



Vilimas GINTALAS

POSSIBILITIES FOR THE IMPROVEMENT
OF THE QUALITY OF DESIGN SOLUTIONS
IN THE GRAVEL ROAD
RECONSTRUCTION PROJECTS

SUMMARY OF DOCTORAL DISSERTATION

TECHNOLOGICAL SCIENCES,
CIVIL ENGINEERING (02T)



LEIDYKLA
Vilnius TECHNİKA 2010

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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Introduction

Formulation of the problem. Despite large investments in the development of the road network of national significance and the improvement of traffic safety, the number of accidents on the roads of the Republic of Lithuania in the last years remained one of the largest in the European Union. This allows us to make an assumption that not all the improvements of the road network are sufficiently effective, including design solutions of the road reconstruction projects. A great concern is caused by the design solutions in the gravel road reconstruction projects which could be unsuitable in terms of traffic safety, since it is common practice in Lithuania to design the planned road axis of the gravel road to be reconstructed with the minimum deviation from the existing road axis. The main motivation for this gravel road reconstruction practice is to reduce the cost of reconstruction works at the expense of taking of land for the planned right-of-way. Another important reason for making the currently used practice of the reconstruction of lower-category roads, including gravel roads, is the liberal road design standards of the Republic of Lithuania allowing to rather freely interpret observance of their requirements.

Topicality of the work. Motivation for the gravel road reconstruction practice used in Lithuania in the last ten years can possibly be insufficiently justified. Besides, in the road design standards of the Republic of Lithuania the main requirements for the solutions of road alignment had been essentially changing, therefore, the current design standards can contain certain inaccuracies which must be corrected. Also, it is necessary to supplement the road design standards with the new requirements ensuring the solutions of a smooth and safe road alignment.

The object of research. The object of research – regularities for the design of road alignment, design solutions in the gravel road reconstruction projects and their links with the requirements of road design standards.

Aim and tasks of the work. The aim of this work – to determine regularities for the design of road alignment, their links with the requirements of road design standards and to suggest the methods for improving the quality of design solutions.

The following tasks were solved to achieve the aim of the work:

1. To make analysis of the requirements of road design standards regulating the solutions of road alignment and to give suggestions for the improvement of these regulations.
2. To evaluate the quality of the existing road alignment and the volume of possible correction of horizontal and vertical alignment of the gravel road sections to be reconstructed.

3. To carry out investigations of accident rate of the reconstructed gravel road sections by comparing the accident rate before and after reconstruction.
4. To determine the quality of design solutions of road alignment in the gravel road reconstruction projects.
5. To identify the volume of taking of land for the right-of-way in case if the gravel road reconstruction projects had been prepared according to the requirements of design standards.
6. To evaluate if the current practice in Lithuania when reconstructing gravel roads to use the least deviation from the existing road axis is justified.

Methodology of research. In order to determine possible inaccuracies in the requirements of road design standards of the Republic of Lithuania regulating the solutions of road alignment and to give suggestions for correcting and supplementing these requirements the method of comparative analysis was used for the investigations of this work. Three experimental investigations were carried out using methodology developed during the preparation of this work, i.e.:

- for the investigation of horizontal alignment of gravel roads;
- for the investigation of vertical alignment of gravel roads;
- for the prediction of the volume of taking of land for public needs.

Statistical methods were used for the investigations of the accident rate of gravel roads before and after reconstruction. For experimental investigations to define the quality of design solutions in the gravel road reconstruction projects the methodology of traffic safety criteria was applied.

Scientific novelty. The following results new to the science of civil engineering were obtained in the course of preparation of the dissertation:

- a new design methodology adjusted to the improvement of requirements of road design standards regulating the solutions of road alignment and to the improvement of the quality of design solutions in the road reconstruction projects, intended for studying road alignment as a succession of interrelated elements;
- geometrical parameters of the existing alignment of gravel roads in the road network of national significance of the Republic of Lithuania;
- determination of the quality of design solutions of road alignment in the gravel road reconstruction projects;
- changes in the accident rate of gravel roads before and after reconstruction.

Practical value. The practical application of the results of investigations carried out within the framework of this work would enable to improve the

quality of design solutions when preparing reconstruction projects for the low-category rural roads:

- road design standards of the Republic of Lithuania would be improved and would ensure design solutions for a geometrically smooth and safe road alignment;
- the use of methodology of traffic safety criteria would enable to identify and eliminate the potentially dangerous road sections early in the stage of their design.

Defended propositions

1. It is necessary to improve the requirements of road design standards of the Republic of Lithuania based on regularities for the design of road alignment and the quality of design solutions in the road reconstruction projects.
2. When preparing the gravel road reconstruction projects a possibility of deviation from the existing road axis shall not be restricted.

Approval of the results of work

6 scientific articles have been published on the topic of the dissertation: 3 in the reviewed scientific periodical publications and 3 in the other editions. Results of investigations, carried out within the framework of this dissertation, were presented and discussed in 3 scientific conferences in Lithuania and other countries.

