and roads in urban areas should allow people to move around the vicinity of their houses safely and comfortably, and this residential function can be combined with the access function. A residential function for areas means that pedestrians, playing children, cyclists, and parked cars can use the same area. The roads in these areas should be designed in such a way that the residential function is immediately recognizable, and driving speeds of more than 30 km/h within urban areas or 60 km/h within rural areas are prohibited. The possibility of conflicts between slow and fast traffic may still exist, but the lower speed allows good anticipation and avoidance of hazards. Furthermore, any accident that does occur should have less serious consequences.

2.2 Design speed

Design speed is a selected speed used to determine the various design features of the roadway. Geometric design features should be appropriate for environmental and terrain conditions and consistent with the selected design speed. For instance, in the United States of America (USA), designers are encouraged to select design speeds equal to or greater than the minimum values shown in Table 2.1. Low design speeds are generally applicable to roads with winding alignment in rolling or mountainous terrain or where environmental conditions dictate. High design speeds are generally applicable to roads in level terrain or where other environmental conditions are favorable. Intermediate design speeds would be appropriate where terrain and other environmental conditions are a combination of those described for low and high speed. [1] Table 2.1 lists values for minimum design speeds as appropriate for traffic volumes and types of terrain.

Table 2.1 Minimum design speeds for local rural roads [1]

Type of terrain	Metrix						USA Customary					
	Design speed (km/h) for specified Design volume (vehicles/day)						Design speed (mph) for specified Design volume (vehicles/day)					
	under 50	50 to 250	250 to 400	400 to 1500	1500 to 2000	2000 and over	under 50	50 to 250	250 to 400	400 to 1500	1500 to 2000	2000 and over
Level	50	50	60	80	80	80	30	30	40	50	50	50
Rolling	30	50	50	60	60	60	20	30	30	40	40	40
Mountainous	30	30	30	50	50	50	20	20	20	30	30	30

Design speed most depends on types of terrain and traffic volume. For roads of up to 400 vehicles per day the maximum speed is 60 km/h and the minimum speed is 30 km/h.

The design speeds of Lithuanian roads is determined by the technical regulation KTR 1.01:2008 “Automobilių keliai“. The document indicates the classification and the speed assigned to a road.

Roads of national significance are classified into AM and roads of I-V categories. Local roads are classified into Iv-IIIv category roads. Each road category is characterized by the traffic volume, speed, cross section and function type. Road category design indicators are presented in the table bellow. [18]

Table 2.2 Classification of roads by category and significance (prepared by the author, based on KTR)

Road significance		**Road category**	**Designed average annual daily traffic volume**	**Design speed, km/h**	**Cross section type**	**Junction type**
National signifi-cance roads	Main roads	AM AM	>45000 12000-55000	130/110 130/110	1 2	different levels
		I II IIa III	12000-55000 <15000 (20000) <18000 (23000) <15000 (20000)	110/100 90 100 90	3 5 6 7	different levels, one level
	National roads	Ia IIa III (IV)	12000-30000 <18000 (23000) <15000 (20000) <10000 (12000)	90 90 90 90	4 6 7 8	one (different) level
	Regional roads	IV V Va	<10000 (12000) <3000, <1000[1)] <1500	90 70 70/50	8 9, 10 11	one level
Local roads		Ia	1000–2000	50/40	12, 13	one level
		IIa	500–1000	40/30	14, 15	one level
		IIIv	<500	30/20	16	one level

Remarks:
1. Design speeds are chosen according to the significance and functional purpose of roads and the complexity of the area.
2. (...) - applied in exceptional cases.
[1)] applied in case of gravel coating

For traffic management and road designing purposes the design speed V_d and permitted speed V_L are established. The design speed V_d is established considering the category and purpose of a road, and road construction (reconstruction) conditions. It should be projected that the design speed was stable on the longest possible sections of the roads.

In Germany, road design requirements are specified in the design guidelines "Richtlinien für die Anlage von Landstraßen, R1, RAL". Road designing is subject to high requirements in Germany. In respect of traffic safety and traffic quality, roads should be designed in such a way that they are suitable to be driven on at steady speeds designed considering the functional purpose of a road. Design speed is set based on evaluation of the functional purpose of a road.

In order the principle of the functional purpose of a road is comprehensible for road users, different design classes (from PKK 1 to PKK 5) are applied, that differ in cross section profile, alignment of a road and profile, road marking, overtaking principle and intersection layout. Roads of different design classes should clearly differ in their appearance. The appearance of roads of one (the same) design class should be as uniform as possible. The design class of road sections should be selected as uniform as possible. [22]

The design class and design speed for low volume roads are presented in Table 2.3.

Table 2.3 Road design class and main design features (prepared by the author, based on RAL)

Design class	**Design/operational features**			
	Design speed, km/h	**Traffic mode**	**Cross section**	**Bicycle traffic arrangements**
PKK 5	70	General traffic	KP 8	Bicycle carriageway traffic

2.3 Design traffic volume

Roads should be designed for a specific traffic volume and a specified acceptable level of service. The AADT volume, either current or projected to some future design year, should be the basis for design. Usually, the design year is about 20 years into the future but may range from the current year to 20 years depending on the nature of the improvement. [1]

In Lithuania, for the purposes of traffic management, road construction and reconstruction, traffic volume measurement should be performed and its growth forecast carried out. Design hourly or average annual daily traffic volume is forecasted applying direct traffic monitoring (on existing roads) or traffic modelling methods. In specific cases, by selecting the category of a road or the number of lanes, there is a possibility to evaluate the intensity of traffic congestion hours.

Design traffic volume in both directions is estimated using the data of the last year of the perspective period (design usage time). The annual increase in traffic is established with regard to the data of multiannual monitoring and the growth of the GDP. [18]

Roads are usually designed for the service life of 20 years. In economic and technical terms, while designing the pavement coatings, the design life of 10, 15 or 30 years may be set. The onset of the design life is the year when the construction of a road (or its section) is to be completed.

2.4 Level of service

Procedures for estimating the traffic operational performance of particular highway designs in the USA are presented in the Highway Capacity Manual (HCM) [10], which also presents a thorough discussion of the level of service concept. According to the above-mentioned document, it is highly recommended for the designers to strive to provide the highest level of service practical and consistent with anticipated conditions. Level of service characteristics are presented in Table 2.4. Since local roads primarily provide access to adjoining properties, a level of service D is acceptable. [1]

Table 2.4 General definitions of level of service [1]

Level of service	General operating conditions
A	Free flow
B	Reasonably free flow
C	Stable flow
D	Approaching unstable flow
E	Unstable flow
F	Forced or breakdown flow

The level of service characterizes the operating conditions on the facility in terms of traffic performance measures related to speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience. The levels of service range from level of service A (least congested) to level of service F (most congested). Table 2.4 shows the general operating conditions represented by these level of service. The specific definitions of level of service differ by facility type.

In Germany, high requirements are applied to the designing of roads. With growing transport demand, higher speeds are often projected for freely moving vehicles. The quality of vehicle traffic on a designed road should meet the average driving speed requirements on roads of certain category.

When planning a road network, design speeds and other important road quality parameters are set in order to prepare the design task. To this end, every projected road segment is categorized. The category reveals the importance of road links. It is recommended to set higher driving speeds for road links of greater significance.

Different functional purposes of roads also determine different traffic quality requirements on road sections. These requirements are set by establishing road parameters characteristic of certain road categories corresponding to average design speed of passenger cars, which should be reachable on sections of a designed road within an hour.

On the sections and junctions of a designed road should be reached within a measuring hour. Traffic quality indicators are established in line with the requirements set in the Highway Capacity Manual HCM2010 [10].

Design objectives and measures in terms of traffic quality are described in Table 2.5.

Table 2.5 Traffic quality (prepared by the author, based on RAL)

Objectives	Measures
Traffic quality sufficient for motor vehicle traffic	to establish sufficient cross section profile parameters; to select road planning elements corresponding to the design class; to create sufficient conditions for vehicles to pass each other on long sections of even traffic.
Good service quality for bicycle traffic, and depending on the situation, for pedestrians	to limit the number of intersections; on a road significant in term of communication it is recommended to give priority at intersections; to allow all traffic to flow without stopping during peak hours; to plan highly congested intersections as split-level or multiple junctions.
Good quality of freight traffic	to regulale the operations of traffic control devices (e.g. traffic lights) depending on traffic, and to coordinate the interaction of densely installed devices; to separate bicycle traffic from vehicle traffic; to avoid steep slopes for bicycle traffic; to plan more direct routes for pedestrian and bicycle traffic; to create pedestrian crossings where needed.
Sufficient conditions for the development of the adjacent areas	on roads significant in terms of communication, any access roads to agricultural parcels should be avoided, instead access roads should be designed from minor roads, such as regional; there should be space on a road sufficient for road maintenance and construction works.

2.5 Alignment

In the USA, alignment between control points should be designed to be as favorable as practical, consistent with the environmental impact, topography, terrain, design traffic volume, and the amount of reasonably obtainable right of way. Sudden changes between curves of widely different radii or between long tangents and sharp curves should be avoided. Where practical, the design should include passing opportunities. Where crest vertical curves and horizontal curves occur together, greater than minimum sight distance should be provided so that the horizontal curves are visible to approaching drivers.

2.5.1. Straight lines

According to Lithuanian design standards, while constructing roads of national significance, sections of long straight lines with constant longitudinal gradients and short lines between curves of the same direction should be avoided. When the length of a straight insert is less than 100 m., both curves should be replaced with one large-radius curve. [18]

The German design standards indicate that straight lines, as elements of road design, fit well with flat landscape space and broad valleys, as well as with other straight objects (railway lines, canals, boundaries of land plots), allow good visibility in intersections, and ensure good overtaking conditions on two-lane roads. [22]

Long straight line segments, especially with constant longitudinal gradient, have the following shortcomings:

- are difficult to adapt to the environment;
- complicate the estimation of distance and speed of approaching vehicles;
- reduce traffic safety (dazzling caused by the lights from the headlamps of an opposing vehicle, risk of fatigue, monotony, provoke drivers to overspeed).

The length of straight lines is recommended to be limited down to:

$$L_{max} = 1500 \text{ m.}$$

In exceptional cases, when there is a need to adapt to current terrain or other conditions or limitations, longer straight lines can be designed. The radii of adjacent elements, i. e. lenghths of straight lines and radii of curves, should be consistent with each other so that driving could be safe and the speed was steady.

2.5.2. Circular curves

In Lithuania the minimum radii of circular curves should be selected with respect to design speed, transverse gradients and the lengths of connecting straight lines of the carriageway (Table 2.6 and Figure 2.1). Besides, the radii should be of such size that the curves could fit into the structure of an area, landscape, and the elements of road longitudinal profile.

In the roads of national significance, the radii of consecutive curves should be consistent with each other (Figure 2.1). When reconstructing or performing major repairs of roads, this requirement is allowed to be disregarded based on proper technical and economical justification.

Table 2.6 Minimum radii of horizontal curves [18]

Curve radii, m, when speeds are Vp, km/h									
30	40	50	60	70	80	90	100	110	130
50	90	140	200	300	400	600	800	1000	1500

Note: the Table indicates radii, when the slope of a superelevation is 4 %.

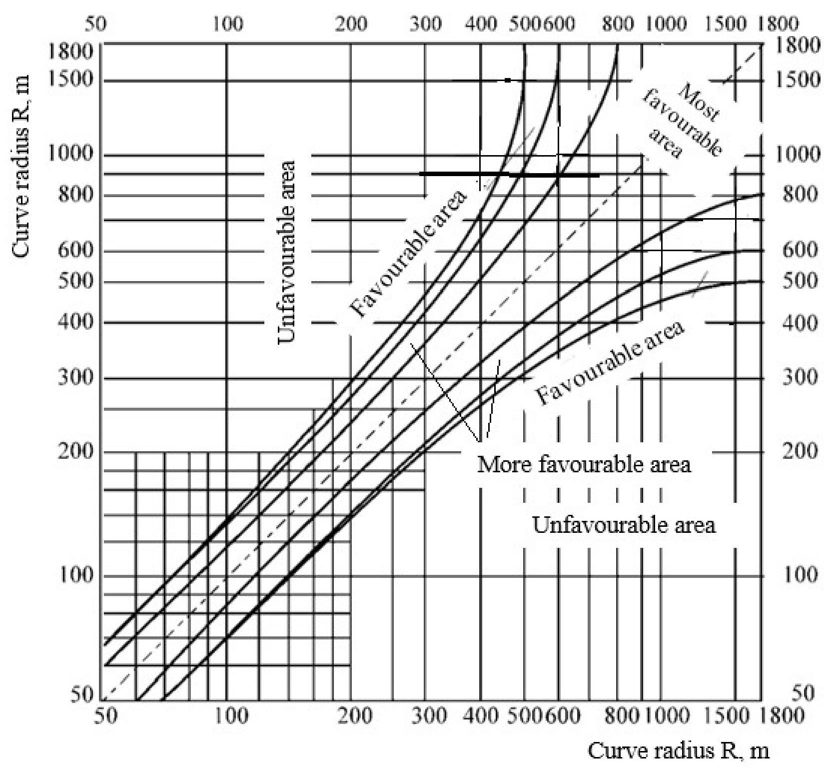


Figure 2.1 Alignment of curve radii [18]

Table 2.7 Minimum curve radii with respect to the length of straight insert L (prepared by the author, based on KTR)

Road categories	Length of straight insert between curves, L	Minimum radius of circular curve, R
Ia, III, IV, V	$L \geq 500$	$R > 500$
	$L < 500$	$R > L$
Va	Not regulated	

When the direction of a road changes at a small angle, radii of circular curves should be applied for constructed roads of AM, I–IV categories, as it is shown in Table 2.8.

Table 2.8 Curvatures of small turns [18]

Turning angle	Minimum radius of circular curve, m	Turning angle	Minimum radius of circular curve, m
1°	30000	5°	5000
2°	20000	6°	3000
3°	10000	7°– 8°	2500
4°	6000		

According to German designing standards, a road should make a smooth, slowly meandering spatial line, so that it could be possible to drive on the whole route at quite a steady speed. The radii of circular curve should be of such size that the curves could fit into the structure of an area, landscape, and the elements of road longitudinal profile. The recommended values of radii of circular curves and minimum lengths of arcs of the curves are given in Table 2.9.

Table 2.9 Recommended circular curve radii R and minimum lengths of their arcs K (prepared by the author, based on RAL)

Design class	Design speed, km/h	R, m	K_{min}, m
PKK 5	70	200–300	40

Circular curve radii larger than indicated in Table 2.9, may be selected when the road alignment is to be fit into the terrain or other features of the area. Radii of adjacent curvatures should be consistent with each other so that it would be possible to drive safely and at a steady speed (Figure 2.2). In order the radii of adjacent curves were compatible; their sizes should al least fall into the favourable area. For PKK 5 roads it is sufficient that the sizes were in the favourable area.

If it is not possible to adjust the radii of adjacent circular curves as it is shown in Figure 2.2, or if smaller circular curve radii than indicated in Table 2.9 are used, additional engineering traffic safety measures should be applied. In case of more significant deviation from the favourable area, speed limitations in the direction of the curve of smaller radius are necessary. [22]

If a straight line of less than 300 m is projected between adjacent curves, the radii of the adjacent curves should be consistent with each other and the sizes of the radii should fall into the required area (Table 2.12). Straight short inserts between compound curves consisting of one-direction curves with common roundings at their intersection points, should be avoided.

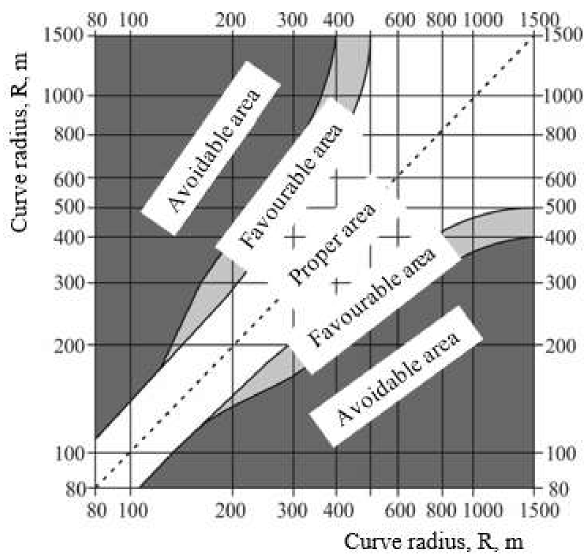


Figure 2.2 Adjusting the curve radii [22]

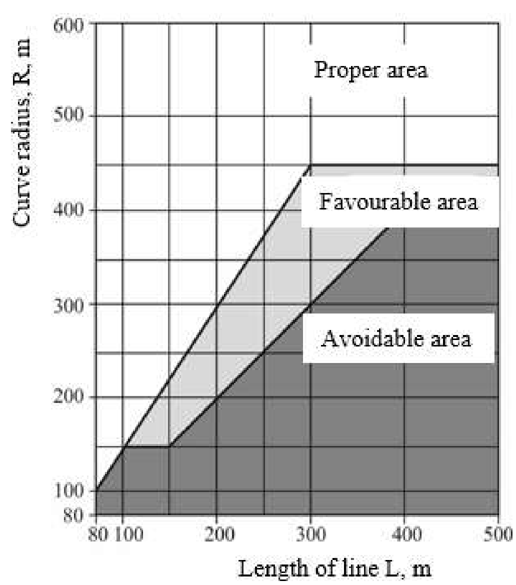


Figure 2.3 Adjustment of minimum curve radii and straight lines [22]

2.5.3. Transition curves

According to the Lithuanian design standards, transition curves are applied betweed straight lines and circular curve. In constructed or reconstructed roads, transition curves are essential, while in the roads, where repair works are performed constantly widening the roadway, they are desirable.

Clothoid is used for the transition curve, and its formula is the following:

$$A^2 = R \cdot L,$$

where: A is clothoid parameter, m; R is clothoid end radius, m; L is the length of clothoid till the radius, m.

The minimum clothoid parameter in roads of all categories is A = R/3. The data presented in Table 2.10 should also be taken into account.

Table 2.10 Minimum clothoid parameters [18]

V_d, km/h	min. A, m	V_d, km/h	min. A, m
40	30	80	110
50	50	90	140
60	70	100	170
70	90	120	270

In case of large circular curve radii, a parameter smaller that R/3 can be selected, nevertheless, the displacement of the initial circular curve should be no less than 0.25 m. The maximum parameter of clothoid can be A = R.

Parameter A limits are valid: $R/3 \leq A \leq R$. In all cases, the length of clothoid L should be sufficient to set a superelevation development section. Simple clothoids which connect straight lines with circular curves are commonly used. When the sequence of radii is not maintained, clothoids of small parameters should be applied (A = R/3).

In exceptional cases a biclothoid can be used, which consists of two clothoids without an insert of circular curve, with parameters A1, A2, and a common radius R at the intersection point. Clothoids of this type with corner radii shorter than 500 m should be avoided. Under favourable conditions, parameters of both biclothoid branches should be equal (A1 = A2). The minimum parameters A of such clothoids are given in Table 2.10.

In Germany, to calculate trasition curves the same method is used, and the formulas applied should meet certain requirements. Between a straight line and a circular curve, and between circular curves, circular curves should be set. Using transition curves may be rejected only in exceptional cases, with proper technical and economic justification, when the direction of the road changes at a small angle. Using transition curves may be rejected between straight lines and the curve only in the case when large circular curve radii R ≥ 1000 m, and between two circular curves, the radii of which are R ≥ 2000 m.

For a transition curve, a clothoid with the following formula is used:

$$A^2 = R \cdot L;$$

where:

A is clothoid parameter, m; R is radius of the clothoid end or the radius of a circular curve, m; L is the length of the clothoid till radius R, m.

The size of the clothoid parameter should meet this condition:

$$R/3 \leq A \leq R.$$

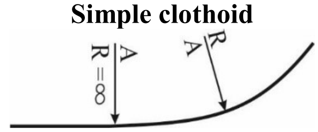
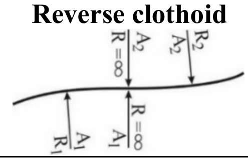
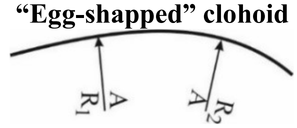
In cases when curve radii are smallest, the ratio A/R should usually be in the upper allowable interval, and when the radii of the curve are largest, the ratio should be in the lower allowable zone.

Clothoid parameter A < 100 m should be avoided. The largest clothoid parameter A ≥ R/3 ensures that the transition curve is optically smooth in the space ($\tau \geq 3.15°$). Sequences of different elements wherein transition curves are used, are shown in Table 2.12. The usage of transition curves can be refused when the turn angle is very small ($\gamma \leq 9$) and the turn is flat. In such cases, the length of curve arc, depending on the designed road class, should be no less than indicated in Table 2.11.

Table 2.11 Minimum lengths of curve arcs K_{min}, when the turn is flat wihout clothoids, or the turn is vertex-shaped, with biclothoid (prepared by the author, based on RAL)

Design class	**K_{min}, m**
PKK 5	100

Table 2.12 Application forms of transition curves in the sequence of elements of an alignment plan [22]

<table>
<tr><th>Sequence of alignment plan elements</th><th>Application form</th></tr>
<tr><td>Straight line – transition curve – circular curve</td><td>Simple clothoid
</td></tr>
<tr><td rowspan="2">Circular curve – transition curves – circular curve</td><td>Reverse clothoid
</td></tr>
<tr><td>“Egg-shaped” clohoid
</td></tr>
</table>

2.6 Grades

Suggested maximum grades, in the USA, for local rural roads are shown in Table 2.13 as a function of type of terrain and design speed.

Table 2.13 Maximum grades for local rural roads [1]

Type of terrain	Metrix									U.S. Customary								
	Maximum grade (%) for specified design speed (km/h)									Maximum grade (%) for specified design speed (mph)								
	20	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**15**	**20**	**25**	**30**	**40**	**45**	**50**	**55**	**60**
Level	9	8	7	7	7	7	6	6	5	9	8	7	7	7	7	6	6	5
Rolling	12	11	11	10	10	9	8	7	6	12	11	11	10	10	9	8	7	6
Mountainous	17	16	15	14	13	12	10	10	-	17	16	15	14	13	12	10	10	-

In the Lithuanian design standards, the longitudinal road gradient should be as low as possible due to the reasons of traffic safety, operating costs, energy saving and environmental pollution. However, for water drainage it should be not lower than 0.3%, where terrain conditions permit. When kerbs are constructed, the longitudinal road gradient should not be lower than 0.5%. In order to cause as little adverse effects on the landscape around a roadas possible, and to reduce road construction costs, the longitudinal profile should be fitted well with the terrain conditions. [18]

The highest allowable longitudinal gradients used in Lithuania are presented in Table 2.14. In the vicinity of inhabited areas lower gradients may be projected in case of special circumstances – due to intense non-motorized traffic and specific traffic processes at vehicle stopping and parking points.

Table 2.14 Ranges of road longitudinal profile elements (prepared by the author, based on KTR)

Road longitudinal profile elements	Ranges depending on speeds V_p, km/h									
	30[2)]	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**130**
Maximum longitudinal gradient, %	9,0	8,0	8,0	7,0	7,0	6,0	5,0	5,0	5,0	4,0
Minimum longitudinal gradient, %	0,3[1)]									

Remarks:

1) in exceptional cases, the gradient can be lower;

2) on local roads.

In roads under reconstruction, straight lines are allowed not to be interconnected by a curve, when their algebraic difference is less than 1% on roads of categories I, Ia II, IIa, and III, 2% on roads of categories IV, V, Va, and Iv, and 3% on roads of categories IIv and IIIv.

The German design standards first of all distinguish what the biggest advantages are to design minimum and maximum longitudinal road profiles.

Low longitudinal profile gradients:

- ensure traffic safety;
- add capacity and improve traffic quality;
- reduce operating and maintenance costs;
- reduce emissions into the environment.

The lowest value of the longitudinal road gradient is presented in Table 2.15.

Higher longitudinal profile gradients:

- allow a road to be fitted better with the terrain of the area;
- allow less intervention into the environment;
- enable reducing costs of road construction works.

The maximum allowable longitudinal gradient is shown in Table 2.15.

Table 2.15 Longitudinal road gradients (prepared by the author, based on RAL)

Road longitudinal profile elements	**Design class**	**q_{max}, %**
Minimum longitudinal gradient, %	PKK 5	4,0
Maximum longitudinal gradient, %	PKK 5	8,0

2.7 Cross slope

Carriageway cross slope in the USA should be adequate to provide proper drainage. Normally, cross slopes range from 1.5 to 2 percent for paved surfaces and from 2 to 6 percent for unpaved surfaces. For unpaved surfaces, such as stabilized or loose gravel, and for stabilized earth surfaces, a 3 percent cross slope is desirable.

Undivided carriageways on tangents, or on flat curves, have a crown or high point in the middle and a cross slope downward towards both edges. Unidirectional cross slopes across the entire width of the carriageway may be utilized. The downward cross slope may be a plane or rounded section or a combination. In the case of plane cross slopes, there is a cross slope break at the crown line and a uniform slope on each side. Rounded cross sections usually are parabolic, with a slightly rounded surface at the crown line and increasing cross slope towards the edge of the carriageway. Because the rate of cross slope is variable, the parabolic section is described by the crown height. The rounded section is advantageous in that the cross slope steepens towards the edge of the carriageway, thereby facilitating drainage. Disadvantages are that rounded sections are more difficult to construct, the cross slope of the outer lanes may be excessive, and warping of pavement areas at intersections may be awkward or difficult to construct. [1]

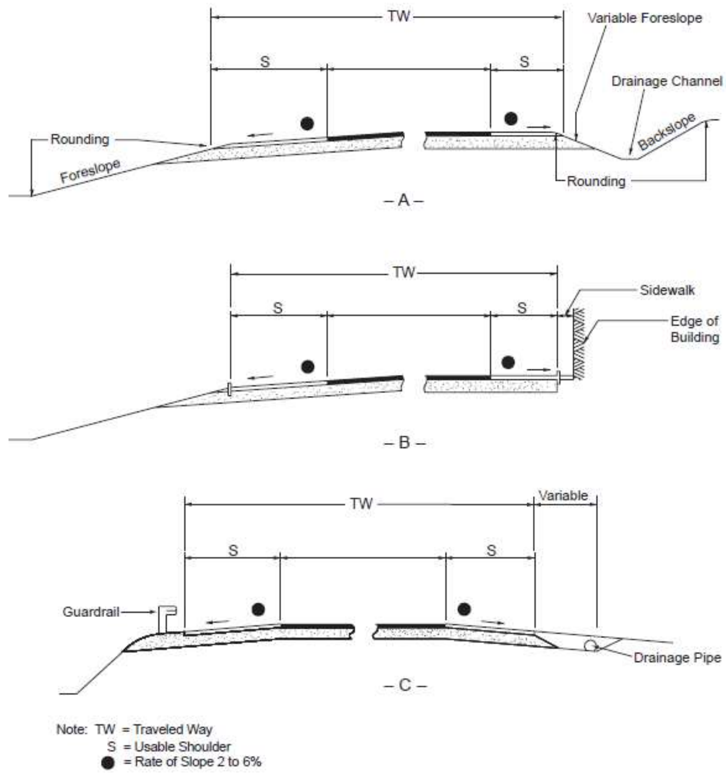


Figure 2.4 Typical cross section [1]

The USA standards distinguish three main cross sections applicable for low volume roads (Figure 2.4.). The cross sections are shown under different design conditions.

The design standards in Lithuania state that while designing new roads or reconstructing existing ones, typical cross section profiles should be applied (Table 2.16 and Figure 2.5), with regard to the category of a road, its functional purpose, and traffic volume.

The crossfall of the carriageway may be some direction or standard. The minimal cross slopes of the carriageway on straight lines and curvatures should be 2.5% (for gravel roads it should be 3%). [18]

The main parameters of cross section profiles of low volume regional roads are presented in Table 2.16 and Figure 2.5.

Table 2.16 Parameters of cross profiles of regional roads (prepared by the author, based on KTR)

1. Roadways	**Regional roads**		
	IV	**V**	**V_a**
1.1. number of lanes, units	2	2	1
1.2. lane width	3.00	3.00	4.50
1.3. carriageway width	6.00	6.00	4.50
1.4. roadway width (carriageway, safety lanes)	7.00	6.00	4.50
2. Safety lanes			
2.1. width of lateral safety lane	2x0.50	-	-
3. Shoulders			
3.1. shoulder width	2x1.00	2x1.00	2x1.25; 2x1.00
3.2. shoulder widening for barrier instalation (according to the barrier type)	0.30	0.30	-
4. Central reservations			
4.1. minimum central reservation width	-	-	-
5. Road width (excluding widenings)	9.00	8.00	7.00; 6.50

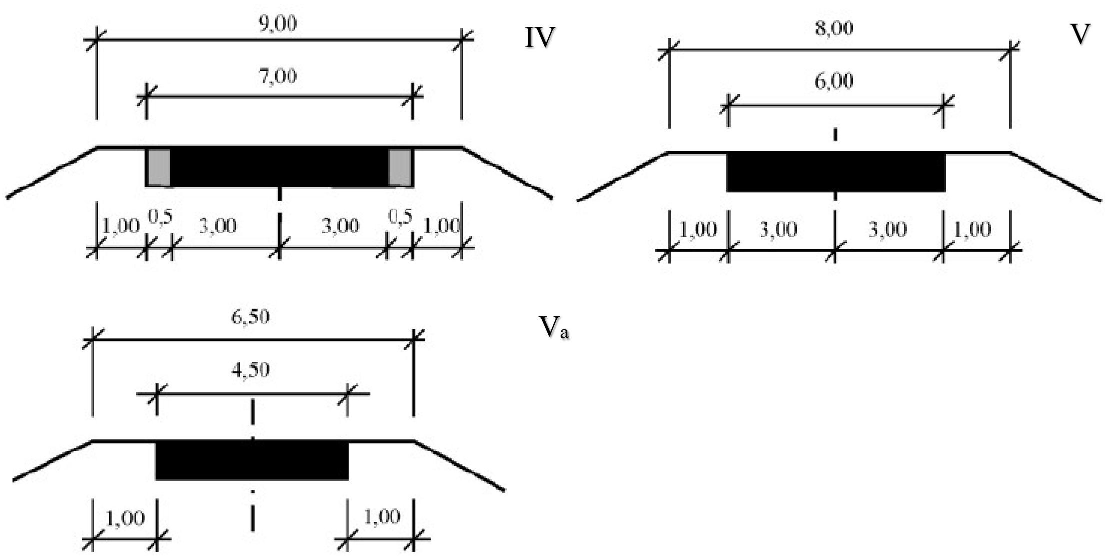


Figure 2.5 Cross sections of regional roads [18]

In German design standards, the minimum permissible cross slope of the carriageway is 2.5 %. For low volume roads road cross profile of KP 8 is applied most frequently. It is a cross profile of a single-lane road without separate lanes in both directions, applied for PKK 5 roads.

This type of cross profile is recommended for roads with traffic volumes of up to 1500 vehicles a day and heavy duty vehicle traffic flow of up to 50 vehicles a day. These roads can be paved with gravel or a mixture of gravel and stone grit. [22]

Road cross section profile recommended for low volume roads is shown in Figure 2.6.

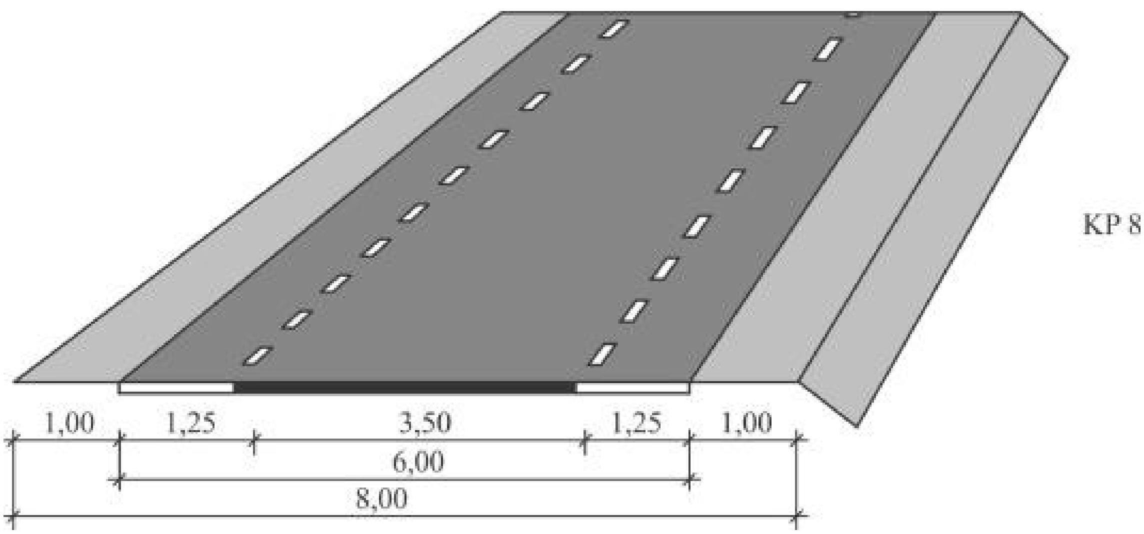


Figure 2.6 Standard road cross section profile for PKK 5 roads [22]

Shoulder cross slopes should be directed towards the outer side of the road:

- 12%, when the carriageway is drained through shoulders or side median strips;
- 6%, when road sides or side median strips are not used for drainage of the carriageway (for draining the surface water).

2.8 Superelevation

The regulations in the USA indicate that for rural roads with paved surfaces, superelevation should not exceed 12 percent, except where snow and ice conditions prevail, in which case the superelevation should be not more than 8 percent. For unpaved roads, superelevation should be not more than 12 percent. [1]

The Lithuanian technical regulations establish that the minimum cross slopes of carriageways in straight lines and curvatures should be 2.5% (for gravel roads – 3%), and the maximum slopes in curvatures, depending on the speed – 4%, in exceptional cases – 6% (Table 2.17.).

The constant slope of a superelevation in biclothoids and circular curvatures with a small turning angle should be projected for a road section of a length sufficient for driving on it at the design speed for no less than 2 s.

In composite unidirectional curvatures the cross profile slope of the pavement should not be changed. The cross slopes of side safety, emergency, and deceleration and acceleration lanes should be the same as of the adjacent main traffic lane. [18]

Table 2.17 Slopes of superelevations [KTR]

Curve radii in plan, m	Cross profile of carriageway in a superelevation, %, when design speed V_P km/h is not less than									
	130	110	100	90	80	70	60	50	40	30
more than 4000	–	–	–	–	–	–	–	–	–	–
from 4000 to 3200	2.5	–	–	–	–	–	–	–	–	–
from 3200 to 2500	2.5	–	–	–	–	–	–	–	–	–
from 2500 to 2100	2.5–3.0	2.5	–	–	–	–	–	–	–	–
from 2100 to 1800	3.0–3.5	2.5	2.5	–	–	–	–	–	–	–
from 1800 to 1500	3.5–4.0	2.5–3.0	2.5	–	–	–	–	–	–	–
from 1500 to 1200	4.0–(5.0)	3.0–3.5	2.5–3.0	2.5	–	–	–	–	–	–
from 1200 to 1000	(5.0–6.0)	3.5–4.0	3.0–3.5	2.5	–	–	–	–	–	–
from 1000 to 800	–	4.0–(5.0)	3.5–4.0	2.5–3.0	2.5	–	–	–	–	–
from 800 to 700	–	(5.0–6.0)	4.0–(4.5)	3.0–3.5	2.5	–	–	–	–	–
from 700 to 600	–	–	(4.5–5.5)	3.5–4.0	2.5–3.0	2.5	–	–	–	–
from 600 to 500	–	–	–	4.0–(5.0)	3.0–3.5	2.5	2.5	–	–	–
from 500 to 400	–	–	–	(5.0–6.0)	3.5–4.0	2.5–3.0	2.5	–	–	–
from 400 to 300	–	–	–	–	4.0–(5.5)	3.0–4.0	2.5–3.0	2.5	–	–
from 300 to 250	–	–	–	–	(5.5–6.0)	4.0–(5.0)	3.0–3.5	2.5	–	–
from 250 to 200	–	–	–	–	–	(5.0–6.0)	3.5–4.0	2.5–3.0	2.5	–
from 200 to 150	–	–	–	–	–	–	4.0–(5.5)	3.0–3.5	2.5	–
from 150 to 100	–	–	–	–	–	–	–	3.5–(4.5)	2.5–3.0	2.5
from 100 to 70	–	–	–	–	–	–	–	–	3.0–4.0	2.5
from 70 to 40	–	–	–	–	–	–	–	–	–	2.5–4.0

Note:
1. In the area below the lower thick line, curve radii indicated in the table are not applicable.
2. In the area above the upper thick line, superelevations are set based on technical and economic justification.
(...) Applied in exceptional cases.

The slope of a superelevation is selected considering the curve radius and design driving speed.

In the German design standards, it is indicated that cross slopes of carriageways in curvatures should be directed towards the internal side of the curve, and the cross slope may be: minimum i_{min} = 2.5%, maximum i_{max} = 4.0%. In exceptional cases, when small curves are used, the maximum cross slope may be: i_{max} = 7.0 %.

Cross slopes of lateral, safety, emergency, acceleration and deceleration lanes should be identical to the ones of the adjacent (main) lane. Cross slopes of the carriageway depend on the size of the selected curve radius. The values should be rounded up to 0.5%.

The dependency of the cross slope of the road on curve radii in the plan is described in Figure 2.7.

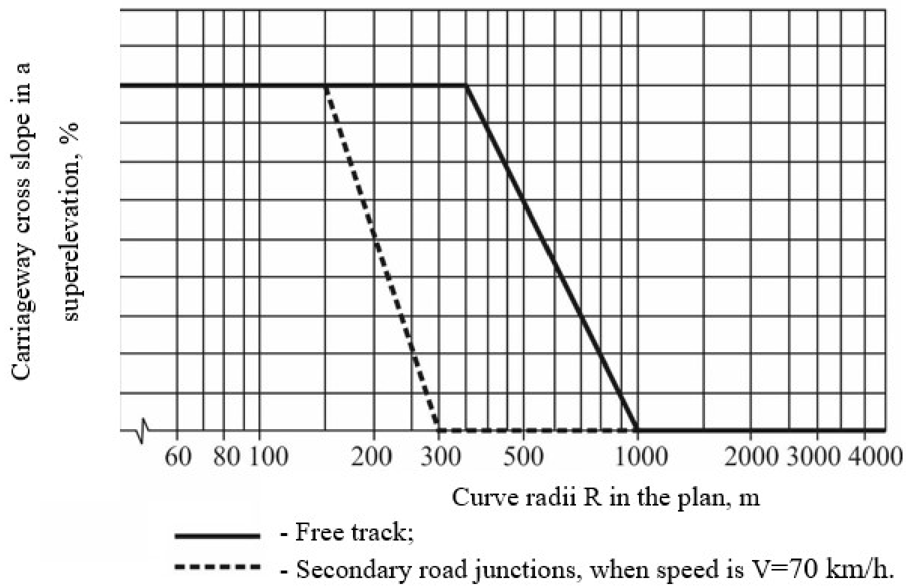


Figure 2.7 The dependency of cross slope of the carriageway on curve radii in the plan [22]

In order to avoid problems related to possible high cross slope on the main roads, while connecting secondary roads, curve radii at junctions should be designed in accordance with the maximum speed of 70 km/h.

Dotted line (Figure 2.6) is also used to design a superelevation in a tunnel. The curve radii should be selected so that a superelevation on bridges does not exceed i = 5.0 %. In exceptional cases, due to carriageway drainage, the cross slope of the pavement on road bends may be i = –2.5% (directed towards the external side of the curve, i. e. “negative superelevation”), when the longitudinal road profile slope is close to zero. In such case, the minimal curve radii R > 3 000 m.

If the directions of the cross slope and longitudinal profile slope of the carriageway coinside, in order to avoid slipping from the lane during winter time, the diagonal road slope is limited to: p = 10.0%. [22]

Diagonal road slope: $p = \sqrt{q^2 + i^2}$;

where:

q – longitudinal road slope, %;

i – cross slope, %.

2.9 Sight distance

The USA standards suggest that minimum stopping sight distance and passing sight distance on the road should be as shown in Tables 2.18 and 2.19. The criteria for measuring sight distance, both vertical and horizontal, are as follows: for stopping sight distance, the height of eye is 1.08 m and the height of object is 0.60 m; for passing sight distance, the height of eye remains the same, but the height of object is 1.08 m. [1]

Values for stopping sight distance in relation to the driving speed are given in Table 2.18.

Table 2.18 Design controls for stopping sight distance and for crest and sag vertical curves [1]

Metrix				**USA Customary**			
Initial speed (km/h)	**Design stopping sight distance (m)**	**Rate of vertical curvature, K^a (m/%)**		**Initial speed (mph)**	**Design stopping sight distance (ft)**	**Rate of vertical curvature, K^0 (ft/%)**	
		Crest	**Sag**			**Crest**	**Sag**
20	20	1	3	15	80	3	10
30	35	2	6	20	115	7	17
40	50	4	9	25	155	12	26
50	65	7	13	30	200	19	37
60	85	11	18	35	250	29	49
70	105	17	23	40	305	44	64
80	130	26	30	45	360	61	79
90	160	39	38	50	425	84	96
100	185	52	45	55	495	114	115
				60	570	151	136
				65	645	193	157

Remarks:

A rate of vertical curvature, K, is the length of curve per percent algebraic difference in the intersecting grades.

Values for passing sight distances are presented in Table 2.19.

Table 2.19 Design controls for crest vertical curves based on passing sight distance [1]

Metrix			USA Customary		
Design speed	**Design passing sight distance (m)**	**Rate of vertical curvature, K^a (m/%)**	**Design speed (mph)**	**Design passing sight distance (ft)**	**Rate of vertical curvature, K^0 (ft/%)**
30	120	17	20	400	57
40	140	23	25	450	72
50	160	30	30	500	89
60	180	38	35	550	108
70	210	51	40	600	129
80	245	69	45	700	175
90	280	91	50	800	229
100	320	119	55	900	289
			60	1000	357
			65	1100	432

Remarks:

A rate of vertical curvature, *K*, is the length of curve per percent algebraic difference in the intersecting grades (i.e., $K = L/A$).

The Lithuanian designing standards first of all emphasize what distance sight should be to ensure a smooth flow of vehicle traffic.

On the roads such minimum distance sight is necessary so that a driver could:

- to come to a stop before an object in good time;
- to overtake other vehicles safely;
- to cross intersections and pedestrian crossings safely.

Obstacles should be eliminated from the fied of vision to up to the height of observation radius (cuts, buildings, woods). Scattered trees, tree rows, bushes may be kept in the field of vision as long as they do not impair visibility and help drivers to remain oriented.

The scheme of sight distance calculation should include:

- the hight of eye of a car driver above the carriageway – 1.0 m;
- the hight of eye of a truck driver above the carriageway – 2.0 m;
- the height of an object above the carriageway – 0.15 m;
- the hight of the oncoming vehicle above the carriageway – 1.0 m.

It is also important to ensure sight distance in direct lanes, where objects on roads must be visible, so that a driver could come to a stop before the object (stopping sight distance) or pass it (passing sight distance).

Stopping sight distance Ss is a road section necessary for a driver moving at Vp speed to stop before a sudden obstacle on the carriageway. The minimum stopping sight distance should be as it is illustrated in Figure 2.8.[18]

Passing sight distance, which is required on roads of categories II–V and Iv due to numerous intersections and exit lanes, is not regulated for the access to residential areas.