The scope of the scientific work. The scientific work consists of the general characteristic of the dissertation, five chapters, conclusions, the list of literature, the list of publications and addenda. The total scope of the dissertation – 107 pages, 51 picture, 18 tables and 6 addenda.

1. Gravel road network and its development in the Republic of Lithuania and analysis of its development

A large part of the road network of national significance of Lithuania is still made of gravel roads. In 1998 the Gravel Roads Paving Programme was started to be implemented the main objectives of which is to increase the density of road network with the improved pavement and to eliminate the current disproportions in the development of road network. During implementation of the Gravel Roads Paving Programme in 1998–2009 the part of gravel roads in the road network of national significance was decreased from 49.1% to 35.9%, and until the year 2015 it is aimed to decrease this part to 30%.

However, the practice of implementing the Gravel Roads Paving Programme revealed serious deficiencies, the most important of which – hastiness in the programme implementation having the aim that the period from the be-

ginning of design works to the end of reconstruction works would last no more than 1–2 years. Such a short period of time is possible in those cases when the alignment of the existing gravel road is not being corrected or the correction of alignment is restricted by the requirement that the planned roadbed would go into the existing right-of-way. Such design solutions of road alignment are supposed to be acceptable in the gravel road reconstruction projects and this became a common practice of implementing the Gravel Roads Paving Programme. This practice of laying the improved pavement on gravel roads is not applied in the neighbouring Baltic countries.

The reasoning and consequences of the current practice of implementing the Gravel Roads Paving Programme has not been objectively determined yet. Since accident indices in Lithuania remain one of the worst in the European Union the assurance of road traffic safety is one of the most important tasks of present-day. Therefore, it is very important to avoid the worsening of traffic conditions in the reconstructed gravel roads.

2. Analysis of the road design standards of the Republic of Lithuania and foreign countries

The aim of investigation – to compare the requirements of road design standards regulating the solutions of road alignment of various countries, to determine possible inaccuracies in the design standards of the Republic of Lithuania and to give recommendations for the correction of inaccuracies determined and for the improvement of design standards.

It was determined during the comparison of requirements of road design standards of the Republic of Lithuania and other countries that some requirements for the solutions of road alignment in Lithuania are significantly different from the analogical requirements in the design standards of other countries:

- only two speeds are determined for design needs – design speed V_p and permissible speed V_L ;
- there is no concept of the 85th-percentile speed V_{85} characterizing a real driving speed of vehicles;
- no indication is given on the methodology based on which the design speed V_p is determined;
- the minimum radii of horizontal and vertical curves are obviously different from the average used in other countries.

The minimum radii of horizontal curves defined in the current road design standards of the Republic of Lithuania are higher than those defined in the standards of other countries, whereas, the radii of humps are apparently lower. The least deviation from the average of foreign countries is represented by the

radii of transverse depressions. Therefore, there are some doubts if the radii of horizontal and vertical curves in the current road design standards of the Republic of Lithuania are properly justified.

The radii of horizontal and vertical curves were checked by the formulas presented in the literature sources, making an assumption that pavement properties in Lithuania correspond to the average of West European countries and USA – the values of tangential friction factor f_T and side friction factor f_R used in the formulas were calculated by overall regression equations that were made during the investigations carried out in the above mentioned countries.

It was determined that in the road design standards of the Republic of Lithuania:

- the values of the radii of horizontal curves are set with a large reserve, and this reserve is unjustified;
- the values of the radii of vertical curves are inconsistent with the visibility requirements and, in contrast to the horizontal curves, are too low or having no reserve.

When preparing road construction or reconstruction projects it is very important to not only properly design separate elements of road alignment but also to properly combine them in-between. In order to ensure the solutions of smooth and safe road alignment the following requirements are given in the road design standards:

- for the compatibility of the radii of adjacent horizontal curves;
- for the compatibility of the radii of horizontal curves and the lengths of tangents between the curves;
- for a geometrical smoothness of the whole road alignment.

To properly select the radii of adjacent horizontal curves usually the detail nomograms of radii compatibility are presented which are almost the same in the road design standards of various countries. Requirements for the compatibility of the radii of horizontal curves and the lengths of tangents between the curves are usually not so comprehensive as for the compatibility of the radii of adjacent horizontal curves, and this is a certain deficiency of design standards. Another deficiency of the road design standards of the Republic of Lithuania is that the smoothness of the whole road alignment is only mentioned and no recommendations are given on how to achieve it.

This work describes a new road design methodology according to which road alignment is studied as a sequence of successive interrelated elements. This methodology is based on the concepts of Curvature Change Rate CCR_S and traffic safety criteria.

The traffic safety criteria are as follows:

- criterion I – stability of the design speed V_P ;

- criterion II – stability of the 85th-percentile speed V_{85} ;
- criterion III – dynamic stability on horizontal curves.

Having summed up the values of traffic safety criteria and having calculated their average, the design level of traffic safety module is identified.

Methodology based on the traffic safety criteria allows us:

- to properly select the design speed V_p according to the calculated values of V_{85} for the whole road section to be reconstructed or for its separate segments;
- to properly combine between each other the elements of road – horizontal curves and tangents between them.