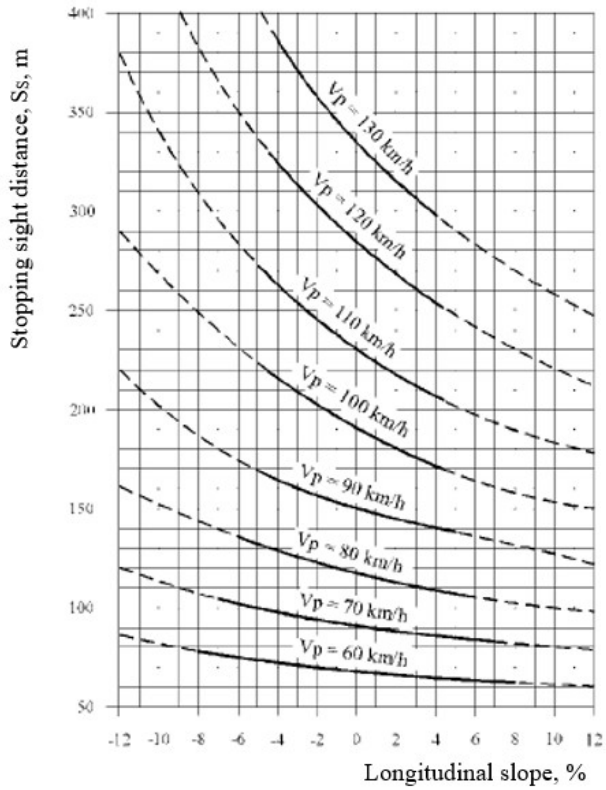


Figure 2.8 Stopping sight discance S_S required for roads of national significance [18]

Bypass conditions should be ensured as it is described in Table 2.20. When such conditions are not available, additional passing lanes should be projected on roads of categories II and III. Road sections with sufficient passing sight distance should be spaced as evenly as possible or their variation (shortening, elongation) should be approximately uniform.

Table 2.20 Passing sight distance (prepared by the author, based on KTR)

Sight distance type	**Speeds Vp, km/h**								
	40	**50**	**60**	**70**	**80**	**90**	**100**	**120**	**140**
Minimum passing sight distance, Sa, m	-	-	400	450	500	575	650	-	-
Minimum part of sections suitable for passing, %	70 (on highways) 50 (on national and regional roads)								
	25 (on local roads of category Iv)								

The German designing standards provide for general requirements for sight distance on the road. The required stopping sight distance is necessary so that a driver moving at a design speed could observe objects on the carriageway form any point, or in case of wet road, could stop the vehicle on time. [22]

For every design class, the required stopping sight distance depends on the speed and longitudinal slope, as it is shown in Figure 2.9.

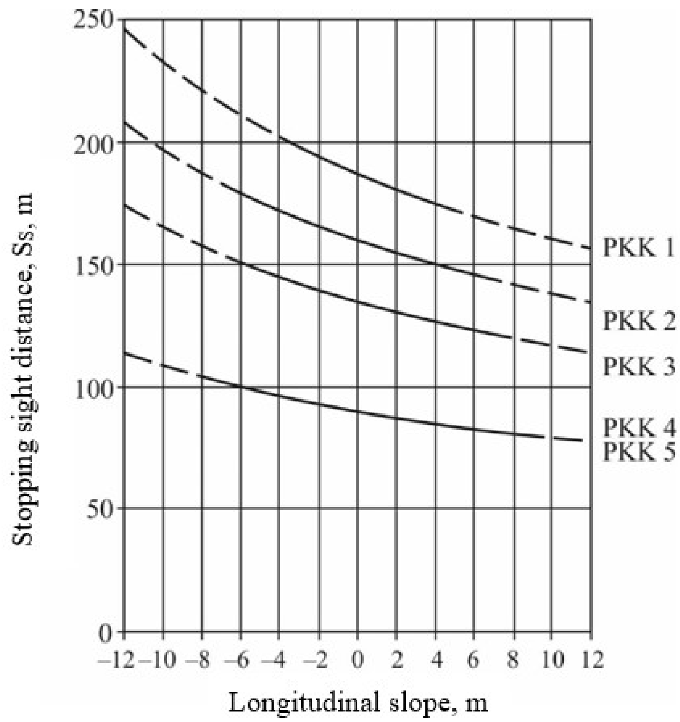


Figure 2.9 Required stopping sight distance on selected design class roads [22]

In order to inform drivers about changes on the road in a timely manner, and ensure safe and relaxed driving conditions, it is usefull to project a longer sight distance than it is required. Therefore, the sight distance on every sight connection (point) should be no less than by 30% longer than the required stopping sight distance.

For the reasons of traffic safety and in order to ensure traffic flow, it is preferable to ensure smooth bypassing conditions for vehicles moving at different speeds. Road sections with sufficient passing sight distance are suitable for this purpose.

During the designing process it is essential to properly estimate the sight distance. The sight distance is comprised of: horizontal road plan, longitudinal profile, cross profile and objects in the surroundings of the road.

Sight distance is established at the point in the sight line between driver's eyes and an object on the road. The height of driver's eye (ha = 1.0 m) and height of an object (hz = 1.0 m) above the carriageway are established in the middle of the right lane or in the middle of the lane.

Sight distance should be verified for each direction separately. While verifying it, intersections, road installations, vegetation and other road surroundings should be taken into account (i. e. sight distance connection points should be established). Sight distance should also be verified when driver's sight line passes through shoulder safety barriers and other road installations.

It is important to verify stopping sight distance. For traffic safety reasons, it should be examined, whether stopping sight distance at any point on the road is longer that it is required.

Verification of sight distance is performed section by section. On each section, based on the required stopping sight distance values according to the average longitudinal slope, the current sight distance is compared to the required stopping sight distance. If the current sight distance is shorter than the required stopping sight distance, and this deficiency can not be eliminated due to surrounding conditions, it is considered, whether speed limitations should be applied.

Another important parameter related to sight distance on the road is ensurance of proper passing sight distance. In order heavy-duty vehicles could be safely overtaken on the road, the minimum sight distance of 600 m is required. If the current sight distance on two-lane road sections is between 300 m and 600 m, it may lead a driver to confusion whether or not the road part in the sight can be used for overtaking considering the possible oncoming traffic. In case such shortcoming can not be avoided by means of designing measures, it is then examined whether or not, due to reasons of traffic safety, passing should be prohibited. [22]

For safe overtaking of slow-moving vehicles the minimum sight distance of 300 m is required.

2.10 Cross sectional elements

2.10.1 Width of road

In the USA The minimum road width is the sum of the traveled way and graded shoulder widths given in Table 2.23. Graded shoulder width is measured from the edge of the road to the point of intersection of shoulder slope and foreslope. Where roadside barriers are proposed, it is desirable to provide a minimum offset of 1.2 m from the traveled way to the barrier whenever practical. [1]. The minimum allowable graded shoulder width is 0.6 m. The design scheme is illustrated in Figure 2.4.

The road width is selected based on the design speed: the higher the speed, the wider the designed road. The width may vary from 5.4 m to 6.6 m. (Table 2.23).

The Lithuanian designing standards establish that the design width of the road is selected according to road category, functional purpose and projected traffic volume. For low volume roads V and V_a under investigation, the width of the carriageway of 6 m and 4.5 m is designed (Table 2.21). Shoulders are also designed for these roads, if necessary safety barriers are installed for which shoulder widenings are foreseen.

Cross profile parameters for low volume roads are given in Table 2.21 below, and a schematic illustration is presented in Figure 2.5.

Table 2.21 Cross profile parameters of roads (prepared by the author, based on KTR)

	Roads of national significance			Local roads		
	Regional roads					
	IV	V	V_a	I_v	II_v	III_v
1. Road						
1.1. number of lanes	2	2	1	2	1	1
1.2. lane width	3.00	3.00	4.50	3.00	4.50	3.50; (4.50)
1.3. carriageway width	6.00	6.00	4.50	6.00	4.50	3.50; (4.50)
1.4. roadway width (carriageway, safety lanes and emergency lanes)	7.00	6.00	4.50	6.00	4.50	3.50; (4.50)
2. Shoulders						
2.1. shoulder width	2×1.00	2×1.0	2×1.25 2×1.00	2×1.00	2×1.00	2×1.00; (0.0)
2.2. shoulder widening due to safety barriers (by barrier type)	0.30	0.30	–	–	–	–
3. Road width (widenings excluded)	9.00	8.00	7.00; 6.50	8.00	6.50	5.50; (4.50)

In the German designing standards, the width of the road is selected according to the design class. The indicator of the projected traffic volume and quality of the traffic is taken into account. For low volume roads the design class is PKK 5. The width of carriageway of 6 m and the width of shoulder of 1.5 m are designed for the roads of this type.

Road cross profile parameters for class PKK 5 are given in Table 2.22, and a schematic illustration is presented in Figure 2.6.

Table 2.22 Road cross profile parameters for PKK 5 design class (prepared by the author)

Design class	**PKK 5**
Number of lanes	1
Lane width, m	3.5
Carriageway width, m	3.5
Roadway width (carriageway, safety lanes)	6.0
Width of lateral safety lane, m	1.25
Shoulder width, m	1.5

In the Netherlands, the width of a designed low volume road depends on the type of the road. The roadway width of access roads varies between 2.50 and 6 metres. The lane width (in the middle of the carriageway) for motor vehicles is between 2.50 and 3.50 metres. The roadway width is the sum of the widths of the above and the widths of two non compulsory cycle lanes (discontinuous line; no cycle symbols/pictograms). Access roads are also divided into two types, and each type has the essential characteristics of this category (Figure 2.10): [23]

- type I : vehicle lane with separate cycle path(s), priority junctions are possible;
- type II : single lane for all road users; at level, no-priority crossroads.

Figure 2.10 Examples of access roads outside built-up area [23]

The access road, type 1, has cycle lanes (discontinuous line, red surface) and raised plateaus (to reduce speeds to 60 km/h). The type II road has no markings and semi surfaced shoulder.

2.10.2 Number of lanes

Two travel lanes on the roads in the USA usually can accommodate the normal traffic volume on rural local roads. If exceptional traffic volumes occur in specific areas, additional lanes may be provided based on a level of service analysis . [1]

Table 2.23 describes road width parameters for low volume roads depending on the design speed.

Table 2.23 Minimum width of traveled way and shoulders [1]

Metric					**USA Customery**				
Design speed (km/h)	**Minimum width of traveled way (m) for specified design volume (veh/day)**				**Design speed (mph)**	**Minimum width of traveled way (ft) for specified design volume (veh/day)**			
	under 400	**400 to 1500**	**1500 to 2000**	**over 2000**		**under 400**	**400 to 1500**	**1500 to 2000**	**over 2000**
20	5.4	6.0[a]	6.0	6.6	15	18	20[a]	20	22
30	5.4	6.0[a]	6.6	7.2[b]	20	18	20[a]	22	24[b]
40	5.4	6.0[a]	6.6	7.2[b]	25	18	20[a]	22	24[b]
50	5.4	6.0[a]	6.6	7.2[b]	30	18	20[a]	22	24[b]
60	5.4	6.0[a]	6.6	7.2[b]	40	18	20[a]	22	24[b]
70	6.0	6.6	6.6	7.2[b]	45	20	22	22	24[b]
80	6.0	6.6	6.6	7.2[b]	50	20	22	22	24[b]
90	6.6	6.6	7.2[b]	7.2[b]	55	22	22	24[b]	24[b]
100	6.6	6,6	7.2[b]	7.2[b]	60	22	22	24[b]	24[b]
					65	22	22	24[b]	24[b]
All speed	Width of graded shoulder on each side of the road (m)				All speed	Width of graded shoulder on each side of the road (ft)			
	0.6	1.5[a, c]	1.8	2.4		2	5[a, c]	6	8

Notes:

a For roads in mountainous terrain with design volume of 400 to 600 veh/day, 5.4 m traveled way width and 0.6 m shoulder width should be used.

b Where the width of the traveled way is shown as 7.2 m, the width may remain at 6.6 m on reconstructed highways, where there is no crash pattern suggesting the need for widening.

c May be adjusted to achieve a minimum roadway width of 9 m for design speeds greater than 60 km/h.

In Lithuania, two lanes are designed for low volume roads, except for road categories V_a (Table 2.21). The number of lanes depends on the category of the designed road.

The German designing standards suggest that one-lane roads should be selected for low volume roads (Table 2.22). The number of lanes is established according to the road design class.

2.10.3 Bicycle and pedestrian facilities

As concerns bicycle and pedestrian facilities in the United States, it may be stated that many local roadways are sufficient to accommodate bicycle traffic, where special facilities for bicycles and pedestrian are desired.

In suburban and urban locations, a border area generally separates the roadway from a community's homes and businesses. The main function of the border is to provide space for sidewalks. Border width varies considerably, but 2.4 m is considered an appropriate minimum width. Swale ditches may be located in these borders to provide an economical alternative to curb and gutter sections.

Sidewalk widths in residential areas may vary from 1.2 to 2.4 m. Sidewalks less than 1.5 m in width require the addition of a passing section every 60 m for accessibility. The width of a planted strip between the sidewalk and traveled way curb, if provided, should be a minimum of 0.6 m to allow for maintenance activities. Sidewalks covering the full border width are generally justified and often appropriate in situations such as commercial areas, through adjoining multiple residential complexes, near schools and other pedestrian generators, and where border width is restricted. [1]

Pedestrian facilities such as sidewalks must be designed to accommodate persons with disabilities. The cross slope on sidewalks is not permitted to exceed 2 percent.

The Lithuanian design standards indicate that pedestrian and cycling facilities are built to separate pedestrian and bicycle traffic from vehicle traffic. Separate pedestrian, bicycle paths, or shared pedestrian and bicycle paths may be constructed. In case of shared pedestrian-bicycle paths, the path cover width should be no less than 2.5 m.

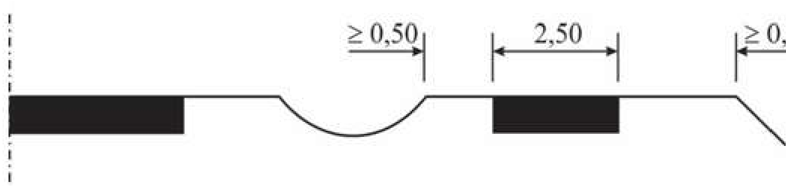
Bicycle and shared bicycle-pedestrian paths should be built outside the edge of the road roadbed or separated from the carriageway with a curb or safety barriers. Such paths may be on one or both sides of the carriageway. Traffic on a shared bicycle-pedestrian path should be regulated by road signs, pavement striping or with different colour surfaces. [18]

In case a pedestrian path is built, the minimum surface of the path should be 2.0 m. In duly justified cases, the width of a pedestrian path may be decreased to 1.5 m or 1.0 m. The widths of pedestrian paths depend on the intensity of pedestrian traffic in peak hours. In case a one-direction bicycle path is designed, the surface width should be 2.0 m, or 1.6 m in exceptional cases. If the path is projected to be a two-direction one, the width should be 2.5 m, which in exceptional cases may be reduced to 2.0 m.

In Germany, pedestrian and bicycle paths alongside the carriageway are most frequently constructed on one side of the road observing the standard for two-direction shared pedestrian-bicycle paths (Figure 2.11). Their width is 2.50 m. Pedestrian and bicycle tracks built alongside the carriageway should be designed using the natural terrain, at a variable distance from the carriageway, if conditions permit.

The arrangement of shared pedestrian-bicycle paths is planed in such a manner that the cyclists were not unduly dazzled by the lights of oncoming vehicles. The minimum width of the lateral safety zone is 1.75 m, depending on the traffic volume on pedestrian and bicycle paths. The width of the shoulders beside pedestrian and bicycle paths is 0.50 m. In exceptional cases, based on proper technical and economic justification (e. g., due to kerbs), the width may depend on the obligatory lateral safety zone between the carriageway and the pedestrian-bicycle track.

a) Ouside the drainage zone (ditch)



b) With lateral dividing bar

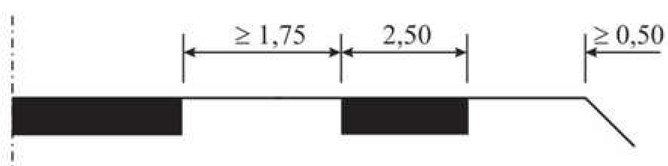


Figure 2.11 Location and dimensions of shared pedestrian-bicycle path [22]

2.11 Structures

2.11.1 New and reconstructed structures

In the USA, the design of bridges, culverts, walls, tunnels, and other structures should be in accordance with the current AASHTO LRFD Bridge Design Specifications. [3]

The minimum design loading for new bridges on local rural roads should be the HL-93 design vehicle live loads. The minimum clear roadway widths for new and reconstructed bridges should be as given in Table 2.24.

Table 2.24 Minimum clear roadway widths and design loadings for new and reconstructed bridges [22]

Metric			USA Customary		
Design volume (veh/day)	**Minimum clear roadway width for bridges**	**Design loading structural capacity**	**Design volume (veh/day)**	**Minimum clear roadway width for bridges[a]**	**Design loading structural capacity**
400 and under	Traveled way + 0.6 m (each side)	HL 93	400 and under	Traveled way + 2 ft (each side)	HL 93
400 to 2000	Traveled way + 1 m (each side)	HL 93	400 to 2000	Traveled way + 3 ft (each side)	HL 93
over 2000	Approach roadway width[b]	HL 93	over 2000	Approach roadway width[b]	HL 93

Notes:

a Where the approach roadway width (traveled way plus shoulders) is surfaced, that surface width should be carried across the structures.

b For bridges in excess of 30 m in length, the minimum width of traveled way plus 1 m on each side is acceptable.

For the designing of new bridges or tunnels in Lithuania, Regulation on Technical Requirements for Construction STR 2.06.02:2001 "Tiltai ir tuneliai. Bendrieji reikalavimai" ("*Bridges and tunnels. General requirements*") is applied. [27]

The width of the outer lateral lane of a bridge depends on the category of the road. The minimum width of the outer lateral lane of a low volume road is 0.5 m.

In Germany, for designing of new brides, design standards „Richtzeichnungen fur lngenieurbauten" (Riz-ING) are applied. These standards indicate that the minimum width of the lateral lane is 0.5 m.

2.11.2 Bridges to remain in place

The design rules of the United States establish that, where an existing road is to be reconstructed, an existing bridge that fits the proposed alignment and gradeline may remain in place when its structural capacity, in terms of design loading and clear roadway width, are at least equal to the values shown in Table 2.25 for the applicable traffic volume.

The values shown in Table 2.25 do not apply to structures with total lengths greater than 30 m. These structures should be analyzed individually, taking into consideration the condition of the structure, the clear width provided, traffic volume, remaining structure life, pedestrian volume, snow storage, design speed, crash history, and other pertinent factors. [1]

Table 2.25 Minimum structural capacities and minimum carriageway widths for bridges to remain in place [1]

Metric			USA Customary		
Design volume (veh/day)	**Design loading structural capacity**	**Minimum clear roadway width (m)a,b,c**	**Design volume (veh/day)**	**Design loading structural capacity**	**Minimum clear roadway width (ft)a,b,c**
0 to 50	MS 13.5	6.0[d]	0 to 50	HS 15	20[d]
50 to 250	MS 13.5	6.0	50 to 250	HS 15	20
250 to 1500	MS 13.5	6.6	250 to 1500	HS 15	22
1500 to 2000	MS 13.5	7.2	1500 to 2000	HS 15	24
Over 2000	MS 13.5	8.5	Over 2000	HS 15	28

Notes:

a Clear width between curbs or rails, whichever is the lesser.

b Minimum clear widths that are 0.6 m narrower may be used on roads with few trucks. In no case should the minimum clear width be less than the approach traveled way width.

c Does not apply to structures with total length greater than 30 m.

d For single lane bridges, 5.4 m should be used.

2.11.3 Vertical clearance

Vertical clearance at underpasses, as suggested by the USA design recommendations, should be at least 4.3 m over the entire roadwaywidth, with an allowance for future resurfacing. Pedestrian, bicycle, and sign structures should be provided with a vertical clearance of at least 4.5 m. [1]

In the Lithuanian design standards it is established that vertical clearance for vehicle, bicycle, and pedestrian traffic should be 5 meters. Vertical clearance is measured from the highest point of the carriageway surface.

The German design rules suggest a lower vertical clearance – 4.50 m. In case the reconstruction of the top layer of the pavement is foreseen, vertical clearance could be increased by 0.25 m. In such case the vertical clearance will make 4.75 m.

2.12 Roadside design

There are two primary considerations for shoulder design along the carriageway for local rural roads: clear zones and lateral offset.

2.12.1 Clear zones

A clear zone of 2 to 3 m or more from the edge of the carriageway, appropriately graded with relatively flat slopes and rounded cross sectional design, is desirable in the design standards of the USA. An exception may be made where guardrail protection is provided. The clear zone should be clear of all unyielding objects such as trees, sign supports, utility poles, light poles, and any other fixed objects that might increase the potential severity of a crash when a vehicle runs off the road. [1]

The Lithuanian designing standards also touch upon a clear zone and its significance on the road. In order to reduce the number of traffic accidents and minimise their consequences, it is recommended that on the roadsides of roads with very high, high, and moderate level of traffic quality, clear zones should be created, which should be clear of trees, poles, pillars or other similar objects, or otherwise these objects should be fenced.

Optimal and minimum widths of clear zones are described in Table 2.26.

Table 2.26 Clear zone width [18]

Speed limit, km/h	70	90	100/110	110/130
Optimal width, m	4.00	8.00	11.00	15.00
Minimum width, m	3.00	6.00	8.50	11.00
Note. Clear zone width is measured from the edge of the lane to the outer side.				

The width of a clear zone depends on the speed limit on a designed road.