Using this methodology the problem of modelling the 85th-percentile speed in horizontal curves and the tangent between them was solved in this work (Fig. 1), the aim of which – to give detail recommendations for the compatibility of the elements of horizontal alignment.

Problem formulation – to find out the maximum tangent length TL when the following is given:

- the radii of horizontal curves R_1, R_2 ;
- the permissible difference ΔV_{85} between the 85th-percentile speed V_{85} in horizontal curves and the tangent.

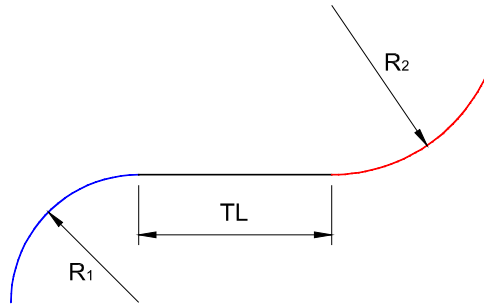


Fig. 1. The scheme for solving the problem of compatibility between the elements of horizontal alignment

Problem solution:

- speed in horizontal curves

$$V_{85_i} = 105,31 + 2 \cdot 10^{-5} \cdot CCR_{Si}^2 - 0,071 \cdot CCR_{Si}, \quad (1)$$

where CCR_{Si} – the curvature change rate in curve i ;

- speed in tangent

$$V85_T = \min\left(\frac{\min(V85_1, V85_2) + \Delta V_{85}}{105,31}\right); \quad (2)$$

- tangent length

$$TL = \frac{2 \cdot V85_T^2 - V85_1^2 - V85_2^2}{22,03}. \quad (3)$$

By joining (1)–(3) formulas together the final expression of tangent length is obtained

$$TL = \min\left(\frac{105,31 + 2 \cdot 10^{-5} \cdot \left(\frac{63700}{\min(R_1, R_2)}\right)^2 - 0,071 \cdot \frac{63700}{\min(R_1, R_2)} + \Delta V_{85}}{105,31} - \right. \\ \left. -1006,8 - \frac{2,9895 \cdot 10^8}{R_1^4} + \frac{3,3321 \cdot 10^7}{R_1^3} - \frac{1,7044 \cdot 10^6}{R_1^2} + \frac{43240}{R_1} - \right. \\ \left. -1006,8 - \frac{2,9895 \cdot 10^8}{R_2^4} + \frac{3,3321 \cdot 10^7}{R_2^3} - \frac{1,7044 \cdot 10^6}{R_2^2} + \frac{43240}{R_2}\right). \quad (4)$$

Based on (4) formula the tables of recommended maximum tangents between the small-radius (100–500 m) horizontal curves were worked out.

3. Methodology of experimental investigations

The chapter describes methodology developed or adjusted during the preparation of this work for the following experimental investigations:

- for the investigation of horizontal alignment of gravel roads;
- for the investigation of vertical alignment of gravel roads;
- for the investigation of accident rate of gravel roads;
- for the determination of the quality of design solutions in the gravel road reconstruction projects;
- for the prediction of taking of land for the right-of-way.

Investigation of horizontal alignment was carried out in the following stages:

- vectorization of road alignment in the digital orthophotographical map ORT10;
- separation of a linear object, representing the road axis, into the tangents and circular arcs, determination of the position of turning points (vertices of the angles) of road alignment and identification of coordinates;
- drawing-up and analysis of the lists of turning angles, tangents and curves.

Investigation of vertical alignment of gravel roads was carried out in the following stages:

- measurements of vertical alignment by the GPS (Global Positioning System) receiver;
- modeling of the existing vertical alignment with the tools of computer-aided design (CAD) system;
- drawing-up and analysis of the lists of elements of vertical alignment.

Using the tools of computer-aided design system the modelling of the existing vertical alignment was carried out in the following order:

- development of a digital model of location;
- design of horizontal alignment without deviation from the existing axis;
- design of vertical alignment without deviation from the existing heights.

The main objective of the investigation of accident rate of gravel roads is to compare accident indices on the reconstructed gravel road sections before and after their reconstruction.

Investigation of accident rate of gravel roads was carried out in the following stages:

- collection of accident data on the reconstructed gravel road sections;
- comparison of accident indices before and after reconstruction;
- economic evaluation of accident losses.

For the analysis of the quality of design solutions in the gravel road reconstruction projects the following investigations were implemented:

- evaluation of the correspondence of the solutions of horizontal alignment to the requirements of design standards;
- identification of potentially dangerous road segments based on the methodology of traffic safety criteria.

The aim of evaluating the correspondence of the solutions of horizontal alignment to the requirements of design standards was to determine what part of horizontal curves is designed improperly. The following horizontal curves were attributed to the improperly designed ones:

- curves the radii of which are lower that it is required by the design standards valid at the time of project preparation;
- curves with the improperly designed transition curves.

When identifying potentially dangerous segments that may appear in the implemented gravel road reconstruction projects each section under investigation was divided into segments in a way that one segment correspond to one element of horizontal alignment. Investigation was carried out in the following stages:

- identification of dangerous segments on the sections under investigation;

- collection of accident data on the sections under investigation;
- determination of statistical relationship between the accidents on the sections under investigation and the identified dangerous segments on them.