The German design standards make no reference to clear zones. However, the function of a clear zone is performed by one of the parts that comprise a road: a safety zone (lateral safety space). The whole clearance of a road should be clear of fixed obstacles. Road sign posts should be fixed on the edge of the clearance area. Road safety facilities and easily deformable parts of traffic installations may protrude outside the clearance area and be close to the traffic area to up to 0.50 m. In exceptional cases, based on proper economic and technical justification, when installing safety barriers, this value may be reduced to 0.25 m. Curbs in the clearance area may encroach to up to the edge of the traffic area. [22]

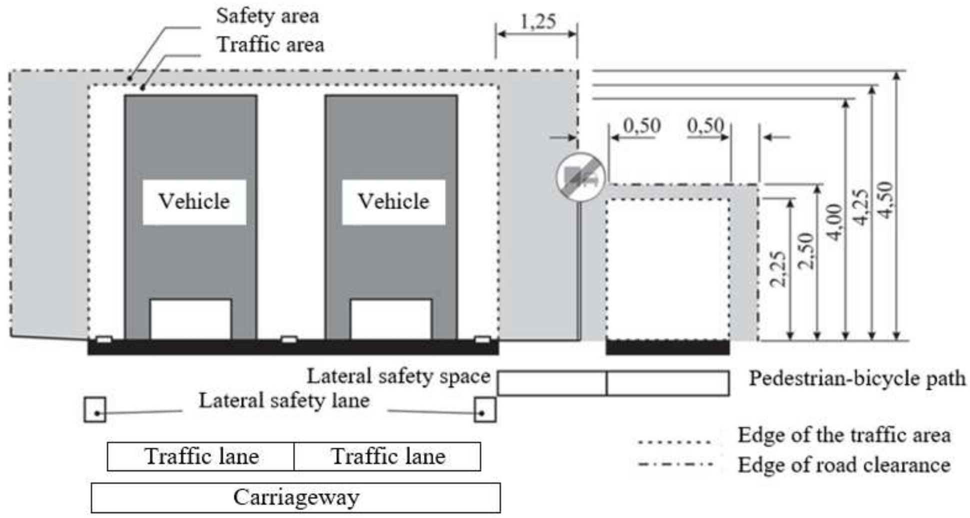


Figure 2.12 Parameters of road structure clearance [22]

The width of lateral safety areas of carriageways is 1.25 m. This dimension may be decreased to 0.25 m. in case there is a speed limitation of 70 km/h.

2.12.2 Lateral offset

The full approach width (traveled way plus shoulders) should be carried along the roadwayand across bridges and overpasses where practical, as suggested by design standards of the USA. To the extent practical, where another highway or railway passes over the roadway, the overpass should be designed so that the pier or abutment supports, including barrier protection systems, have a lateral offset equal to or greater than the lateral offset on the approach roadway. [1]

This lateral offset to obstructions helps to:

- Avoid adverse impacts on vehicle lane position and encroachments into opposing or adjacent lanes;
- Improve driveway and horizontal sight distances;
- Reduce the travel lane encroachments from occasional parked and disabled vehicles;
- Improve travel lane capacity;
- Minimize contact between obstructions and vehicle mirrors, car doors, and trucks that overhang the edge when turning.

On curbed facilities located in transition areas between rural and urban settings, there may be opportunity to provide greater lateral offset in the placement of fixed objects. These facilities are generally characterized by higher operating speeds and may have pavements separated from the curb by a buffer strip.

2.12.3 Foreslopes

The maximum rate of foreslope depends on the stability of local soils as determined by soil investigation and local experience. Slopes should be as flat as practical, taking into consideration other design constraints. Flat foreslopes reduce potential crash severity for vehicles that run off the road by providing a maneuver area in emergencies. In addition, they are more stable than steep slopes, aid in the establishment of plant growth, and simplify maintenance work. Vehicles that leave the traveled way can often be kept under control if slopes are gentle and drainage ditches are well rounded. Such recovery areas should be provided where terrain and right of way controls permit.

Combinations of rate and height of slope should provide for vehicle recovery. Where controlling conditions (such as high fills, right of way restrictions, or the presence of rocks, watercourses, or other shoulder features) make this impractical, consideration should be given to the provision of guardrail, in which case the maximum rate of foreslope consistent with slope stability may be used.

Cut sections should be designed with adequate ditches. Preferably, the foreslope should not be steeper than 1V:2H, and the ditch bottom and slopes should be well rounded. The backslope should not exceed the maximum rate needed for stability. [1]

According to the design standards in force in Lithuania, the steepness of foreslopes depends on the soil type. According to stability requirements, 12 meter-high slopes are created as it is shown in Table 2.27 when:

- the basement of embankments are stable;
- soils of normal humidity are compacted in line with requirements;
- roadbeds are not flooded with water;
- slopes are fixed by grassing.

Flooded roadbed slopes should be no steeper than 1:2.

Table 2.27 Steepness of embankment slopes [18]

Soils of embankments	Maximum steepness , when the height of an embankment is		
	up to 6 m	up to 12 m	
		lower part 0–6 m	upper part 6–12 m
Sand (except medium sand and dusty sand)	1:1.5	1:1.5	1:1.5
Medium sand and dusty sand, silt of low and moderate plasticity, clayey sand, clay of low and moderate plasticity	$\frac{1:1,5}{1:2}$	$\frac{1:1,75}{1:2}$	$\frac{1:1,5}{1:1,75}$
Note. Values indicated below the dash are applied to dusty soils and medium sand.			

Typical solutions are applicable to cuts of up to 12.0 m. in depth, which have stable soils and are climate resilient, without watery interlayers, suitable for roadbed. The slopes of such cuts are usually not steeper than 1:2.

In areas with significant snowfall cuts alongside roads should be made:

- down to 1.0 m in depth, with outer slope gradient of 1:6–1:10;
- from 1.0 m to 5.0 m in depth, with slope gradient of 1:2 and ditches with bottoms of 1.5 m in width.

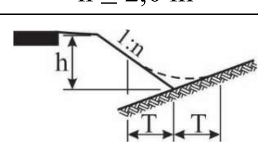
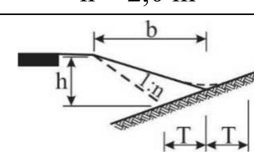
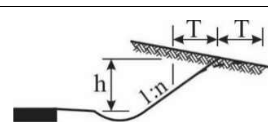
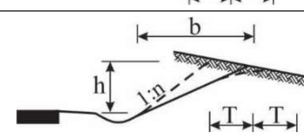
It is recommended to create slopes of embankments with a gradient no steeper than 1:3, and gradients of cuts should be no steeper than 1:2. The edges of embankment slopes should by rounded by radius R ≥ 9.00 m, and the edges of cuts slopes – R ≥ 6.00 m.

The Germany, design standards suggest slope designing schemes, which are described in Table 2.28. The slope on embankments and cuts is formed (designed) with a gradient of 1:1.5. Other values for slope gradient and shape may be applied in cases when:

- there is no change in the width of the lane;
- the road is adapted to the landscape;
- it is an unoccupied territory, a more gentle slope is designed, avoiding construction of road restraint systems, and creating safer traffic conditions;
- pollution control requirements dictate;
- snowing-up in to be avoided;
- disclocation of engineering communication facilities should be taken into account.

On steeper slopes (h ≥ 5.00 m), in order to maintain the stability of roadbed, safety, or to simplify the maintenance works of the slopes, it is useful to create drive-through (suitable for mowing) berms.

Table 2.28 Design of typical slopes [22]

	Slope hight, h	
	h ≥ 2,0 m	h < 2,0 m
Embankment		
Cut		
Slope	Typical slope gradient 1:1.5	Typcal slope width b = 3.00 m
Length of rounding	T = 3.00 m	T = 1.5 h

The slope and the surface are connected by rounding, as shown in Table 2.28. On embankments and cuts they should be created at the foot of the slope, and are usually fixed by grassing.

2.13 Intersection design

Intersections in the USA should be carefully located to avoid steep profile grades and to provide adequate approach sight distance. An intersection should not be situated just beyond a short crest vertical curve or on a sharp horizontal curve. When there is no practical alternate to locating an intersection on a curve, the approach sight distance on each leg should be checked, and where practical, backslopes should be flattened and horizontal or vertical curves lengthened to provide additional sight distance. The driver of a vehicle approaching an intersection should have an unobstructed view of the entire intersection and sufficient lengths of the intersecting roadways to permit the driver to anticipate and avoid potential collisions. [1]

Intersections should be designed with corner radii adequate for a selected design vehicle, representing a larger vehicle that is anticipated to use the intersection with some frequency.

Intersection legs that operate under stop control should intersect at right angles, wherever practical, and should not intersect at an angle less than 60 degrees.

In Lithuania intersections are designed according to recommendations on construction R 36-01 [28].

In general cases, intersections are constructed considering the functional purpose, significance, and category of the road. When constructing an intersection, the following factors should be taken into account:

- adjacent intersections;
- prospective volume of traffic flows and possible future development of the intersection;
- the area (terrain, soil and geological conditions, landscape features, environmental issues), traffic control during construction works etc.

In more complicated cases, several versions of intersection schemes are created, and the most optimal one is selected, based on economic, traffic safety and convenience criteria. Separate nodes on split-level intersections with traffic intersections on secondary roads of lower categories are constructed following solutions of flat intersections, taking into account traffic peculiarities on such intersections. [18]

According to the German designing standards, intersections should be designed in such a manner, that they could ensure traffic safety at all times (either traversing, leaving or entering the intersection). They should satisfy the needs of all vehicles and adapted to all access roads, as well as:

- noticed in good time;
- clear;
- understandable, i. e. traffic control on them and driving priority should be clearly understood;
- easily and safely accessed and passed.

The number and design of intersections should allow reaching preferable safe speed on the section of the main road between intersections. With regard to the desirable recognizability of the category of the roads, it is useful to design the intersections uniformely on the whole road. [22]

It should also be identified, whether, according to the requirements of the road development plan, in order to attribute separate parts of road sections to the foreseen road category, average vehicle speed could be maintained on the main road.

2.13.1 Railway highway grade crossings

Road designing rules of the USA suggest that appropriate grade crossing warning devices should be installed at railway highway grade crossings on local roads. In some states, the final approval of these devices may be vested in an agency having oversight over railways.

A railway highway crossing, like any highway intersection, involves either a separation of grades or a crossing at grade. The geometrics of a highway and structure that involves the overcrossing or undercrossing of a railway are substantially the same as those for a highway grade separation without ramps.

The horizontal and vertical geometrics of a highway approaching a railway grade crossing should be constructed in a manner that facilitates driver's attention to roadway conditions.

Designed horizontal alignment, the highway should intersect the tracks at a right angle with no nearby intersections or driveways. This layout enhances the driver's view of the crossing and tracks, reduces conflicting vehicular movements from crossroads and driveways, and is preferred for bicyclists. To the extent practical, crossings should not be located on either highway or railway curves. Railway curvature may inhibit a driver's view down the tracks from both a stopped position at the crossing and on the approach to the crossing. Those crossings that are located on both highway and railway curves present maintenance challenges and poor rideability for highway traffic due to conflicting superelevations.

Where highways that are parallel with main tracks intersect highways that cross the main tracks, there should be sufficient distance between the tracks and the highway intersections to enable highway traffic in all directions to move expeditiously. Where physically restricted areas make it impractical to obtain adequate storage distance between the main track and a highway intersection, the following should be considered:

- Interconnection of the highway traffic signals with the grade crossing signals to enable vehicles to clear the grade crossing when a train approaches;
- Placement of a "Do Not Stop on Track" sign on the roadwayapproach to the grade crossing.

Designed vertical alignment, it is desirable from the standpoint of sight distance, rideability, braking, and acceleration distances that the intersection of highway and railway be made as level as practical. Vertical curves should be of sufficient length to provide an adequate view of the crossing.

In some instances, the roadway vertical alignment may not meet acceptable geometrics for a given design speed because of restrictive topography or limitations of right of way. To prevent drivers of low clearance vehicles from becoming caught on the tracks, the crossing surface should be at the same plane as the top of the rails for a distance of 0.6 m outside the rails. The surface of the highway should also not be more than 75 mm higher or lower than the top of nearest rail at a point 9 m from the rail unless track superelevation makes a different level appropriate, as shown in Figure 2.13. Vertical curves should be used to traverse from the highway grade to a level plane at the elevation of the rails. Rails that are superelevated, or a roadway approach section that is not level, need a site-specific analysis for rail clearances. [1]

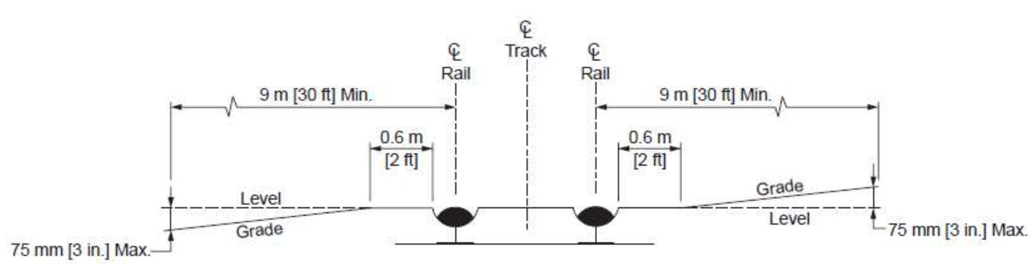


Figure 2.13 Railway highway grade crossing [1]

The geometric design of railway highway grade crossings should be made jointly when determining the warning devices to be used. When only passive warning devices such as signs and pavement markings are used, the highway drivers are warned of the crossing location but need to determine for themselves whether or not there are train movements, for which they should stop. On the other hand, when active warning devices such as flashing light signals or automatic gates are used, the driver is given a positive indication of the presence or the approach of a train at the crossing. A large number of significant variables should be considered in determining the type of warning device to be installed at a railway grade crossing. For certain low volume highway crossings where adequate sight distance is not available, additional signing may be needed.

The designing standards applicable in Lithuania establish that railway crossings on roads of categories III and IV should involve a separation of grades, when:

- three or more main railway tracks are to be crossed;
- the crossing is on the high-speed railway track (> 120 km/h);
- traffic volume is higher than 100 trains per day;
- the railway that is crossed is located in a cut;
- proper sight distance can not otherwise be ensured.

Raiway level crossings should be constructed on straight sections of raiways and highways, behind cuts and outside poor visibility areas. Most often those crossings are constructed at right angles. If this condition can not be met, the acute angle between the intersecting sections should be not less than 60^{o}. Level crossings with sharper angle are rearranged by reconstructing highways.

When reconstructing highways or constructing new ones, the access conditions should be such that the longitudinal profile of the road situated at the distance of not less than 20 m from the closest rail had no slope (horizontal), and on curved railway sections it had a slope which is determined by the cant. Highway access to a railway level crossing at the distance of not less than 50 m should be designed with longitudinal slope of not more than 3%.

In areas with difficult conditions (mountainous terrain, city streets etc.), the longitudinal road profile accessing railway level crossings may be designed individually, coordinated with the police, road operators or other road owners. [18]

The width of a railway level crossing should be equal to the width of the carriageway of a highway with 0.5 m on both sides, but not narrower than 6 m, while the width of the shuttering in livestock driving areas should not be narrower than 4 m.

Railway level crossing construction schemes are given in Annex 1.

2.13.2 Trafic control devices

Signs, pavement and other markings, and, where appropriate, traffic signal controls are essential elements for all local roads. The requirements for the installation of traffic signs, vertical and horizontal markings as well as traffic lights, if appropriate, are established by State rules.

2.13.3 Drainage

In the USA, drainage, both on the pavement and from the sides and subsurface, is an important design consideration. Inadequate drainage can lead to high maintenance costs and adverse operational conditions. In areas of significant snowfall, roadwayshould be designed so that there is sufficient storage space outside the traveled way for plowed snow and proper drainage for melting conditions. Further guidance can be found in the AASHTO Model Drainage Manual [2].

While designing roads in Lithuania, special attention is paid to road drainage. Water should be drained from the road and its lane to lateral ditches or shoulders (where it does not conflict with the interests of land users) or into a closed water drainage system.

Protective frost-resistant layer should be drained by exending this layer down to the roadbed or by drainage, at the same time draining excavation slopes, where practical. In a roadbed the depth of pipe drainage grooves should be no less than 1.20 m and width should be no less than 0.3 m. The minimum diameter of a drainage pipe should be 100 mm (in exceptional cases it may be 80 mm), and the gradient should be 0.3% (in exceptional cases it may be 0.2%). Drainage pipes are coated with two 0.15 m thick layers of filtering materials of varying coarseness. For this purpose geotextile, as a separator or filter layer, can be used. Concrete pipes are covered by one layer of filtering material. For purposes of road drainage line maintenance, inpection chambers should be installed as densely as 80 m. [18]

In Germany, due to ecological and economic reasons, road water drainage should be open, directing the surface water through the shoulder and infiltrating it into drainpipes or allowing it to penetrate into natural soil. Closed water drainage may be necessary, when:

- it is not possible to ensure open drainage;
- the road alignment is crossed by a potable water protection zone;
- it is necessary due to other aquacultural reasons or the design of directional carriageway involves a cross slope towards the centre of the lane.

Surface water collected at the edge of the carriageway is chanelled to catch pits through channel systems, usually with the aid of special installations (water retention pool, rain-water treatment pool etc.).

2.13.4 Erosion control and landscaping

Road design rules of the USA emphasize that consideration should be given to the preservation of the natural ground cover and the growth of shrubs and trees within the right of way when designing local rural roads. Shrubs, trees, and other vegetation should be considered in assessing the sight distance available to the driver and the lateral offset to shoulder objects. Seeding, mulching, sodding, or other acceptable measures for covering slopes, swales, or other erodible areas should be considered in the local rural road design.

Erosion prevention is one of the major factors in design, construction, and maintenance of rural roads. It should be considered early in the location and design stages. Some degree of erosion control can be incorporated into the geometric design, particularly in the cross section elements. Of course, the most direct application of erosion control occurs in drainage design and in the writing of specifications for landscaping and slope planting. [1]

Erosion and maintenance are minimized largely by using specific design features:

- flat side slopes, rounded and blended with natural terrain;
- serrated cut slopes;
- drainage channels designed with due regard to width, depth, slopes, alignment, and protective treatment;
- inlets located and spaced with erosion control in mind;
- prevention of erosion at culvert outlets;
- proper facilities for groundwater interception;
- dikes, berms, and other protective devices to trap sediment at strategic locations;
- protective ground covers and planting.

To the extent practical, these features should be designed and located to minimize the potential crash severity for motorists who unintentionally run off the roadway.

Landscape development should be in keeping with the character of the rural roads and its environment. Programs include the following general areas of improvement:

- preservation of existing vegetation;
- transplanting of existing vegetation where practical;
- planting of new vegetation;
- selective clearing and thinning, and regeneration of natural plant species and material.

The objectives in planting or the retention and preservation of natural growth on shoulders are closely related. In essence, they provide vegetation that:

- will be an aid to aesthetics;
- will aid in lowering construction and maintenance costs;
- create interest, usefulness, and beauty for the pleasure and satisfaction of the traveling public without increasing the potential crash severity for motorists who unintentionally run off the roadway.

Landscaping of roads and streets assumes additional importance in mitigating the many nuisances associated with urban traffic. Landscaping can reduce this contribution to urban blight and make the urban roads and streets better neighbours.

Rather strict requirements related to nature protection and landscape care are in force in Germany. Federal Law on Nature Protection (BNatSchG) together with Federal Land Regulations provide for protection of landscape features, variety and beauty, as well as protection of historical cultural spaces. Those provisions oblige to restore the landscape or to re-shape it in case it has been affected.

For the maintenance of spatial line alignments, tree planting should be foreseen on the lateral space alongside the road.

In general, in landscape formation in terms of vegetation, it should be ensured that the necessary stopping sight distance is not obstructed in the long-term. The same requirements are applicable to the central reservations of dual carriageways.

One of the factors that should be evaluated in relation to the vegetation on shoulders is traffic safety. Therefore, lateral spaces are designed in such a manner that the consequences of traffic accidents caused by inintentional running off the carriageway could be minimized. Shrubs are considered non-critical obstacles, if they are trimmed when the diameter of the stem is not more than 0.08 m. Shrubs are planted at a minimum distance of 3.00 m from the road edge with pavement and must not affect the clear sight distance fields.

When planting new trees, it should be kept in mind that they might grow up into dangerous obstacles in terms of restrictions provided in document RPS. Thus, trees should be planted only in spaces not reachable by forward-moving vehicles (e. g., behind traffic route control systems or in the slopes of cuts). Also, they are planted behind traffic route control systems at a distance of at least 3.00 m from the edge of road pavement so that the nature of their efficiency is not affected. [22]

2.14 Comparison of designing standarts

Having analysed the regulations on low volume road design of the United States, Germany, the Netherlands, and Lithuania, several main differences of designing standards are distinguished.

On low volume roads in Lithuania best traffic conditions are ensured for drivers who use the carriageway. Other road users, such as cyclists and pedestrians are made to adapt themselves to the situation. Traffic lanes or paths are not provided for them.

The maximum allowable speed on low volume road in the USA and the Netherlands is 60 km/h, while in Germany and Lithuania the design speed may be 70 km/h.

For designed roads in the USA and Germany traffic quality indicators LOS are established according to HCM, while in Lithuania designed roads are not subject to the traffic quality indicator LOS.

The maximum longitudinal slope in the USA and Lithuania is 7%, when the design speed is 70 km/h, while in Germany the maximum longitudical slope is 8%.

The slope of roadway cross section profile in the USA should not exceed 2%, where a road is paved, while in Germany and Lithuania it may be 2.5% in the case of a paved road.

When designing low volume roads, the maximum allowable slope of a superelevation may reach 12% in the United States. In Germany the maximum permissible superevelation is designed to be 7%, while Lithuanian design standards suggest that it should be 6%, the lowest in comparison to the other two mentioned countries.

Passing sight distance in the USA, Germany and Lithuania is different at the same driving speed of 60 km/h. The minimum passing sight distance in the United States is allowed to be 180 m., while in Germany it is 300 m. In Lithuania 400 m are required for the maximum passing sight distance.

It is recommended that the width of a low volume road carriageway in the USA should be 5.4 m, when the speed is 60 km/h, while in Germany and Lithuania the width of the carriageway should be 6 m, where the maximum design speed is 70 km/h. In the Netherlands the width of the carriageway may vary from 2.5 m to 6 m depending on the type of the road. The maximum allowable speed on these roads are 60 km/h.