Identification of dangerous segments on the road sections under investigation was carried out in the following order:

- determination of the average Curvature Change Rate CCR_S ;
- determination of the 85th-percentile speed V_{85} using the overall world-wide regression equations;
- analysis of the planned road alignment by defining for each segment a design level of traffic safety module;
- identification of a dangerous road segment if the value of a dangerous design level of traffic safety module is obtained;

Dangerous segments were identified for both traffic directions.

When reconstructing roads the following situations may occur:

- correction of horizontal alignment (position of the road axis is changed);
- increase in the width of right-of-way.

In both cases the taking of land for the right-of-way is necessary by the established order of the Law on Territorial Planning.

The objectives of predicting the volume of taking of land for the right-of-way are as follows:

- to determine the volume of possible taking of land for the right-of-way in case when the detail designs for the gravel road reconstruction are prepared according to the requirements of design standards;
- to determine possible costs of taking of land and their ratio to the cost of road reconstruction works.

Investigation of the volume of possible taking of land for the right-of-way was implemented in the following stages:

- design of one of the possible alternatives for the planned road alignment with the tools of computer-aided design system;
- determination of land areas to be taken for the right-of-way according to the deviation of the planned road axis in respect of the existing road axis;
- identification of the number of land plots the limits of which have to be corrected due to the deviation of the road axis based on the database of SE Registrų centras (Centre of Registers);
- determination of possible costs of taking of land for the right-of-way;
- analysis of results.

4. Results of experimental investigations

Investigations of horizontal and vertical alignment were carried out on the planned to be reconstructed gravel roads under the supervision of SE Telšiai regiono keliai. Investigations of horizontal alignment were implemented on 24 sections with the total length of 111.90 km. Investigations of vertical alignment of gravel roads were carried out on 21 road section with the total length of 95.50 km. Investigation results showed that the quality of the existing road alignment of gravel roads is poor – 56–78% of horizontal curves (making 19–27% of the length of investigated sections) and 68–89% of vertical curves (making 25–36% of the length of investigated sections) should be corrected (Fig. 2).

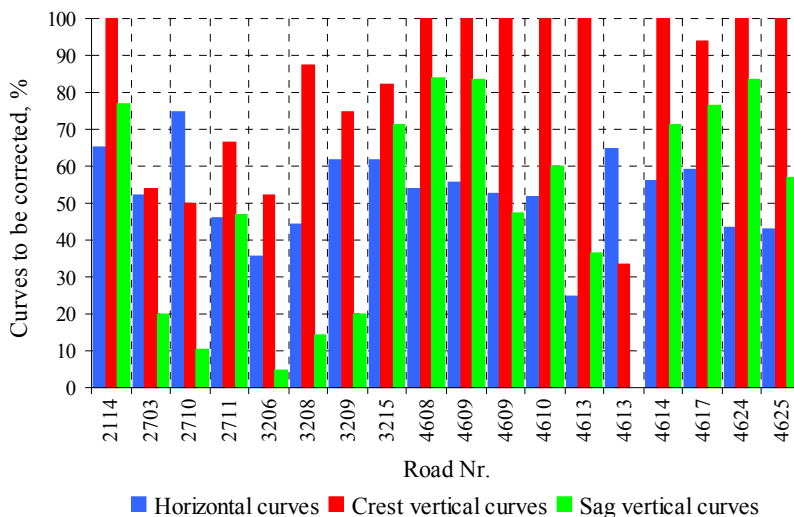


Fig. 2. Distribution of horizontal and vertical curves to be corrected when $V_p = 70$ km/h

Investigation of accident rate was implemented on 53 reconstructed gravel road sections in the Western Lithuania, the total length of which – 204.88 km. On those sections in the period 1998–2006 199 fatal and injury accidents were recorded, 76 of which – before reconstruction, 123 – after reconstruction. Besides, after reconstruction 2 high-accident sections and 2 black spots were recorded on the gravel roads under investigation. Investigation results showed that:

- after reconstruction the average density of fatal and injury accidents on the sections of investigation sample has increased twice – from 0.06 to 0.13 accidents per year;
- accident costs per 1 km of the reconstructed gravel road, in the investigated sections were about 93 thousand Lt per year (based on 2006 prices).

A more comprehensive analysis of accident rate was carried out on the gravel roads under the supervision of SE Telšių regiono keliai by analyzing both types of accidents – fatal and injury as well as damage-only accidents (Fig. 3). It was determined that after reconstruction of the gravel roads under the supervision of SE Telšių regiono keliai the density of both types of accidents has increased 2.7 times.