The number of lanes on low volume roads in the USA and in Lithuania should be 2, while the Netherlands and German designing standards indicate that it is sufficient to construct one lane, which could be used by vehicles moving in opposite directions. In the Netherlands only one lane on low volume roads is recommended.

Where low volume roads should accommodate pedestrian and bicycle traffic, the design standards in the USA and Lithuania suggest that separate pedestrian and bicycle paths should be designed, except in cases when the low volume road passes through a settlement. In these cases, paths for pedestrians and cyclists are designed alongside the carriageway. German and Dutch design standards establish that pedestrian and bicycle traffic is accommodated alongside the carriageway and separated from vehicle traffic by a continuous line.

When low volume roads cross bridges, overpasses, and elevated highways in the USA and Germany, the vertical clearance should be 4.5 in width. The height of vertical clearance in Lithuania should be 5.0 m.

The recommended width of clear zone in the USA is 2 m, and in Lithuania it depends on the design speed. Where the speed is 70 km/h, the width of clear zone is 3 m, while in Germany it is 1.25 m.

Maximum foreslopes for low volume roads in the USA are allowed to have a gradient of 1:2, a gradient which is any higher is not recommended. German design standards permit lower gradient, which may be 1:1.5. In Lithuania the foreslope gradient is selected according to the type of the soil. The gradient of foreslopes may be 1:1.5, 1:1.75 and 1:2.

Where a low volume road crosses a railway, the design rules of the USA indicate that the longitudinal profile of the road situated at the distance of not less than 0.6 m from the closest rail should be horizontal. In Lithuania the longitudinal profile of a road should be horizontal at a distance of 10 m from the closest rail.

3. RESEARCH METHODOLOGY

3.1 Analysis of gravel road paving projects

The total length of Lithuania roads of national significance is 21 252 km, the biggest part 69% (14 579 km) being taken by roads of regional significance. Almost a half of these roads are gravel roads (Table 3.1). As it can be seen from Table 3.1, regional gravel covered roads make up nearly 34% of the whole road network of Lithuania. Due to this reason, each year efforts are made for paving as many roads as possible, thus improving the condition of the whole road network, the quality of traffic, and dust control on roads. Presently, gravel roads in Lithuania are paved under the programme "Zebra". "In the course of implementation of the "Zebra" programme, more than a hundred of kilometres of present gravel roads will be paved during the next two years. With the aid of the European Union funds and Road Maintenance and Development Programme funding 591 kilometers of gravel roads are planed to be paved during 2016–2017 in Alytus, Kaunas, Klaipėda, Marijampolė, Panevėžys, Šiauliai, Tauragė, Telšiai, Utena, and Vilnius districts" [29]. Most frequently gravel roads between settements or between paved roads are selected for asphalting so that the roads could be connected. Road safety conditions on regional roads are usually poor, and road alignments are uneven. For this reason, five asphalting projects were chosen to be examined in this thesis. The sections of these gravel roads fall under the above-mentioned gravel road paving program.

Table 3.1 Pavements of roads of national significance as of 2017-01-01 [14]

Pavements	Roads of National Significance			
	Higways	**National**	**Regional**	**Total**
Asphalt pavement, km	1686.124	4925.491	7550.129	14166.172
Cement concrete pavement, km	59.883	-	1.366	61.282
Gravel pavement, km	-	-	7009.534	7009.534
Stones pavement, km	0.252	-	7.168	7.419
Total	1750.719	4925.491	14568.197	21244.407

Gravel road paving projects are selected on the basis of traffic volume on these roads, which should not exceed 400 vehicles/day. Also, much attention is paid to the longitudinal road profile. Before implementing the projcts, the current road condition is evaluated. Having assessed all the mentioned criteria, five gravel road paving projects are selected.

- Project of the reconstruction of national significance regional road No 2811 Kapanauza – Čivyliai – Verbiškės section from 0.005 km to 3.123 km in Molėtai district (thereinafter referred to as Section One);
- Project of the reconstruction of national significance regional road No 2816 Inturkė – Kertuoja – Lakaja section from 0.400 km to 2.163 km in Molėtai district (thereinafter referred to as Section Two);
- Project of the reconstruction of national significance regional road No 4903 Utena – Pakalniai – Alanta secton from 24.140 km to 24.894 km in Molėtai district (thereinafter referred to as Section Three);
- Project of the reconstruction of national significance regional road No 1211 Viešintos – Papiliai – Pelyšėlės section from 0.609 km to 2.129 km (thereinafter referred to as Section Four);
- Project of the reconstruction of national significance regional road No 1213 Juostininkai – Raguva section from 0.715 km to 3.750 and section from 4.49 to 5.123 km (thereinafter referred to as Section Five).

All five paving projects are to be implemented in the eastern part of Lithuania, in the region of Utena. Sections One, Two, and Three are located in Molėtai district, and Sections Four and Five are situated in Anykščiai district. The region where the gravel road paving projects in question are being implemented are shown in Figure 3.1.

Figure 3.1 The site of selected road sections on the map of Lithuania (prepared by the author)

All the sections under interest are subject to reconstruction. According to KTR, "Road reconstruction is a type of construction, when according to the requirements established by the regulation to a particular road category: road components are completely restored or strengthened including all accessories and facilities belonging to the road complex, or they are rebuilt; the road alignment in the plan is changed to up to 30% increasing the horizontal radii of curvatures or straightening it localy on an additionaly designated land plot" [18]. The repair works comprise the renewal of road pavement structure replacing the gravel pavement with asphalt pavement, solving the issue of surface water collection, installing road signs, and fixing safety barriers, where appropriate. The road alignment should be changed to the least extent possible.

Reconstruction projects are analysed with regard to traffic volume, road alignment elements, road longitudinal profile elements, and cross section elements. First of all, traffic volume is estimated, then horizontal road alignment and its elements are investigated, and finally the longitudinal road profile with its elements as well as cross section profile are evaluated.

3.1.1 Analysis of traffic volume

The analysis of traffic volume is carried out in order to assure that regional roads can be attributed to low volume ones. Vehicle traffic is analysed based on the data uploaded into Lithuanian highway information system LRA. The information system contains data on traffic intensity on the roads in question. In this case, the data is taken from the project.

According to the data available for 2015, on road No 1211 Viešintos – Papiliai – Pelyšėlės section from 0.609 km to 2.129 km, AADT is 115 vehicles/day. Out of this number heavy vehicles make 7 vehicles/day. On road No 1213 Juostininkai – Raguva section from 0.715 to 5.123 km, AADT is 186 vehicles/day, out of which there are 42 heavy vehicles a day. On road No 2811 Kapanauza – Čivyliai – Verbiškės section from 0.005 km to 3.123 km, AADT is 142 vehicles/day, where there are 40 heavy vehicles a day. On road No 2816 Inturkė – Kertuoja – Lakaja section form 0.400 km to 2.163 km, AADT is 110 vehicles/day, and the traffic volume of heavy vehicles is 11 vehicles/day. On road No 4903 Utena – Pakalniai – Alanta section from 24.140 km to 24.894 km, AADT is 77 vehicles/day, out of which the traffic of heavy vehicles is 23 vehicles/day.

Traffic volume on all the five regional roads of national significance did not exceed 400 vehicles/day, hence, these roads are attributable to low volume roads. The highest AADT was on Section Five, 186 vehicles/day, and the volume of heavy vehicle traffic was the highest on the same section – 42 vehicles/day.

3.1.2 Analysis of road longitudinal profile elements

The longitudinal profiles of the present gravel roads are wavy, with rising and falling gradients. For this reason, longitudinal road section profiles are designed observing the existing longitudinal profiles, and the existing terrain. Road Technical Regulation states that "road longitudinal slope should be as low as possible due to road safety, operating cost saving, energy saving, and environmental reasons, however, due to drainage reasons, the slope should not be lower than 0.3%, if terrain conditions allow" [18]. On Section One, the longitudinal slope varies from 0.3% to 8.75%. On a segment, where the longitudinal gradient reaches 8.75%, the design speed should be 50 km/h. The highest maximum longitudinal slope may be 8.0%, when the design speed is 50 km/h [18]. On Section Two, the longitudinal slope varies from 0.15 to 9.22%. On sections, where longitudinal slope is to be 9.22%, the design speed is 50 km/h, althought according to designing standards it should be 8.0%. On Section Three, the longitudinal slope varies from 0.05 to 6.1%. The design speed on the whole section long is 50 km/h. On Section Four, the longitudinal slope varies from 0.1 to 4.59%. The design speed on the whole section is 70 km/h. On Section Five, the longitudinal slope varies from 0.1% to 5.4%. The design speed on the whole section varies from 50 km/h to 70 km/h, depending on road bends. On the first two road sections the maximum allowable longitudinal slope is exceeded. On Sections Three, Fourth, and Five, the allowed longitudinal slope is maintained. More detailed information about the longitudinal profiles designed for all road sections is given in Table 3.2.

Table 3.2 Analysis of longitudinal profile in the selected gravel road paving projects (prepared by the author)

No.	Road No.	Minimum slope, %	Maximum slope, %	Convex curve radii, m	Concave curve radii, m
1.	2811	0.3	8.75	500, 550, 600, 700, 800, 1000, 1300, 1400, 1500, 1700	450, 550, 700, 750, 800, 900, 1000, 1400, 2000, 2500, 4500
2.	2816	0.15	9.22	320, 335, 350, 450, 500, 680, 880, 900, 1420, 1525, 1610, 1630	370, 470, 560, 580, 600, 660, 700, 800, 860, 1320, 2670
3.	4903	0.05	6.1	500, 1100, 2100, 2300	850, 1000, 1200, 1600, 2400
4.	1211	0.1	4.59	3000, 4000	2000, 2500, 3000
5.	1213	0.1	5.4	3000, 6000	3000, 4000, 6000, 8000, 10000

According to the data provided in Table 3.2, convex curve radii of Section One vary from 500 m to 800 m, while concave curve radii varying from 450 m to 700 are too small. The smallest radius of the vertical convex curve may be 1000 m, and that of the concave curves may be 750 m, when the speed is 50 km/h [18]. On Section Two different speeds are designed throughout the whole section. When the speed is 30 km/h, the convex curve radius of 335 m does not meet the requirements, since at such speed the radius should be 400 m. When the speed is 50 km/h, convex curve radii of 320, 350, 450, 680, 880 and 900 m and concave curve radii varying from 370 to 700 m are too small. On Section Three only the convex curve radius of 500 m does not meet the requirements, because the design speed is 50 km/h. Design speed of 70 km/h is foreseen for Section Four, and convex and concave curve radii are in compliance with the minimum requirements. When the speed is 70 km/h, the minimum convex curve radii and concave curve radii shoud be 3000 m of 2000 m, correspondingly [18]. On the last Section Five, the design speed constantly varies, at turning points the speed of 50 km/h is designed, and on straight lines it is designed to be 70 km/h. The requirements for convex and concave curve radii values are met for both design speed values.

Having analysed five gravel road projects, it may be stated that in the majority of the projects there are designing solutions which do not correspond to the requirements of design regulations. In some of the projects only minimal requirements are fulfilled.

3.1.3 Analysis of horizontal road alignment elements

Horizontal road alignments are designed according to the current road trajectory, with minimal changes, where necessary. New road alignments are designed using straight lines and horizontal curves, with or without track transition curves. In some sections breaking points without horizontal curves are inserted. The major part of inserted curves meets the relevant requirements according to the design speed at those points, however, there are points where curves of too small radii are inserted or only the minimal values are met. On Section One three curves of too small radii are inserted. Horizontal curves with radii of 60, 80 and 85 projected speed of 50 km/h. The minimal radii of horizontal curves may be 140 m, where the speed is 50 km/h [18]. On Section Two, horizontal curve radii meet the minimal possible values. On Section Three and on Section Two horizontal curve radii correspond to the requirements. Section Four has an insertion of horizontal curve with too small radius, which is 180 m, while the projected speed is 70 km/h (according to KTR, the minimum curve radius should be 300 m at such speed [18]). On Section Five, similarly as on Sections One and Four, there are curves not meeting the requirements. Throughout the whole section the speed varies from 70 km/h to 50 km/h. On segments, where the speed is designed to be 70 km/h, horizontal curve radius of 180 m is non-compliant with the requirements, since at such speed the recommended curve radius is 300 m. On three segments minimal curve radii values are within the allowed range, while on segments where the speed is designed to be 50 km/h, 7 horizontal curves with too small radii are inserted. The values for curves are 70, 80, 90, 120 and 140, though where the speed is 50 km/h, the value should be 140 m [18]. More detailed information about the road alignments designed for all the road sections is given in Table 3.3.

Table 3.3 Analysis of horizontal road alignment in gravel road paving projects (prepared by the author)

No.	Road No.	Values for horizontal curve radii, m	Values for superelevations, %	Design speed, km/h
1.	2811	60; 80; 85; 145; 180; 300; 350; 600; 1700; 1800; 2000; 3000; 4000; 4500; 6000; 11000; 12000	2.5; 3.3; 4.0	50
2.	2816	130; 150; 180; 290; 300; 450; 700; 800; 850	2.5; 3.0; 3.3; 4.0	30; 50
3.	4903	200; 1000; 1500; 2500	3.0	50
4.	1211	180; 400; 700; 2200	3.5	70
5.	1213	70; 80; 90; 120; 140; 145; 170; 180; 200; 300; 350; 400; 700	2.5; 3.5	50; 70

For smoother driving on the road, each regional gravel road in question has superelevatios. “A superelevation is a segment of a road the pavement of which has a slope directed towards the centre of the curve. A superelevation is set for reasons of driving comfort, vehicle stability and traffic safety in curvatures“ [18]. On Section One there are 8 superelevations with different slopes varying from 2.5% to 4.0%. Section Two has 5 superelevations the slope of which vary withing the range of 2.5% to 4.0%. Section Three has only one superelevation set with a slope of 3.0%. Three superelevations are planned for Section Four each with a 3.5% cross slope. On Section Five the largest number of superelevations are designed: 21. Their slopes are projected to be 2.5% or 3.5%. The exact values of cross slopes of the superelevations designed for all the sections are described in Table 3.3.

Having analysed the horizontal road alignment elements of the gravel road paving projects, it was established that numerous horizontal curve radii are non-compliant with the requirements at certain design speeds. All the superelevations meet the requirements and are varying from 2.5% to 4.0%.

3.1.4 Analysis of road cross section profile elements

The designed road cross section profile is of great importance to the whole visual appearance of the road. Road cross section profile is designed road elements, gradients, number of lanes and structure of the pavement. In the gravel road paving projects in question, the most attention is devoted to the selected width of roadway and shoulders, the number of lanes, and cross slopes. All the reconstructed roads are designed in line with parameters applicable for roads of category V. The design road width in road segments is planned to be 8.0 m (carriageway width of 6.0 m and shoulder width of 2 x 1.0 m), two lanes are foreseen. The shoulders are widened to up to 1.3 m in places where safety barriers are set. On Section One in places where superelevations are foreseen, the carriageway is widened by up to 0.3 m to 1.0 m, depending on the curve radius in the superelevation. The width of the carriageway at superelevations on Section Two is widened by 0.3 m. to 0.6 m. On Section Three, where curve radius is 200 m, the carriageway is widened by 0.4 m. In places where slopes are foreseen in Section Four, the carriageway is widened by 0.5 m. On Section Five, the carriageway at the points of superelevations is widened by 0.5 m to 1.2 m.

In all the gravel road paving projects under interest the carriageway is designed to be standard with a gradient of 2.5%. Superelevations are set where there are curves of smaller radii. Slopes of superelevations are given in Table 3.3. Drawings of cross profiles of road pavement structures are presented in Annex 3.

Having analysed cross section profile elements of all the 5 sections, it may be stated that no non-compliances with design standards have been identified. All the sections had been designed in line with applicable requirements of design standards.

3.2 Analysis of annual traffic volumes on regional roads of national significance

There are 1632 roads in the road system of the regional roads of national significance in Lithuania [14]. The average annual daily traffic is calculated for all these roads. The average annual daily traffic is the average number of vehicles passing through during one day of a year. [11]. The website of the Lithuanian Road Administration under the Ministry of Transport and Communications contains the data of the average annual daily traffic on regional roads of national significance for 2016. Detailed data of annual daily traffic on regional roads are given in Annex 2. In order the information about traffic volumes on regional roads was more compherensive and accurate, most roads are divided into sections and only then annual daily traffic on them is calculated. In total the annual daily traffic on regional roads is measured on 3941 road sections.

In order to find out the dominant traffic volumes on regional roads, traffic volume values of road sections are divided into intervals, the first interval being of up to 200, the second one being of 200 to 300, the third one being of 300 to 400, and the fourth – more than 400 AADT. The results of the calculations are presented in Figure 3.2.

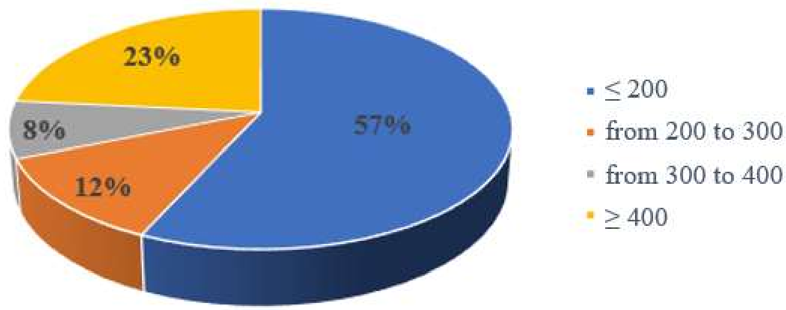


Figure 3.2 Distribution of annual daily traffic on sections of regional roads (prepared by the author)

As it can be seen from Figure 3.1, more than a half (57%) of regional roads are low volume roads with AADT reaching 200, while the part of roads with AADT higher than 400 is 23%. Figure 3.2 describes the average daily car traffic, and in order to perform a precise analysis of traffic on regional roads, the average number of cars and trucks on the road sections should be calculated. The numbers of cars and heavy vehicles are indicated in Table 3.4.

Table 3.4 Numbers of cars and heavy vehicles on regional road sections according to AADT (prepared by the author)

Range	Number of road sections	Average number of cars	Average number of heavy vehicles
up to 200	2240	99	13
from 200 to 300	474	247	27
from 300 to 400	303	347	37
more than 400	924	1088	92
Total	**3941**	**1781**	**169**

Table 3.4 illustrates the fact that most cars and heavy vehicles use regional roads, where traffic volume is higher than 400 veh/day. The difference between road sections where traffic

volumes reach 200, and road sections where the volume is above 400 is almost 2.5 times. The number of cars differs by 11 times, while the number of heavy vehicles differ by 7 times.

Having assessed the traffic volume data, a conclusion can be drawn that the traffic volume on most regional roads is low. The largest part of the network of regional roads is comprised by road sections where the average number of cars is lower than 100, and the average number of heavy vehicles is lower than 15. Therefore, a single carriageway road having no separate lanes in both directions is recommended to be constructed for newly designed low volume roads.

3.3 Analysis of carriageway width of regional roads of national significance

A road consists of road width, carriageway, shoulders, dividing strip, road ditches, intersections, bus stops, rest areas, pedestrian and bicycle tracks, road structures, technical traffic management measures, green spaces alongside the road, weather monitoring and traffic density recording, lighting, and other equipment, including the land occupied by these objects. [16]. The width of the carriageway is selected in the designing stage depending on the category of the road. It should be sufficient for safe movement and passing of vehicles.

While analysing the existing regional roads and in order to suggest the latest engineering solutions for their renewal, it is necessary to evaluate the present width of the carriageway. Information on the carriageway width of regional roads is taken from the project [30]. The differences of regional road carriageway widths are described in Figure 3.2 and Table 3.3.

In Table 3.5 regional roads of national significance are divided according to the width of the carriageway. Carriageway width is distributed with regard to the possibility to set certain road width. If the carriageway width is 3.5 m, all regional roads are selected where the road of indicated width can be constructed without widening its road width.

Table 3.5 Carriageway widths of regional roads of national significance (prepared by the author)

Carriageway width, m	Regional roads	Percentage, %
< 3.5	2	0
3.5	17	1
4.5	277	17
6.0	1230	75
7.0	85	5
≥8.0	21	1
Total:	**1632**	**100**

The smallest number of regional roads have carriageway widths of 3.5 m, there are only 2 of them. Also, there is a small number of roads where it could be possible to construct a 3.5 m or more than 8 m wide carriageway; 17 roads have the carriageway width of 3.5 m, and the carriageway width of more than 8 m belong to 21 regional roads. The dominant part of roads is roads where the carriageway width can be 6 m, there are 1230 of such roads. Figure 3.3 graphically represents the number of regional roads with the values for their carriageway width.

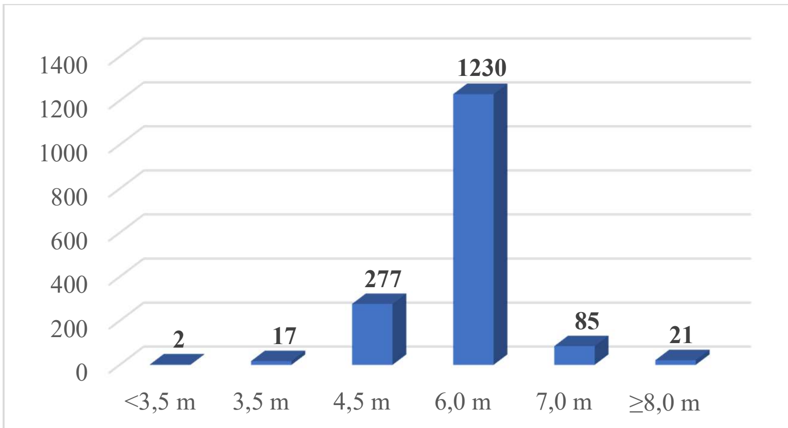


Figure 3.3 Number of regional roads by the width of the carriageway (prepared by the author)

Roads with road width of 6.0 m constitute the majority, which accounts for 76% of the roads under interest. The second biggest number of roads are those with road width of 4.5 m, and it makes 17% of the regional roads. Regional roads where the road width is 7 m make 5% of the roads. Roads with road width of 3.5 m and more than 8 m make only 1%. The percentage of road widths by the number of regional roads is given in Figure 3.4.

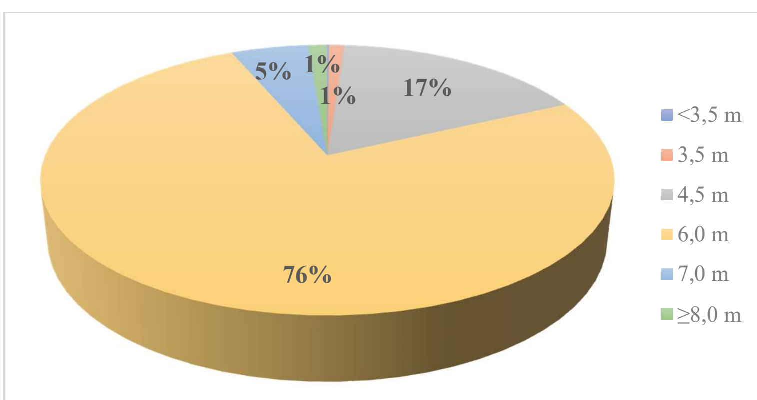


Figure 3.4 Percentage of carriageway width of regional roads (prepared by the author)

Detailed information on carriageway width of regional roads is presented in Annex 2.

Based on the data of carriageway width analysis, a conclusion may be drawn that carriageway width of most regional roads is 6.0 m. A wider carriageway for low volume roads would not be viable economically.

3.4 Analysis of road width of regional roads of national significance

A most essential part of a road is a road width. Road width is a soil structure performing functions of road foundation. It is constructed from brought in soil and (or) natural intact soil [18]. When designing a road width, natural conditions should be considered, current ecological situation and valuable land should be preserved, as well as road category and pavement structure should be taken into consideration. Road width, high embankments and deep cuts on unconsolidated foundations should be arranged in line with individual design solutions, developed applying road width stability calculation methods.

The calculations of the width of a road width are based on data obtained from the project [30], which contains the data of all measured widths of regional road widths. The values of road width are divided into five categories of values. The first one stands for pavement width not less than 7 m., and it means that the width of the road width is not sufficient to mount a 7-meter-wide road width. Other width values are 7, 8, and 10 m, and for these widths roads were calculated for which road width is sufficient for the indicated value. The last value is more than 10, hence all roads with very wide road widths were calculated. A graphic illustration of regional roads and their road width values is given in Figure 3.5.

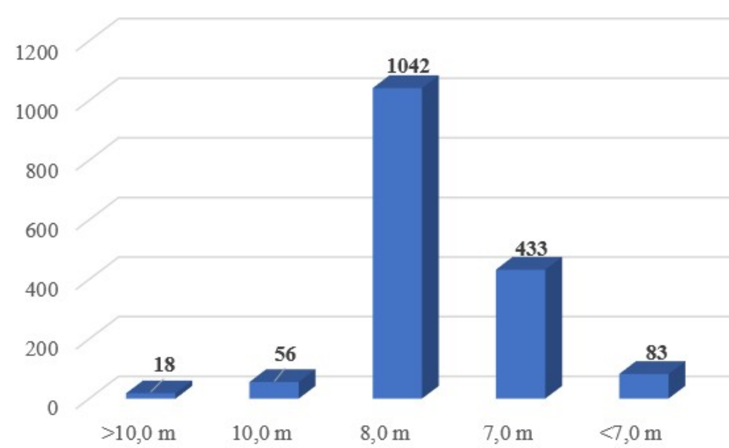


Figure 3.5 Number of regional roads according to road width (prepared by the author)

The largest part of regional roads had the road width of 8.0 m, and they make up 64% of all regional roads of national significance. These are 1042 roads out of 1632. A substantial share is taken by roads with road width of 7.0 m, there are 433 roads. It makes 27% of all regional roads. Roads with road width of 7.0 and 8.0 m together account for 91% of the whole network of regional roads. The smallest share is taken by roads, where road width is less than 7 m, 10 m, or more than 10 m. Roads with road width of more than 10 m reach 1%. Percentage of road widths according to the number of regional roads are presented in Figure 3.6.

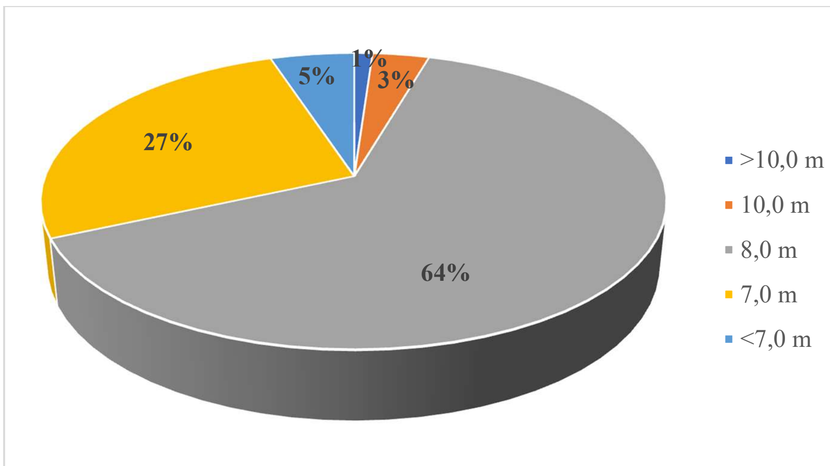


Figure 3.6 Percentage of road width in regional roads (prepared by the author)

The width of road width necessary to construct regional roads of national significance is 9.60 m, when designing a road of category V. Road width is selected according to road width used in gravel road paving projects. Having analysed all the road widths of the regional roads, it may be stated that only 4% of all regional roads have sufficient road width to build a new pavement. In order to construct a road of category V, the carriageway of which is 6 m and shoulder widths are 1 m each, road widths on most regional roads should be widened.

3.5 Conclusions

An analysis of 5 gravel road paving projects has been performed during the research: reconstruction projects of regional road of national significance No 2811 Kapanauza – Čivyliai – Verbiškės section from 0.005 km to 3.123 km, regional road of national significance No 2816 Inturkė – Kertuoja – Lakaja section from 0.400 km to 2.163 km, regional road of national significance No 4903 Utena – Pakalniai – Alanta section from 24.140 km to 24.894 km, regional road of national significance No 1211 Viešintos – Papiliai – Pelyšėlės section from 0.609 km to 2.129 km, and regional road of national significance No 1213 Juostininkai – Raguva section from 0.715 km to 3.750 and section from 4.49 to 5.123 km. Traffic volumes, road longitudinal profile elements, horizontal road alignment elements, as well as road cross section profile elements have been investigated.

During the analysis it was established:

- During the analysis of traffic volume, it was established that on none of the sections undergoing repairs AADT reached 200 vehicles/day. The highest traffic volume was 186 vehicles/day, and the lowest was 77 vehicles/day. Correspondingly, the volumes of heavy-duty vehicle traffic were 42 vehicles/day and 7 vehicles/day. All these roads are attributed to low volume roads;

- During the analysis of road longitudinal profile elements, it was found that on Sections One and Two the maximum allowable gradient was exceeded: on Section One the highest gradient was 8.75%, and on Section Two it was 9.22%. Also, on Sections Two, Three, Four and Five the value of the minimum longitudinal slope of 0.3% was not reached. Convex vertical curve radii were too small: on Section One 5 curve radii, on Section Two 7 curve radii, on Section Three 1 curve radius. Concave curve radii were too small on Section One – 7 curve radii, on Section Two – 6 radii. These increpancies jeopardize traffic safety on newly paved roads, and road accident probability increases.

- During the analysis of horizontal road alignment elements, it was established that too small radii of horizontal curvatures have been designed on 3 segments out of 5. On Section One there are 3 non-compliant radii of curvatures, on Section Four there is 1 and on Section Five there are two non-compliances. On Sections Two and Three the minimam values are met or proper size radii have been designed;

- During the analysis of road cross section profile elements, it was found that all the 5 cross section profiles have been designed observing the design standards in force. The designed roads are of category V with two lanes , the width of a lane being 3.0 m. and shoulder width is 1.0 m. The designed cross slope is 2.5%.

Having investigated the traffic volume on regional roads of national significance, it was established that the major part is taken by regional roads where AADT is less than 200 vehicles/day, they make 57% of all regional road sections AADT is measured on. The smallest share is taken by regional roads where AADT is from 300 to 400 vehicles/day, they account for 8% of the roads. Most heavy vehicles use segments of regional roads with traffic volume higher than 400 vehicles/day. Based on the traffic volume data, it can be observed that traffic volumes on most regional roads are low, therefore, these roads should be single carriageway roads.

While analysing carriageway widths of regional roads of national significance, a conclusion was drawn that the largest number of roads have carriageway widths of 6.0 m, they make 76% of all regional road network. The smallest percentage is taken by regional roads where the carriageway width is less than 3.5 m more than 8.0 m. Together they make only 1%. Since most of regional roads are attributable to low volume roads and the carriageway of most roads is 6.0 m, thus, in order to maintain the uniformity of the roads, it would not be useful to design a wider carriageway.

During the analysis of road widths of regional roads of national significance, it was identified that the largest share of regional roads is taken by roads where road width was about 8.0 m which comprise 64% of all regional roads. The smallest part of the roads, 1%, is taken by the roads, where road width is 10.0 m. It would be necessary to increase the road widths while reconstructing low volume roads, as they would not be suitable for the construction of a carriageway of preferable width.

4. JUSTIFICATION OF RESULTS OF THE RESEARCH WORK

The major part of the Lithuanian road infrastructure does not meet road safety requirements. Therefore, in order to improve the road infrastructure, only economically justified and effective measures should be deployed [17]. Presently "National Transport development programme for 2014–2022" is being implemented in Lithuania. The strategic goal of the programme is to create a competitive, modern, cohesive, and high value-added communications system for Lithuania. To achieve this goal proper funding of the road system is necessary. Lithuanian roads of national significance are financed from two main sources: the Law on Road Maintenance and Development Programme Financing of the Republic of Lithuania and funds of the European Union. Financing dynamics of roads of national significance 2008–2017 is illustrated in Figure 4.1.

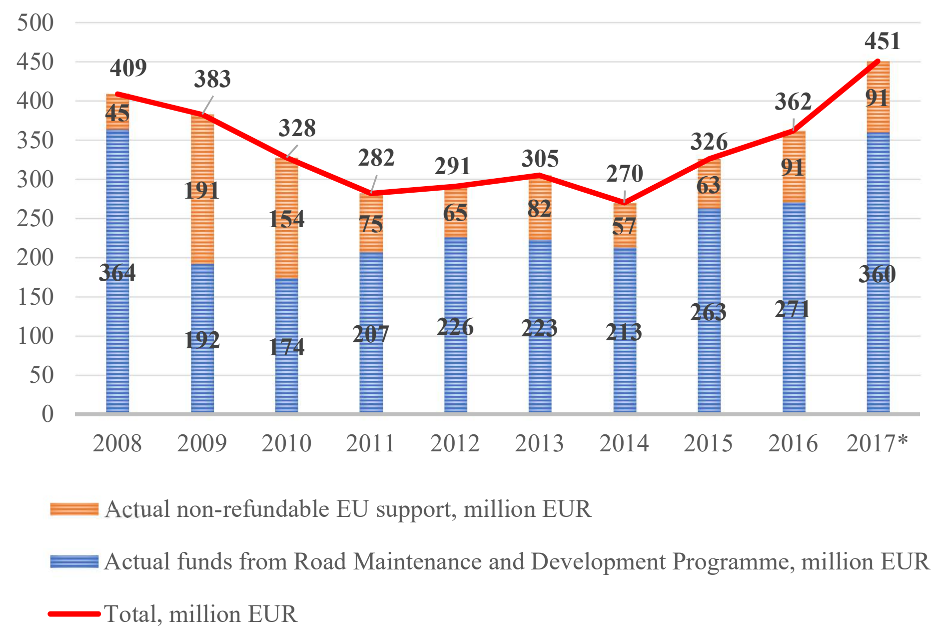


Figure 4.1 Financing dynamics of roads of national significance 2008–2017 (prepared by the author, based on LRA data)

From the data presented above, it can be seen that during the period of 2008–2013 financing for roads of national and local significance decreased 1.34 times – from 409 to 305 million Eur. This was mostly due to reduced funding from the Road Maintenance and Develoment Programme (KPPP) – from 364 to 223 million Eur. For the following 2014 year, the funding from KPPP was further reduced by 1.05 times – to 213 million Eur. Then the following year saw an increase in financing of roads of national and local significance. This was due to notable contributions from the European Union, from 57 million Eur to 31 million Eur, and funding from KPPP, from 213 million Eur to 360 million Eur. In 2017, as compared to 2014, the financing for roads of national and local significance increased by 67 percent, from 270 million Eur to 451 million Eur, while KPPP contributions increased by 69 percent. 2017, in comparison with 2008, saw a 10 percent increase in financing of roads of national and local significance, from 409 million Eur up to 451 million Eur. This was mainly due to the increased contributions from the European Union, from 45 million Eur to 91 million Eur.

A part of the funding is allocated to paving regional gravel roads. According to data available at the website of LAKD [14], about 270000 Eur is allocated to asphalt one kilometre of a gravel road. The average paving cost of Section One, which is 3.118 km long, is 841860 Eur, the cost of Section Two the length of which is 1.763 km is 476010 Eur, paving of Section Three with the length of 0.754 km cost 203580 Eur, the paving price of Section Four, which was 1.520 km long was 410400 Eur, and Section Five which was 3.035 km long cost 819450 Eur. In all the projects in question the whole road structure was planned to be replaced, but according to designing recommendations analysed above, and having changed only the cross section profile of the road, the final cost of the projects should change. There are two suggested cross profiles for low volume roads. The first one would be applied in settlements or on road segments between settlements with high pedestrian and bicycle traffic. The first suggested road cross section profile is presented in Figure 4.2.

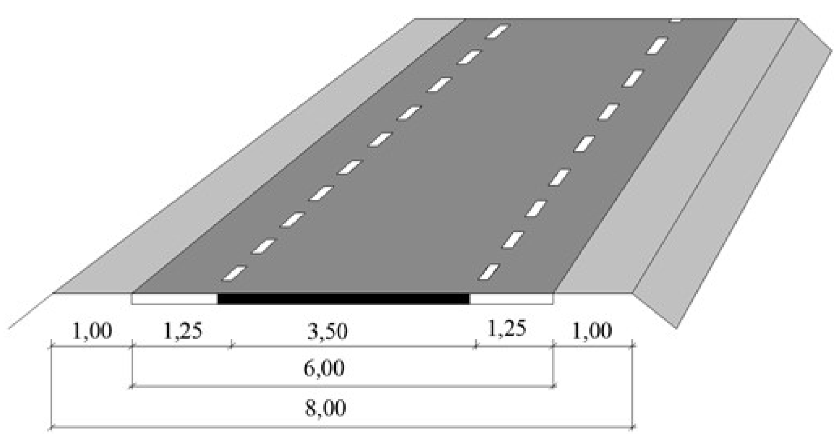


Figure 4.2 Suggested road cross section profile No 1 [30]

The suggested cross section profile ensures a sustainable mobility for all road users: drivers as well as pedestrians and cyclists. Mobility is assurance of smooth movement of road users. The cross section profile is chosen according to the values of cross section profiles applied for low volume roads in Germany. Such cross section profile is used in Germany for roads where traffic volume does not exceed 3000 vehicles per day, and the traffic of heavy vehicles is up to 150 vehicles per day. The road would have only one traffic lane. In Lithuania, regional low volume roads, where the traffic does not even reach 400 vehicles per day, would be designed to have two traffic lanes, and the carriageway would be 6.0 m wide. Applying such cross section profile in Lithuania would be economically viable, because there would be no necessity to construct additional paths for pedestrians and cyclists. Cross section profile is recommended when traffic volume is up to 400 cars per day, and up to 50 heavy vehicles per day. The traffic uses a lane the width of which is 3.5 m, and if it is necessary to pass, vehicles cross the narrow broken line and smoothly pass by. Priority is given to pedestrians and cyclists, which means that vehicles can not cross the broken line if at that moment this will interfere with the most vulnerable road users. Road outside lanes, which are 1.25 m wide each, are intended for pedestrian and bicycle traffic. Another road cross section profile is suggested for low volume regional roads outside settlements and there is no pedestrian or bicycle traffic. The cross section profile is given in Figure 4.3.

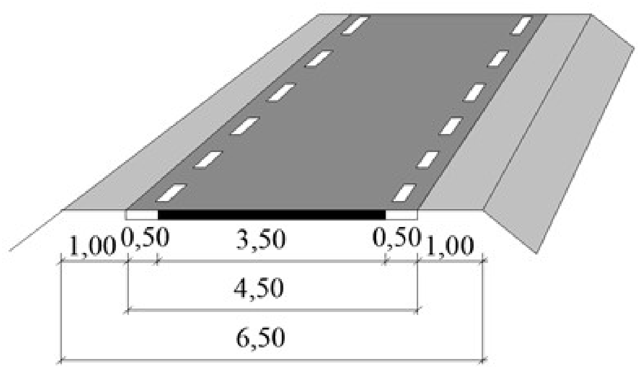


Figure 4.3. Suggested road cross section profile No 2 [30]

Such cross section profile is applied in Germany when traffic volumes are up to 1000 vehicles per day, and the volume of heavy vehicle traffic does not exceed 50 vehicles per day. Single lane is designed in the cross section profile, no separate traffic lanes in both directions are foreseen. In Lithuania such cross section profile could be applicable for low volume roads, where the traffic does not exceed 400 vehicles per day, and heavy vehicle traffic does not reach 50 vehicles per day. With this cross section profile the traffic uses one lane the width of which is 3.5 m. The outside lanes are designed to be 0.5 m wide each. The outside lanes are separated by narrow broken lines which are crossed only in case of passing a vehicle moving in front. To facilitate passing of heavy vehicles, the shoulders should be hard.

Considering the proposed recommendations and having applied the second road cross section profile for the gravel road paving projects under interest, the volumes of excavation works, road construction works, especially asphalt works would be reduced. Asphalt works are among the most expensive works in road construction, the preliminary price being 20 Eur for 1 m^2. In each of the gravel road paving projects, only because of the reduction of the volumes of asphalt works, the total project cost could be reduced by at least 11%. The reduction of excavation works, amounts of chipping and frost-resistant layer should also be taken into account. A summary of the results is presented in Table 4.1.

Table 4.1. Road alignment assessment results (prepared by the author)

No.	Road section, km	Section length, km	Average project price, EUR	Savings of asphalt, m^2	Asphalting costs, EUR	Savings of the total project cost
1.	0.005 – 3.123	3.118	841860	4677	93540	13-17%
2.	0.400 – 2.163	1.763	476010	2645	52900	11-15%
3.	24.140 – 24.894	0.754	203580	1131	22620	11-15%
4.	0.609 – 2.129	1.520	410400	2280	45600	11-15%
5.	0.715 – 3.750	3.035	819450	4553	91060	12-16%

The general objective of sustainable development and modernization of roads is to accommodate environmental, economical and social development aspects ensuring clean and healthy environment, effective use of natural resources, economic well-being of society, and reduction of social exclusion [17]. To achieve this objective innovations and non-standard designing solutions should be implemented which would substantially amend settled typical designing methods. During the research, it was established that using cross section profiles of new type would allow a more rational use of the resources allocated for road development and help preserving natural resources. New type road cross section profiles should be used in all newly designed low volume roads. The suggested cross section profiles are universal, since they are adaptable to all road users.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

1. Having analysed the documents regulating road design in Lithuania, it was found that the normative documents on road designing in force presently do not distinguish low volume roads. Roads are designed with regard to their category and significance, which are decisive factors for selecting all necessary designing parameters.

2. Having examined foreign literature sources, it was noticed that there are documents dedicated to the regulation of low volume roads design. All the sources analysed present many requirements related to the design of low volume roads, schemes for road design and cross section profiles. Road cross section profiles are rational, allow preserving natural resources and, based on mutual understanding, enable all road users using the road.

3. Having performed an analysis of the selected low volume gravel road reconstruction projects, it was found that each project contains non-compliances with designing requirements:

- Only in two sections under interest out of five the maximum allowable design speed was 70 km/h: on Section One the design speed was 50 km/h, on Section Two it was 50 km/h and 30 km/h, on Section Three it was 50 km/h, on Section Four it was 70 km/h, and on Section five the design speed was 70 km/h and 50 km/h. The speed is reduced by vertical road signs according to the values of horizontal curvatures;
- On Section One, Section Four, Section Five, 3, 1 and 8 horizontal curves, respectively, do not correspond to the minimal requirements even at a reduced speed. On Sections Two and Three the minimal values of horizontal curvatures are met;
- On Section One and Section Two the maximum allowable slope was exceeded. On Section Two, Section Three, Section Four and Section Five, the minimal longitudinal slope was not reached;
- Convex vertical curves do not meet the minimal reguirements: on Section One 5 curves, on Section Two 7 curves, and on Section Three 1 curve. Also, on Section One and Section Two, 3 and 6 concave vertical curves, respectively, are non-compliant with the minimal requirements;
- Traffic volume on all the sections analysed did not exceed the value of 200 vehicles/day.

4. During the analysis of the average annual daily traffic on regional roads of national importance it was established that the largest share is taken by the sections of regional

roads, where AADT is measured, with AADT of < 400 vehicles/day. The traffic volume on most regional roads is low. They account for 77% of the whole regional road network.

5. Having performed the analysis of carriageway width of regional roads, it was found that the majority of roads have carriageway widths of 4.5 m and 6 m. Regional roads with carriageway width of 4.5 m make 17% of all roads under interest, while those with carriageway width of 6 m account for 75%. Together they make 92% of the whole network of regional roads.

6. During the analysis of regional road width, it was established that the largest part is taken by the roads with the width of road of 7 and 8 meters. There are 27% of roads with road width of 7 m, while roads with road as wide as 8 m account for 64%. Together they make 91% of the whole network of regional roads.