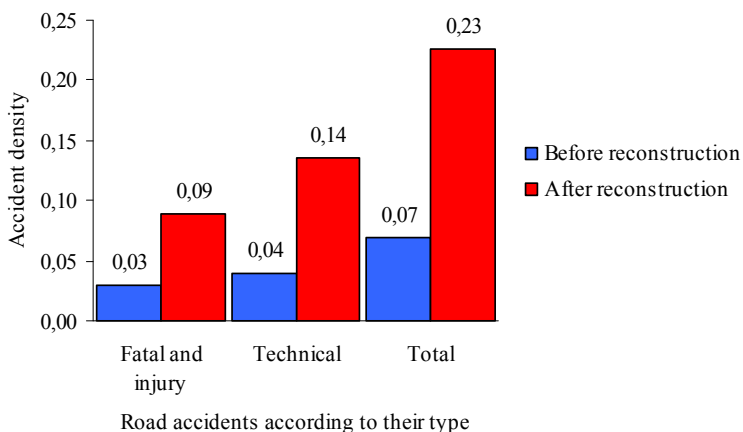


Fig. 3. Comparison of accident density of each type of accidents before and after reconstruction of gravel roads under the supervision of SE Telšių regiono keliai

Evaluation of the correspondence of the solutions of horizontal alignment to the requirements of design standards was carried out on the sections of the accident rate investigation sample – 53 detail designs of gravel road reconstruction, prepared for the road sections with the total length of 204.88 km, were studied. It was determined that 14 gravel road reconstruction projects (26.4% of all the projects) were prepared without giving any solutions for the horizontal alignment. 39 gravel road reconstruction projects (73.6% of all the projects) were fully completed, however, the quality of the solutions of horizontal alignment was poor – on the average 34.9% of horizontal curves were designed improperly.

Investigation for identifying the potentially dangerous segments was implemented on 8 gravel road sections with the total length of 39.26 km. For this investigation the detail designs of gravel road reconstruction were also used. It was determined that at least 5% of the total length of investigated reconstructed gravel road sections is made of the potentially dangerous segments, besides, there is a statistical correlation between the identified dangerous road segments and the accidents on them. When identifying the potentially dangerous segments it was also determined that in all detail designs of investigation sample the design speed V_p was selected improperly – based on the design standards, valid at the time of their preparation, the value of $V_p = 60$ km/h was set, whereas, it had to be set as $V_p = 70\text{--}90$ km/h.

The forecast of the volume of taking of land for the right-of-way shows that:

- when taking land for the right-of-way the predicted costs per one gravel road section to be reconstructed average to 59 thousand Lt (based on 2006 prices) – on the average 2.7% of the calculated cost of laying asphalt pavement;
- the higher the length of the section to be reconstructed the lower ratio would be between the costs of taking of land for the right-of-way and the calculated cost of laying asphalt pavement (Fig. 4).

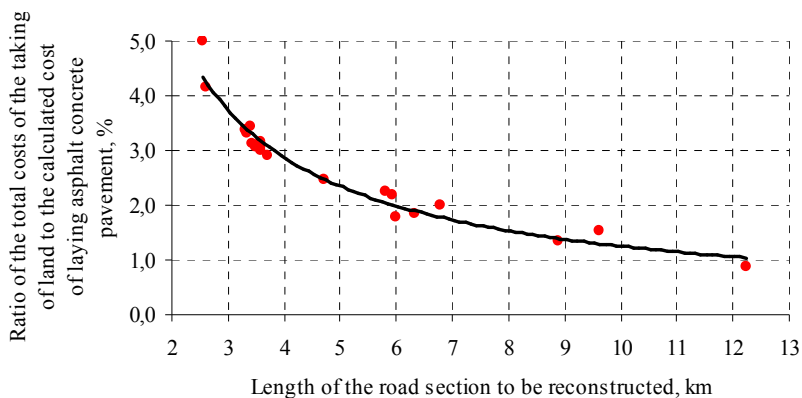


Fig. 4. Dependency of the ratio between the total costs of taking of land for the right-of-way and the calculated cost of laying asphalt concrete pavement on the length of the road section to be reconstructed

It was determined that the ratio between the costs of taking of land for the right-of-way and the calculated cost of laying asphalt pavement is also related to the length of the section to be reconstructed in a dependency which could be described by an exponential function:

$$S = m \cdot L^n, \quad (5)$$

where S – ratio between the total costs of taking of land for the right-of-way and the calculated cost of laying asphalt concrete pavement, %; L – length of the road section to be reconstructed, km; m, n – coefficients of exponential function.

5. Generalization of investigation results

This chapter gives an overview of results of all investigations carried out during the preparation of this dissertation:

- detail recommendations for improving the road design standards of the Republic of Lithuania regulating the solutions of road alignment;
- results of all experimental investigations implemented.

General conclusions

1. When analyzing regularities of the design solutions of road alignment and their links with the regulations of road design standards it was determined that the current regulations of road design standards of the Republic of Lithuania have certain inaccuracies and deficiencies. A further use of these requirements for designing road alignment will result in the preparation of low-quality road reconstruction projects in terms of traffic safety, especially on the roads of lower categories.

2. Investigations of horizontal and vertical alignment of gravel roads show that the quality of the existing alignment of gravel roads is poor – 56–78% of horizontal curves and 68–87% of vertical curves should be corrected.

3. In the result of comparative investigations of accident rate of the reconstructed road sections it was determined that:

- after reconstruction the accident rate (accident density) is increased up to 3 times;
- accident costs per 1 km of the reconstructed gravel road make about 93 thousand Lt per year (based on 2006 prices).