7. Having analysed cost effectiveness, it was estimated that by setting the recommended cross section profile, savings on total project costs are possible: on Section One 13–17% could be saved, on Section Two 11–15% could be saved, on Section Three 11–15% could be saved, on Section Four 11–15% could be saved, and on Section Five 12–16% could be saved.

8. Having performed an overview of Lithuanian and foreign literature and having analysed the selected low volume road reconstruction projects, the following recommendations can be suggested:

- To amend the Road Technical Regulation so that roads were classified by the function instead of road significance. Functions would be attributed to all roads, according to which the roads would represent their functional purpose, and designing would be performed based on uniform parameters throughout the whole road;
- To include the concept of "a low volume road" into designing regulations and establish requirements for the designing of low volume roads.
- To observe recommendations and requirements for low volume road design refered to in the literature of the USA, Germany, and the Netherlands, while designing low volume roads;
- The maximum allowable speed on low volume roads should be 70 km/h independent of the type of road pavement, since the volume of traffic is low, thus, the driving time on low volume roads is short;

- A road should be considered a low volume road when the traffic on it does not reach 400 cars and 50 heavy vehicles per day. About 77% of the whole regional road network would be attributed to low volume roads;
- To supplement the Road Technical Regulation with the suggested road cross section profiles (Figures 4.2 and 4.3) and to include parameters of the suggested cross section profiles. The width of a traffic lane is 3.5 m, and the width of the carriageway is selected considering whether the road passes through a settlement or not. The width of the carriageway may be 6.0 m or 4.5 m;
- The shoulders of low volume roads should be 1.0 m wide, the maximum allowable longitudinal profile should be 8%, the cross slope should be 2.5%, the safety zone width should be set to up to 1.5 m, and vertical clearance should be 4.5 m.

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ANNEXES

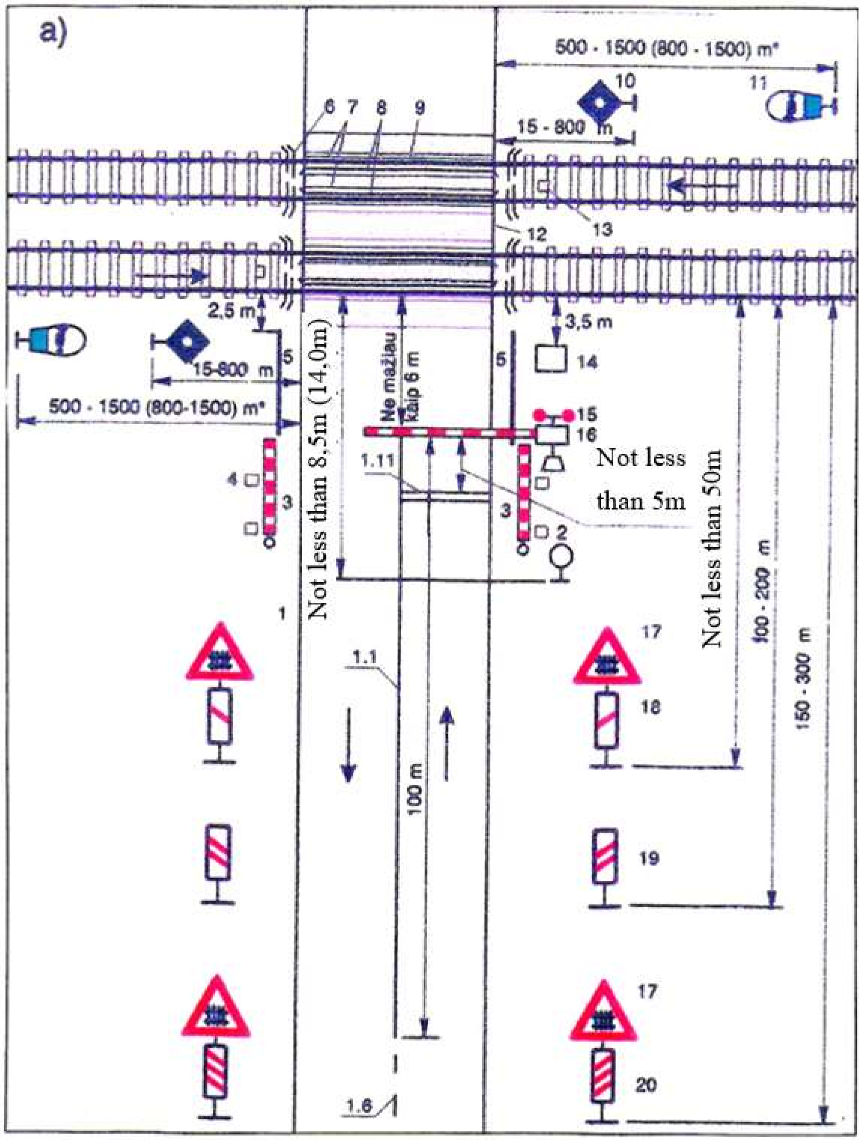
Annex 1. Railway level crossing construction schemes.

Annex 2. Data of the average annual daily traffic on regional roads of national significance of 2016.

Annex 3. Cross section profiles of road pavement structures.

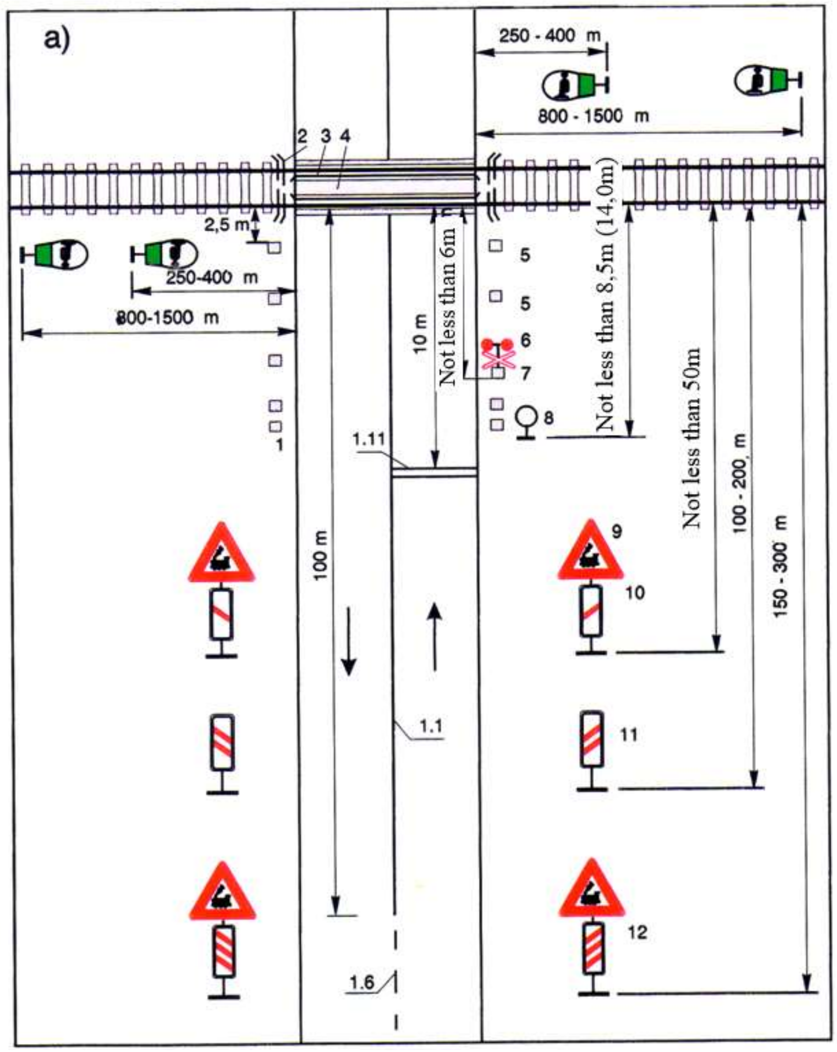
Annex 1.

Arrangement of level crossing with a barrier outside a settlement



1 – edge of road carriageway; 2 – road sign 316 "Verticle clearance restriction"; 3 – alternative manual barriers; 4 – posts; 5 – railings (gate); 6 – water drainage channels; 7 – wooden beams; 8 – check-rails; 9 – railway track rails; 10 – traffic signal; 11 – stationary whistle signal; 12 – crossing formwork.

Arrangement of level crossing without a barrier outside a settlement



1 – edge of road carriageway; 2 – water drainage channels; 3 – check-rails; 4 – crossing formwork; 5 – posts;

Annex 2. Data of the average annual daily traffic on regional roads of national significance of 2016.

where: BEI – total traffic volume, LA – passenger cars, LK – light commercial vehicles and minibuses, KA – trucks without trailers, KAP – trucks with trailers, KASP – trucks with semi-trailers, A – buses, MK – motorcycles and other vehicles not falling under the above classification.

Road No	Start, km	End, km	BEI	Metai	LA	LK	KA	KAP	KASP	A	MK
1001	0.000	4.308	673	2016	576	45	26	2	15	2	7
1001	4.308	9.430	257	2016	212	14	25	0	3	0	3
1001	9.430	11.555	159	2016	143	6	3	1	4	0	2
1002	0.000	4.486	56	2016	44	4	4	0	2	2	0
1002	4.486	13.075	361	2016	247	46	48	8	9	0	3
1002	13.075	14.172	401	2016	261	61	44	2	23	5	5
1002	14.172	14.844	1247	2016	930	142	102	13	30	16	14
1003	0.000	2.300	196	2016	152	10	23	4	3	3	1
1003	2.300	7.380	164	2016	110	31	13	0	8	0	2
1003	7.380	8.200	145	2016	115	18	11	0	0	0	1
1003	8.200	17.576	57	2016	44	6	4	2	1	0	0
1004	0.000	4.770	358	2016	300	27	22	0	2	4	3
1004	4.770	10.553	266	2016	205	31	22	0	5	0	3
1004	10.553	14.810	191	2016	119	46	24	0	1	0	1
1004	14.810	22.240	83	2016	54	16	9	0	2	1	1
1005	0.000	4.451	425	2016	342	31	43	0	4	0	5
1005	4.451	10.158	434	2016	341	39	44	0	5	0	5
1005	10.158	13.761	239	2016	204	15	11	2	3	1	3
1006	0.000	4.260	140	2016	115	8	7	2	2	4	2
1006	4.260	8.868	42	2016	42	0	0	0	0	0	0
1006	8.868	12.080	103	2016	81	14	7	0	0	0	1
1006	12.080	17.587	102	2016	70	19	9	1	2	0	1
1007	0.000	1.006	1136	2016	973	86	51	2	8	11	5
1007	1.006	3.830	1350	2016	1279	19	32	4	2	4	10
1007	3.830	9.331	1191	2016	1078	39	50	3	4	8	9
1008	0.000	3.500	248	2016	162	39	29	6	9	0	3
1008	3.500	8.467	108	2016	72	14	11	3	7	0	1
1009	0.000	2.484	263	2016	213	30	11	2	2	2	3
1009	2.484	9.924	172	2016	155	6	6	1	2	0	2
1009	9.924	12.419	140	2016	116	11	4	0	7	0	2
1010	0.000	6.280	93	2016	72	4	8	2	1	5	1
1011	0.000	1.800	771	2016	553	92	73	5	24	16	8
1011	1.800	3.460	332	2016	254	30	34	3	8	0	3
1011	3.460	6.470	190	2016	125	30	22	3	8	0	2
1011	6.470	14.192	40	2016	30	4	2	0	2	2	0
1012	0.000	5.738	96	2016	67	6	4	2	16	0	1
1013	0.000	2.860	396	2016	325	43	20	1	3	0	4
1013	2.860	7.375	82	2016	75	4	2	0	0	0	1
1014	0.000	0.918	598	2016	502	48	20	1	21	0	6
1014	0.918	3.942	313	2016	248	30	16	0	16	0	3
1014	3.942	8.283	80	2016	52	11	6	0	10	0	1
1015	0.000	1.250	220	2016	164	22	29	0	0	4	1
1015	1.250	6.227	21	2016	14	4	3	0	0	0	0
1015	6.227	15.221	35	2016	21	0	9	2	3	0	0
1015	15.221	15.932	17	2016	14	2	0	0	1	0	0
1016	0.000	3.023	205	2016	168	21	9	0	3	2	2
1017	0.000	1.330	72	2016	54	4	7	0	7	0	0
1017	1.330	5.558	12	2016	7	0	5	0	0	0	0
1018	0.000	1.200	186	2016	167	7	4	0	4	2	2
1018	1.200	11.261	59	2016	42	7	4	0	4	2	0
1018	11.261	16.676	64	2016	47	8	7	2	0	0	0
1018	16.676	20.959	280	2016	202	36	24	4	3	8	3
1019	0.000	1.060	138	2016	113	7	11	1	2	2	2
1019	1.060	4.630	57	2016	55	2	0	0	0	0	0
1019	4.630	10.019	34	2016	34	0	0	0	0	0	0
1020	0.000	2.050	121	2016	97	13	6	1	1	1	2
1020	2.050	7.250	76	2016	67	3	5	0	1	0	0
1020	7.250	10.702	24	2016	19	0	3	0	2	0	0
1021	0.000	0.700	47	2016	41	4	2	0	0	0	0
1021	0.700	2.701	15	2016	3	8	4	0	0	0	0
1022	0.000	3.290	57	2016	39	9	9	0	0	0	0
1022	3.290	3.828	76	2016	71	2	1	0	2	0	0

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1704	19.831	23.008	139	2016	90	20	11	8	7	2	1
1704	23.008	27.958	52	2016	38	0	9	2	2	1	0
1705	0.000	3.750	201	2016	168	4	20	3	2	3	1
1705	3.750	4.540	90	2016	80	6	3	1	0	0	0
1706	0.000	1.921	398	2016	293	56	31	2	7	7	2
1706	1.921	9.702	163	2016	126	21	10	2	3	0	1
1707	0.000	2.820	294	2016	242	15	11	6	9	10	1
1707	2.820	14.330	250	2016	196	21	12	6	9	5	1
1707	14.330	18.234	178	2016	73	54	31	8	5	6	1
1708	0.000	9.886	78	2016	41	17	12	0	0	8	0
1708	9.886	14.040	173	2016	156	7	8	0	0	0	2
1708	14.040	16.528	412	2016	255	95	55	0	3	2	2
1708	16.528	18.921	116	2016	55	30	17	2	8	3	1
1709	0.000	4.520	245	2016	149	51	31	0	6	7	1
1709	4.520	5.701	104	2016	81	4	13	2	2	2	0
1709	5.701	9.074	114	2016	90	4	14	2	1	2	1
1709	9.074	10.045	92	2016	62	13	9	0	6	2	0
1709	10.045	20.048	135	2016	103	17	9	0	5	0	1
1709	20.048	26.985	159	2016	135	6	9	4	3	1	1
1709	26.985	28.293	258	2016	228	3	17	4	3	2	1
1709	28.293	29.390	280	2016	233	10	23	3	4	3	4
1710	0.000	4.840	75	2016	71	2	2	0	0	0	0
1710	4.840	11.629	84	2016	76	5	2	0	0	0	1
1711	0.000	4.584	142	2016	95	14	22	0	7	2	2
1712	0.000	4.137	87	2016	60	13	10	0	1	3	0
1712	4.137	7.508	72	2016	36	19	12	0	0	5	0
1713	0.000	4.149	106	2016	86	8	4	0	5	2	1
1714	0.000	7.357	190	2016	153	16	6	0	11	2	2
1715	0.000	1.950	50	2016	41	3	6	0	0	0	0
1715	1.950	5.390	57	2016	53	4	0	0	0	0	0
1715	5.390	7.595	36	2016	29	7	0	0	0	0	0
1716	0.000	3.780	102	2016	93	1	5	1	0	1	1
1716	3.780	8.611	75	2016	57	11	7	0	0	0	0
1717	0.000	9.238	113	2016	89	9	5	9	1	0	0
1718	0.000	6.753	105	2016	69	16	14	0	3	2	1
1719	0.000	5.780	450	2016	275	93	55	2	2	21	2
1719	5.780	7.079	168	2016	142	4	17	1	1	2	1
1720	0.000	4.135	41	2016	38	2	0	0	1	0	0
1722	0.000	3.150	536	2016	467	38	24	0	1	4	2
1722	3.150	6.184	123	2016	105	8	7	0	0	2	1
1723	0.000	1.639	159	2016	129	4	18	2	2	3	1
1724	0.000	1.500	315	2016	255	36	15	0	4	2	3
1724	1.500	2.365	424	2016	333	52	24	0	6	4	5
1725	0.000	0.820	565	2016	462	51	35	5	5	5	2
1725	0.820	1.765	346	2016	306	18	17	0	4	0	1
1725	1.765	2.299	118	2016	108	5	3	1	0	0	1
1727	0.000	0.879	376	2016	331	16	25	0	1	0	3
1727	0.879	1.770	288	2016	220	32	22	1	10	0	3
1730	0.000	4.600	129	2016	120	2	2	2	1	0	2
1730	4.600	6.984	53	2016	47	4	2	0	0	0	0
1731	0.000	3.185	88	2016	76	6	3	1	1	0	1
1801	0.000	10.378	1050	2016	965	20	41	5	7	5	7
1801	10.378	14.506	585	2016	368	88	57	23	22	25	2
1801	14.506	19.394	439	2016	308	55	35	14	18	7	2
1802	0.000	2.510	338	2016	296	10	21	2	2	3	4
1802	2.510	4.750	195	2016	166	7	16	1	1	2	2
1802	4.750	9.070	112	2016	97	2	9	1	1	1	1
1802	9.070	13.760	159	2016	139	2	14	1	0	2	1
1802	13.760	17.718	64	2016	60	4	0	0	0	0	0
1803	0.000	1.996	1199	2016	1012	60	81	7	8	11	20
1803	1.996	11.182	690	2016	566	40	70	0	3	4	7
1804	0.000	3.080	1963	2016	1686	138	106	4	17	10	2
1804	3.080	5.937	1456	2016	1053	202	128	8	33	26	6
1806	0.000	3.326	2090	2016	1897	67	82	8	15	8	13
1806	3.326	13.307	1067	2016	950	30	56	6	9	7	9
1807	0.000	2.740	2295	2016	1975	143	98	8	51	10	10
1807	2.740	4.520	1931	2016	1649	67	77	0	120	10	8
1807	4.520	7.861	1972	2016	1326	117	367	65	44	50	3
1808	0.000	3.330	827	2016	751	41	23	0	6	3	3
1808	3.330	6.167	1524	2016	1383	74	39	0	15	7	6
…	….	….	….	….	…	...	……..	….	….	….	…
4418	0.000	1.023	537	2016	238	172	105	0	2	14	6
4418	1.023	2.266	259	2016	130	76	46	0	0	4	3
4419	0.000	1.159	139	2016	121	11	5	0	1	0	1