4. Based on the analysis of the quality of design solutions in the gravel road reconstruction projects, it could be stated that:

- the values of design speed are selected improperly;
- requirements for the solutions of horizontal alignment of roads are not observed – approximately one third of horizontal curves are designed incorrectly;

- the elements of horizontal alignment are incompatible – at least 5% of the total length of the reconstructed road sections are comprised of potentially dangerous segments.

5. When taking land for the right-of-way the predicted expenditures per one gravel road section to be reconstructed are averaged to 59 thousand Lt (based on 2006 prices). They make only a small part of the calculated cost of road reconstruction works, and this part has been notably decreasing with the increasing length of the road section to be reconstructed. Therefore, it is recommended to reconstruct gravel roads in the longest possible sections.

6. Annual losses caused by the road accidents on improperly reconstructed gravel road sections are larger than onetime expenditures for taking of land for the planned right-of-way. Therefore, it could be stated that the current practice in Lithuania to design the minimum possible deviation of the design road axis from the existing road axis is not reasonable from the technical and economic point of view.

7. The recommended corrections and supplements to the requirements of road design standards of the Republic of Lithuania are as follows:

- to replace the minimum radii of horizontal and vertical curves with the radii values suggested in this work;
- to present the revised recommendations, suggested in this work, for the compatibility of horizontal curve radii and the lengths of tangents between the curves;
- to supplement design standards with the concepts of 85th-percentile speed, the Curvature Change Rate, traffic safety criteria, traffic safety modulus and its design levels;
- to change requirements for the determination of design speed – to specify that the value of design speed shall be justified by the calculations.

List of published works on the topic of the dissertation In the reviewed scientific periodical publications

Gintalas, V.; Čygas, D.; Žilionienė, D.; Puodžiukas, V. 2007a. Longitudinal profile of the objects included in the Gravel roads paving program of Lithuania, *The Baltic Journal of Road and Bridge Engineering* 2(2): 53–59. ISSN 1822–427X print. (Thomson ISI Web of Science).

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PROJEKTINIŲ SPRENDINIŲ KOKYBĖS GERINIMO GALIMYBĖS ŽVYRKELIŲ REKONSTRUKCIJOS PROJEKTUOSE

Problemos formulavimas. Nepaisant didelių investicijų valstybinės reikšmės kelių tinklo plėtrai ir eismo saugumo gerinimui, avaringumas Lietuvos Respublikoje iki šiol buvo vienas iš didžiausių Europos Sąjungoje. Tai leidžia

daryti prielaidą, kad ne visos kelių tinklo tobulinimui taikomos priemonės yra pakankamai efektyvios, tarp jų ir projektiniai sprendiniai automobilių kelių rekonstrukcijos projektuose. Ypač didelį susirūpinimą kelia žvyrkelių rekonstrukcijos projektų sprendiniai, kurie gali būti netinkami eismo saugumo požiūriu, nes šiuo metu Lietuvoje itin dažnai taikoma praktika, kad projektinė kelio ašis rekonstruojamuose žvyrkelių ruožuose kuo mažiau nukryptų nuo esamos ašies. Tokios žvyrkelių rekonstrukcijos praktikos pagrindinė motyvacija – rekonstrukcijos darbų kainos mažinimas žemės paėmimo projektinei kelio juostai išlaidų sąskaita. Kita svarbi priežastis, dėl kurios susiklostė dabartiniu metu taikoma žemesnių kategorijų kelių, tarp jų ir žvyrkelių, rekonstrukcijos praktika, yra liberalios Lietuvos Respublikos automobilių kelių projektavimo normos, leidžiančios itin laisvai interpretuoti jų nuostatų laikymąsi.

Darbo aktualumas. Paskutinį dešimtmetį Lietuvoje taikomos žvyrkelių rekonstrukcijos praktikos motyvacija gali būti nepakankamai pagrįsta. Be to, Lietuvos Respublikos automobilių kelių projektavimo normose iš esmės keitėsi pagrindiniai reikalavimai kelio trasos sprendiniams, todėl dabartinėse projektavimo normose gali būti netikslumų, kuriuos būtina koreguoti. Taip pat automobilių kelių projektavimo normas būtina papildyti naujomis nuostatomis, užtikrinančiomis sklandžios ir saugios kelio trasos sprendinius.

Tyrimų objektas. Darbo tyrimų objektas – kelio trasos projektavimo dėsningumai, projektiniai sprendiniai žvyrkelių rekonstrukcijos projektuose ir jų sąsajos su automobilių kelių projektavimo normų nuostatomis.

Darbo tikslas ir uždaviniai. Šio darbo tikslas – nustatyti kelio trasos projektavimo dėsningumus, jų sąsajas su automobilių kelių projektavimo normų nuostatomis ir pasiūlyti metodus projektinių sprendinių kokybės gerinimui.

Darbo tikslui pasiekti sprendžiami šie uždaviniai:

1. Atlikti automobilių kelių projektavimo normų nuostatų, reglamentuojančių kelio trasos sprendinius, analizę ir pateikti pasiūlymus šioms nuostatoms tobulinti.
2. Įvertinti esamos kelio trasos kokybę ir galimo trasos plano ir išilginio profilio koregavimo apimtį numatomuose rekonstruoti žvyrkelių ruožuose.
3. Atlikti avaringumo tyrimus rekonstruotuose žvyrkelių ruožuose, lyginant avaringumą iki ir po rekonstrukcijos.
4. Įvertinti kelio trasos projektinių sprendinių kokybę žvyrkelių rekonstrukcijos projektuose.
5. Įvertinti žemės paėmimo kelio juostai apimtį tuo atveju, kai žvyrkelių rekonstrukcijos projektai būtų rengiami pagal projektavimo normų reikalavimus.
6. Įvertinti Lietuvoje taikomos praktikos, rekonstruojant žvyrkelius kuo mažiau nukrypti nuo esamos kelio trasos, pagrįstumą.

Tyrimų metodika. Siekiant nustatyti galimus netikslumus Lietuvos Respublikos automobilių kelių projektavimo normų nuostatose, reglamentuojančiose kelio trasos sprendinius, ir pateikti pasiūlymus šių nuostatų tobulinimui, darbe atlikti tyrimai lyginamosios analizės metodu. Atlikti trys eksperimentiniai tyrimai, naudojant darbo rengimo metu sukurtą metodiką:

- kelio trasos plano žvyrkeliuose tyrimui;
- žvyrkelių išilginio profilio tyrimui;
- žemės paėmimo kelio juostai apimčių prognozei.

Statistiniai metodai pritaikyti, tiriant avaringumą žvyrkeliuose iki ir po rekonstrukcijos. Projektinių sprendinių žvyrkelių rekonstrukcijos projektuose kokybės vertinimo eksperimentiniams tyrimams pritaikyta eismo saugumo kriterijų metodika.

Mokslinis naujumas. Rengiant disertaciją buvo gauti šie statybos inžinerijos mokslui nauji rezultatai:

- automobilių kelių projektavimo normų nuostatoms, reglamentuojančioms kelio trasos sprendinius, tobulinti bei kelių rekonstrukcijos projektų sprendinių kokybei gerinti pritaikyta nauja projektavimo metodika, pagal kurią kelio trasa nagrinėjama kaip nuosekli tarpusavyje susijusių elementų seka.
- esamos kelio trasos geometriniai parametrai Lietuvos Respublikos valstybinės reikšmės kelių tinklo žvyrkeliuose.
- kelio trasos sprendinių kokybės įvertinimas žvyrkelių rekonstrukcijos projektuose.
- avaringumo pokyčiai žvyrkeliuose iki ir po rekonstrukcijos.

Praktinė reikšmė. Praktinis darbe atliktų tyrimų rezultatų panaudojimas leistų pagerinti projektinių sprendinių kokybę, rengiant žemesnių kategorijų užmiesčio kelių rekonstrukcijos projektus:

- Lietuvos Respublikos automobilių kelių projektavimo normos būtų patobulintos ir užtikrintų geometriškai sklandžios ir saugios kelio trasos projektinius sprendinius;
- eismo saugumo kriterijų metodikos taikymas leistų dar projektavimo stadijoje nustatyti ir pašalinti potencialiai pavojingas atkarpas keliuose.

Ginamieji teiginiai

1. Būtina tobulinti Lietuvos Respublikos automobilių kelių projektavimo normų nuostatas, įvertinant kelio trasos projektavimo dėsningumus ir projektinių sprendinių kokybę kelių rekonstrukcijos projektuose.
2. Rengiant žvyrkelių rekonstrukcijos projektus, neturi būti ribojama galimybė nukrypti nuo esamos kelio ašies.

Darbo apimtis. Disertaciją sudaro įvadas, 5 skyriai, bendrosios išvados ir rekomendacijos bei priedai.

Įvardiniame skyriuje aptariama tiriamoji problema, darbo aktualumas, aprašomas tyrimų objektas, formuluojamas darbo tikslas bei uždaviniai, pateikiama trumpa tyrimų metodikos apžvalga, darbo mokslinis naujumas, darbo rezultatų praktinė reikšmė ir ginamieji teiginiai.

Pirmajame skyriuje pateikiama Lietuvos Respublikos valstybinės reikšmės kelių tinklo plėtros ir žvyrkelių rekonstrukcijos patirties analizė.

Antrajame skyriuje analizuojamos automobilių kelių projektavimo normų nuostatos, reglamentuojančios kelio trasos sprendinius. Skyriuje pateikiami nustatyti netikslumai ir trūkumai Lietuvos Respublikos automobilių kelių projektavimo normų nuostatose, taip pat aprašyta užsienio šalyse taikoma nauja automobilių kelių projektavimo metodika, pagal kurią kelio trasa nagrinėjama kaip nuosekli tarpusavyje susijusių elementų seka. Remiantis šia metodika, pateiktos rekomendacijos Lietuvos Respublikos automobilių kelių projektavimo normų tobulinimui.