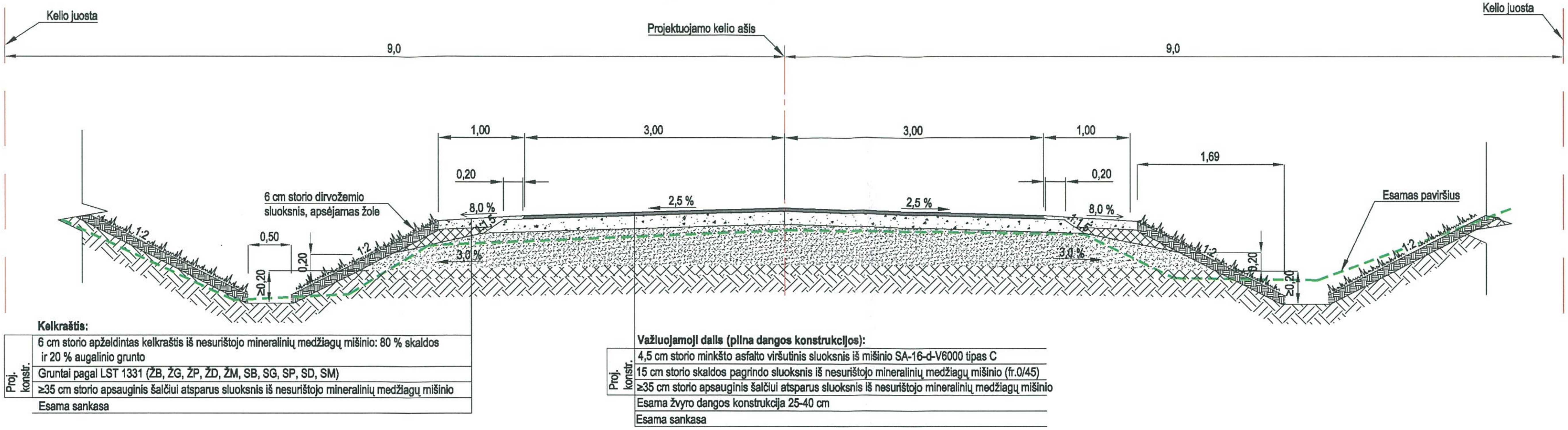
4420	0.000	2.533	25	2016	24	0	0	0	1	0	0
4421	0.000	1.243	263	2016	220	24	10	0	8	0	1
4422	0.000	2.222	310	2016	274	14	9	2	4	6	1
4423	0.000	2.576	126	2016	88	6	21	2	3	3	3
4423	2.576	4.551	309	2016	272	9	19	1	1	3	4
4424	0.000	1.240	349	2016	199	83	48	1	1	14	3
4425	0.000	3.600	72	2016	58	8	4	0	0	2	0
4426	0.000	1.232	21	2016	20	0	0	0	1	0	0
4427	0.000	9.109	118	2016	108	7	2	0	0	0	1
4427	9.109	12.125	88	2016	74	6	7	0	0	0	1
4428	0.000	0.951	197	2016	173	11	7	0	4	0	2
4428	0.951	2.000	68	2016	61	2	1	0	0	4	0
4428	2.000	5.789	33	2016	28	2	2	0	1	0	0
4428	5.789	7.497	71	2016	49	13	6	1	2	0	0
4428	7.497	11.888	29	2016	20	2	2	0	5	0	0
4428	11.888	20.510	69	2016	64	2	0	0	3	0	0
4428	20.510	21.166	190	2016	170	10	5	1	2	0	2
4428	21.166	23.939	207	2016	186	11	4	0	4	0	2
4429	0.000	3.492	61	2016	53	6	2	0	0	0	0
4429	3.492	6.300	64	2016	58	4	2	0	0	0	0
4429	6.300	8.820	30	2016	26	0	4	0	0	0	0
4429	8.820	13.749	73	2016	65	2	4	1	1	0	0
4501	0.000	5.685	1290	2016	1101	89	69	5	18	6	2
4501	5.685	9.140	893	2016	758	29	64	20	13	8	1
4501	9.140	10.563	530	2016	397	65	39	10	7	10	2
4501	10.563	12.356	502	2016	360	65	38	5	16	16	2
4501	12.356	13.568	430	2016	317	57	31	10	6	7	2
4501	13.568	15.077	400	2016	302	47	26	5	10	8	2
4501	15.077	18.041	485	2016	366	58	36	10	6	7	2
4501	18.041	19.488	458	2016	350	45	27	10	9	15	2
4501	19.488	25.075	498	2016	357	65	42	6	19	7	2
4501	25.075	26.625	812	2016	709	22	45	6	9	6	15
4501	26.625	27.531	293	2016	207	41	24	2	9	9	1
4501	27.531	30.523	235	2016	166	29	18	5	9	7	1
4501	30.523	32.587	150	2016	108	22	15	0	2	2	1
4501	32.587	34.629	258	2016	214	16	8	0	15	4	1
4501	34.629	41.038	360	2016	310	20	8	0	18	2	2
4501	41.038	47.212	480	2016	394	35	16	0	31	2	2
4502	0.000	5.895	409	2016	345	29	24	2	7	2	0
4502	5.895	8.620	360	2016	282	23	38	2	8	4	3
4502	8.620	14.330	272	2016	238	6	17	3	4	2	2
4502	14.330	26.996	160	2016	92	30	33	0	1	3	1
4502	26.996	29.657	298	2016	243	23	16	2	5	6	3
4502	29.657	35.044	1026	2016	921	28	51	4	5	8	9
4504	0.000	3.734	793	2016	640	76	49	6	13	6	3
4504	3.734	15.546	438	2016	315	64	39	4	8	6	2
4504	15.546	19.170	510	2016	419	42	28	2	9	3	7
4504	19.170	27.081	848	2016	785	16	31	2	3	5	6
4504	27.081	27.396	1438	2016	1219	112	58	3	15	15	16
4505	0.000	2.489	9038	2016	7596	750	442	17	171	45	17
4505	2.489	5.395	1883	2016	1131	390	215	35	52	29	31
4505	5.395	5.949	1023	2016	842	73	58	3	23	14	10
4505	5.949	14.381	214	2016	186	14	4	0	8	0	2
4506	0.000	5.637	534	2016	438	51	36	4	0	3	2
4506	5.637	8.488	75	2016	66	6	3	0	0	0	0
4507	0.000	2.316	1236	2016	940	68	50	0	152	21	5
4507	2.316	6.899	1356	2016	1022	40	109	99	67	15	4
4507	7.073	8.297	1235	2016	1149	49	22	0	0	10	5
4507	8.297	10.569	910	2016	846	30	19	0	0	11	4
4508	0.000	1.928	126	2016	85	19	16	2	3	0	1
4508	1.928	7.531	98	2016	77	7	10	1	1	1	1
4509	0.000	5.728	691	2016	600	42	30	4	13	2	0
4509	5.728	6.878	214	2016	172	4	21	8	5	3	1
4509	6.878	8.472	150	2016	118	11	14	3	1	2	1
4509	8.472	18.108	99	2016	75	13	10	0	1	0	0
4510	0.000	6.192	49	2016	36	2	6	2	2	1	0
4510	6.192	11.133	65	2016	49	4	7	2	2	1	0
4511	0.000	3.988	187	2016	145	14	21	2	3	0	2
4512	0.000	4.027	619	2016	463	55	68	9	14	4	6
4512	4.027	6.428	454	2016	388	34	20	0	0	7	5
4512	6.428	9.956	222	2016	184	19	17	0	0	0	2
4512	9.956	12.443	306	2016	268	16	14	2	3	0	3
4513	0.000	4.959	208	2016	186	2	14	2	1	2	1
4513	4.959	11.536	125	2016	95	4	18	3	2	2	1
4513	11.536	24.433	140	2016	115	9	6	2	6	0	2

5251	0,000	2.810	902	2016	716	111	58	4	1	8	4
5252	0.000	0.840	306	2016	269	21	10	0	1	2	3
5253	0.000	2.695	14	2016	12	2	0	0	0	0	0
5254	0.000	1.072	531	2016	419	60	37	6	0	7	2
5255	0.000	1.282	245	2016	218	13	10	2	1	0	1
5256	0.000	0.567	809	2016	628	97	69	1	2	4	8
5256	0.567	2.478	217	2016	160	26	28	0	1	0	2
5257	0.000	1.010	46	2016	42	2	0	0	0	2	0
5257	1.010	3.614	42	2016	42	0	0	0	0	0	0
5257	3.614	4.471	35	2016	35	0	0	0	0	0	0
5258	0.000	1.923	8	2016	6	2	0	0	0	0	0
5258	1.923	10.479	305	2016	216	49	25	14	0	0	1
5258	10.479	14.687	191	2016	156	20	9	0	3	2	1
5258	14.687	22.222	704	2016	613	49	31	2	4	2	3
5259	0.000	2.830	894	2016	778	43	48	4	6	7	8
5259	2.830	4.410	1258	2016	1047	104	79	6	7	10	5
5259	4.410	5.862	276	2016	245	9	15	1	1	2	3
5259	5.862	10.090	144	2016	125	6	10	1	0	1	1
5259	10.090	12.050	216	2016	190	18	7	0	0	0	1
5303	0.000	14.205	344	2016	198	80	49	2	6	8	1
5303	14.205	18.023	151	2016	101	18	19	5	7	0	1
5303	18.023	22.009	125	2016	72	6	32	7	4	4	0
5304	0.000	10.121	181	2016	157	16	6	0	0	0	2
5305	0.000	4.646	661	2016	588	39	27	1	4	2	0
5305	4.646	14.652	235	2016	204	17	8	0	3	2	1
5305	14.652	19.502	151	2016	98	32	17	0	1	2	1
5305	19.502	28.285	156	2016	111	26	14	0	4	0	1
5306	0.000	7.444	279	2016	234	22	14	0	5	3	1
5306	7.444	15.430	103	2016	83	6	14	0	0	0	0
5306	15.430	23.072	79	2016	48	14	17	0	0	0	0
5307	0.000	4.533	37	2016	33	2	2	0	0	0	0
5308	0.000	9.445	415	2016	345	34	21	2	5	6	2
5308	9.445	15.821	19	2016	19	0	0	0	0	0	0
5308	15.821	17.065	55	2016	49	4	2	0	0	0	0
5309	0.000	2.672	82	2016	64	10	6	1	0	0	1
5309	2.672	8.382	32	2016	32	0	0	0	0	0	0
5309	8.382	10.360	38	2016	36	2	0	0	0	0	0
5309	10.360	14.393	49	2016	47	2	0	0	0	0	0
5309	14.393	17.746	34	2016	31	2	1	0	0	0	0
5309	17.746	20.242	53	2016	51	2	0	0	0	0	0
5309	20.242	31.866	7	2016	7	0	0	0	0	0	0
5309	31.866	34.339	32	2016	24	4	2	0	2	0	0
5309	34.339	35.510	153	2016	148	2	0	0	0	0	3
5310	0.000	1.938	1667	2016	1334	264	57	0	0	1	11
5310	1.938	7.602	147	2016	134	6	5	0	0	0	2
5310	7.602	23.763	162	2016	94	41	23	0	0	2	2
5310	23.763	33.582	942	2016	725	138	72	0	0	3	4
5311	0.000	4.020	26	2016	26	0	0	0	0	0	0
5311	4.020	6.071	94	2016	85	6	2	0	0	0	1
5312	0.000	4.298	318	2016	262	34	17	0	0	2	3
5312	4.298	10.100	327	2016	192	82	45	1	1	3	3
5313	0.000	5.027	167	2016	56	25	45	16	19	4	2
5314	0.000	2.548	67	2016	55	7	4	0	1	0	0
5314	2.548	8.048	28	2016	22	4	2	0	0	0	0
5314	8.048	10.403	21	2016	14	5	2	0	0	0	0
5315	0.000	1.181	1060	2016	745	110	153	25	16	0	11
5315	1.181	11.221	231	2016	125	46	32	0	11	14	3
5315	11.221	14.706	137	2016	103	21	9	0	2	0	2
5315	14.706	15.850	84	2016	71	8	4	0	0	0	1
5316	0.000	6.194	78	2016	63	4	8	1	1	1	0
5316	6.194	7.917	103	2016	84	9	6	0	1	3	0
5317	0.000	5.358	143	2016	120	9	6	0	2	5	1
5317	5.358	9.020	14	2016	8	4	2	0	0	0	0
5318	0.000	2.249	98	2016	85	2	1	0	7	2	1
5319	0.000	0.861	249	2016	212	21	8	0	3	2	3
5319	0.861	1.997	17	2016	11	4	2	0	0	0	0
5320	0.000	1.975	28	2016	20	6	2	0	0	0	0
5322	0.000	5.142	24	2016	24	0	0	0	0	0	0
5323	0.000	3.584	400	2016	356	17	9	0	6	10	2
5323	3.584	5.779	64	2016	51	9	4	0	0	0	0
5323	5.779	7.848	77	2016	67	7	3	0	0	0	0
5323	7.848	11.166	40	2016	27	9	4	0	0	0	0
5323	11.166	14.613	61	2016	49	8	4	0	0	0	0
5323	14.613	16.827	96	2016	79	6	7	1	1	1	1
5324	0.000	1.179	225	2016	209	6	4	0	3	2	1

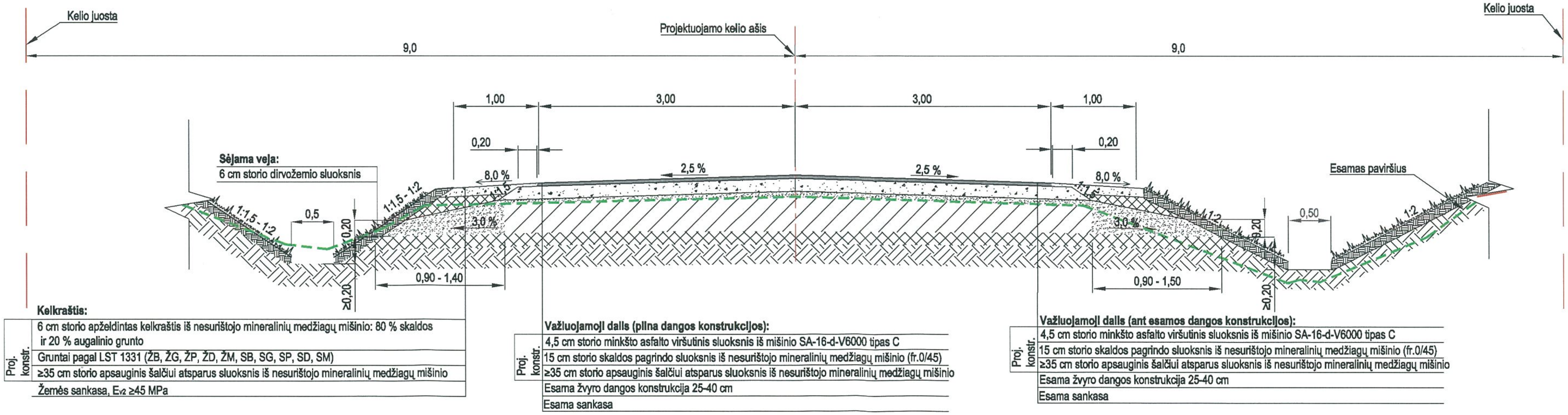
5324	1.179	4.391	69	2016	63	4	0	0	0	2	0
5324	4.391	6.770	49	2016	47	2	0	0	0	0	0
5325	0.000	2.364	32	2016	25	5	2	0	0	0	0
5325	2.364	6.632	32	2016	26	4	2	0	0	0	0
5325	6.632	8.566	36	2016	30	4	2	0	0	0	0
5326	0.000	2.825	147	2016	132	9	4	0	0	0	2
5328	0.000	0.521	55	2016	42	7	4	0	2	0	0
5328	0.521	1.347	83	2016	79	2	1	0	1	0	0
5328	1.347	1.966	20	2016	20	0	0	0	0	0	0
5329	0.000	3.043	34	2016	20	9	5	0	0	0	0
5331	0.000	0.851	128	2016	107	9	5	0	6	0	1
5334	0.000	0.586	209	2016	158	31	16	0	3	0	1
5335	0.000	1.141	371	2016	299	38	19	0	11	2	2
5336	0.000	0.722	133	2016	112	7	5	0	2	6	1
5336	0.722	0.942	52	2016	36	4	4	0	0	8	0
5338	0.000	3.587	75	2016	58	9	4	0	4	0	0
5338	3.587	6.014	80	2016	51	7	19	1	1	0	1
5344	0.000	0.852	85	2016	70	9	5	0	1	0	0
5345	0.000	3.117	44	2016	36	2	2	2	0	2	0
5345	3.117	4.696	66	2016	51	7	6	0	0	2	0
5346	0.000	3.854	21	2016	21	0	0	0	0	0	0
5346	3.854	7.420	29	2016	29	0	0	0	0	0	0
5347	0.000	4.240	57	2016	44	7	4	0	2	0	0
5348	0.000	2.251	1983	2016	1714	154	86	8	10	3	8
5349	0.000	2.109	2398	2016	2009	188	107	7	54	23	10

Detailed information about the average annual daily volume on regional roads of national significance is available on the website of Lithuanina Road Administration under the Ministry of Transport and Communications [14].

Kelio dangos konstrukcijos skersinis profilis Nr. 1



Kelio dangos konstrukcijos skersinis profilis Nr. 2

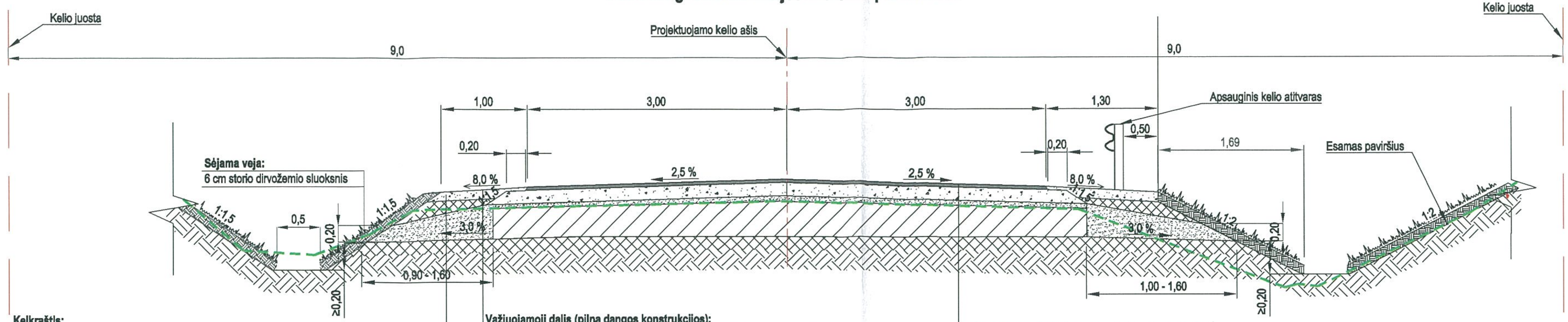


Dangos konstrukcijos skersinių profilių pritaikymo lentelė

Projektiniai Pk +		*Ruožo ilgis, m*	*Tipas*
Nuo	*Iki*		
241+40	241+80	40	1
241+80	247+60	580	2
247+60	248+08	48	3
248+08	248+80	72	4
248+80	248+94	14	1

Pastabos:
1. Matmenys pateikti metrais.
2. Griovio įrengimo vietas žiūrėti Dangų, eismo organizavimo ir nužymėjimo plano brėžinyje UL16-77-TDP-S-BR2
3. Apsauginis šalčiui atsparus sluoksnis įrengiamas permalant jį su esamu pagrindu (bendras storis ≥ 35 cm).

Kelio dangos konstrukcijos skersinis profilis Nr. 3



Kelkraštis:

Proj. konstr.	
	6 cm storio apželdintas kelkraštis iš nesurištojo mineralinių medžiagų mišinio: 80 % skaldos ir 20 % augalinio grunto
	Gruntai pagal LST 1331 (ŽB, ŽG, ŽP, ŽD, ŽM, SB, SG, SP, SD, SM)
	≥35 cm storio apsauginis šalčiui atsparus sluoksnis iš nesurištojo mineralinių medžiagų mišinio
	Žemės sankasa, E_{v2} ≥45 MPa

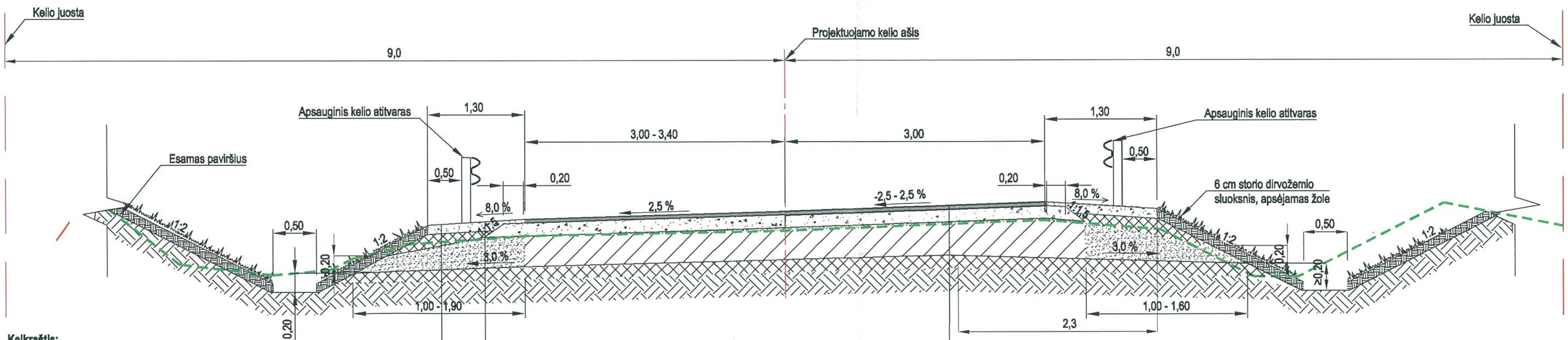
Važiuojamoji dalis (pilna dangos konstrukcijos):

Proj. konstr.	
	4,5 cm storio minkšto asfalto viršutinis sluoksnis iš mišinio SA-16-d-V6000 tipas C
	15 cm storio skaldos pagrindo sluoksnis iš nesurištojo mineralinių medžiagų mišinio (fr.0/45)
	≥35 cm storio apsauginis šalčiui atsparus sluoksnis iš nesurištojo mineralinių medžiagų mišinio
	Esama žvyro dangos konstrukcija 25-40 cm
	Esama sankasa

Važiuojamoji dalis (ant esamos dangos konstrukcijos):

Proj. konstr.	
	4,5 cm storio minkšto asfalto viršutinis sluoksnis iš mišinio SA-16-d-V6000 tipas C
	15 cm storio skaldos pagrindo sluoksnis iš nesurištojo mineralinių medžiagų mišinio (fr.0/45)
	≥35 cm storio apsauginis šalčiui atsparus sluoksnis iš nesurištojo mineralinių medžiagų mišinio
	Esama žvyro dangos konstrukcija 25-40 cm
	Esama sankasa

Kelio dangos konstrukcijos skersinis profilis Nr. 4



Kelkraštis:

Proj. konstr.	
	6 cm storio apželdintas kelkraštis iš nesurištojo mineralinių medžiagų mišinio: 80 % skaldos ir 20 % augalinio grunto
	Gruntai pagal LST 1331 (ŽB, ŽG, ŽP, ŽD, ŽM, SB, SG, SP, SD, SM)
	≥35 cm storio apsauginis šalčiui atsparus sluoksnis iš nesurištojo mineralinių medžiagų mišinio
	Žemės sankasa, E_{v2} ≥45 MPa

Važiuojamoji dalis (pilna dangos konstrukcijos):

Proj. konstr.	
	4,5 cm storio minkšto asfalto viršutinis sluoksnis iš mišinio SA-16-d-V6000 tipas C
	15 cm storio skaldos pagrindo sluoksnis iš nesurištojo mineralinių medžiagų mišinio (fr.0/45)
	≥35 cm storio apsauginis šalčiui atsparus sluoksnis iš nesurištojo mineralinių medžiagų mišinio
	Esama žvyro dangos konstrukcija 25-40 cm
	Esama sankasa

Važiuojamoji dalis (ant esamos dangos konstrukcijos):

Proj. konstr.	
	4,5 cm storio minkšto asfalto viršutinis sluoksnis iš mišinio SA-16-d-V6000 tipas C
	15 cm storio skaldos pagrindo sluoksnis iš nesurištojo mineralinių medžiagų mišinio (fr.0/45)
	≥35 cm storio apsauginis šalčiui atsparus sluoksnis iš nesurištojo mineralinių medžiagų mišinio
	Esama žvyro dangos konstrukcija 25-40 cm
	Esama sankasa

Dangos konstrukcijos skersinių profilių pritaikymo lentelė

Projektiniai Pk +		*Ruožo ilgis, m*	*Tipas*
Nuo	*Iki*		
241+40	241+80	40	1
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Pastabos:

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3. Apsauginis šalčiui atsparus sluoksnis įrengiamas permalant jį su esamu pagrindu (bendras storis ≥ 35 cm).