Trečiajame skyriuje pateikiama atliktų eksperimentinių tyrimų metodika – kelio trasos plano ir išilginio profilio žvyrkeliuose tyrimams, avaringumo analizei ir projektinių sprendinių žvyrkelių rekonstrukcijos projektuose kokybės vertinimui.

Ketvirtajame skyriuje pateikiami eksperimentinių tyrimų metu gauti rezultatai – esamos kelio trasos plano ir išilginio profilio kokybė bei koregavimo poreikis valstybinės reikšmės kelių tinklo žvyrkeliuose, avaringumo rodikliai rekonstruotuose žvyrkelių ruožuose iki ir po rekonstrukcijos, nustatytų potencialiai pavojingų atkarpų ištirtuose ruožuose pasiskirstymas ir projektinio greičio parinkimo klaidos, prognozuojamas žemės paėmimo kelio juostai poreikis tuo atveju, kai žvyrkelių rekonstrukcijos projektai būtų parengti, tenkinant projektavimo normų reikalavimus.

Penktasis skyrius skirtas visų disertacijos rengimo metu atliktų teorinių ir eksperimentinių tyrimų rezultatų apibendrinimui.

Bendrosios išvados

1. Analizuojant kelio trasos projektinių sprendinių dėsningumus ir jų sąsajas su automobilių kelių projektavimo normų nuostatomis, nustatyta, kad dabartinėse Lietuvos Respublikos automobilių kelių projektavimo nuostatose yra netikslumų ir trūkumų. Kelio trasos projektavimui taikant šias nuostatas, išliks didelė rizika, kad bus rengiami saugaus eismo požiūriu nekokybiški kelių rekonstrukcijos projektai, ypač žemesnių kategorijų keliuose.

2. Žvyrkelių trasos plano ir išilginio profilio tyrimai rodo, kad esamos trasos kokybė žvyrkeliuose yra bloga – 56–78 % horizontaliųjų kreivių ir 68–87 % vertikaliųjų kreivių yra taisytinės.

3. Atlikus lyginamuosius avaringumo tyrimus rekonstruotuose žvyrkelių ruožuose nustatyta, kad:

- po rekonstrukcijos avaringumas (eismo įvykių tankis) žvyrkeliuose padidėja iki 3 kartų;

- eismo įvykių kaštai, tenkantys 1 km rekonstruoto žvyrkelio, ištiertuose ruožuose sudaro apie 93 tūkst. Lt per metus (2006 metų kainomis).

4. Remiantis darbe atlikta žvyrkelių rekonstrukcijos techninių projektų sprendinių kokybės analize, galima teigti, kad:

- projektinio greičio reikšmės parenkamos neteisingai;
- nesilaikoma reikalavimų kelio trasos plano sprendiniams – apytikriai trečdalis horizontaliųjų kreivių yra netinkamai suprojektuotos;
- trasos plano elementai tinkamai nederinami tarpusavyje – ne mažiau kaip 5 % bendro rekonstruotų ruožų ilgio sudaro potencialiai pavojingos atkarpos.

5. Paimant žemę kelio juostai, vienam rekonstruojamam žvyrkelio ruožui tenkančios prognozuojamos išlaidos vidutiniškai yra 59 tūkst. Lt (2006 metų kainomis). Jos sudaro nežymią kelio rekonstrukcijos darbų skaičiuojamosios kainos dalį, kuri pastebimai mažėja, didėjant rekonstruojamo ruožo ilgiui. Todėl rekomenduojama rekonstruoti kuo ilgesnius žvyrkelių ruožus.

6. Kasmetiniai nuostoliai, patiriami dėl eismo įvykių netinkamai rekonstruotose žvyrkelių ruožuose, yra didesni už vienkartinę išlaidą, paimant žemę projektinei kelio juostai. Tad galima teigti, kad šiuo metu Lietuvoje taikoma praktika, kad projektinė kelio ašis rekonstruojamuose žvyrkelių ruožuose kuo mažiau nukryptų nuo esamos ašies, yra nepagrįsta techniniu ir ekonominiu požiūriu.

7. Rekomenduojami Lietuvos Respublikos automobilių kelių projektavimo normų nuostatų pataisymai ir papildymai:

- mažiausius horizontaliųjų ir vertikalųjų kreivių spindulius pakeisti darbe pasiūlytomis spindulių reikšmėmis;
- pateikti darbe pasiūlytas patikslintas rekomendacijas horizontaliųjų kreivių spindulių ir tiesių intarpų ilgių tarp kreivių suderinamumui;
- projektavimo normas papildyti 85 procentų greičio, kelio trasos vingiuotumo, eismo saugumo kriterijų ir eismo saugumo modulio bei jo projektinių lygmenų sąvokomis;
- pakeisti reikalavimus projektinio greičio nustatymui – nurodyti, kad projektinio greičio reikšmė, mažesnė už leidžiamą greitį, turi būti pagrįsta skaičiavimais.

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POSSIBILITIES FOR THE IMPROVEMENT
OF THE QUALITY OF DESIGN SOLUTIONS
IN THE GRAVEL ROAD RECONSTRUCTION PROJECTS

Summary of Doctoral Dissertation
Technological Sciences, Civil Engineering (02T)

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