



## EVALUATION OF SHOULDERS FUNCTIONS ON LITHUANIAN REGIONAL ROADS

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**Abstract.** Granular shoulder is an important element of road system. One can frequently notice shoulders rutting, edge breakage, unconformity of cross-section to the norms that could be caused by wind and water-generated erosion. These problems directly affect the drivers, influences their behaviour on the road and traffic safety. Therefore, a constant maintenance of road shoulders is necessary. Investigations of the Lithuanian gravel road network showed that the low-volume roads with gravel surfacing do not correspond to the current standards and the change in their performance due to climatic conditions, traffic volume and the materials used for the structures have a large influence not only on traffic safety but also on traffic conditions. It is very important for the road shoulders to improve traffic safety, to prevent road carriageway edges from degradation, to serve for emergency parking and for the installation of guardrails, warning and informatory signs. Since shoulder deformations are caused by the deformations in the subgrade and its slopes, a properly prepared and erected subgrade should be provided with the shoulder of corresponding structure where inadmissible deformations would not occur. Defects in the low-volume road pavement occur when gravel of unsuitable composition is used for the shoulder pavement, the structure is of insufficient thickness and strength, the top of the subgrade becomes damp due to the lack of proper drainage or road maintenance is of unsatisfactory level. It is very important for the shoulders of low-volume roads to use a proper material for increasing the structural strength of the shoulder and preventing it from defects.

**Keywords:** low-volume roads, performance, road pavement structure, shoulder.

### 1. Introduction

The increasing traffic volume reveals the deficiencies of road infrastructure not only in Lithuania but also on the low-volume roads of many countries in the world. Low-volume rural roads have been, and continue to be, an important component of the World Bank's transport development program (Plessis-Fraissard 2007).

Low-volume roads serve not only the function of access roads where they give possibility to access farmsteads, industrial buildings and other territories, but also the distribution function where traffic in the junctions is distributed between different zones and territories. It is important that when driving on low-volume roads the min level of traffic quality would be ensured and after they are paved with asphalt pavement the average level of traffic comfort would be achieved, i.e. the speed limit would come to 90 km/h. Traffic conditions related to the road technical parameters, pavement defects and visibility characteristics of the road (Gintalas *et al.* 2005, 2007)

The shoulder is an important element of road system allowing for emergency parking and additional zone for vehicles, serving for the structural strength of road pavement, for

the drainage to discharge water from road pavement, ensuring better visibility, functioning as bicycle path or increased road width to serve agricultural machinery. Design and construction of granular shoulders is cheaper than asphalt ones, however, maintenance is more expensive as granular shoulders have more performance-related problems (Price 1990). The problems are as follows: erosion, caused by wind and water, ruts, edge breakage, variability of grading. Therefore, granular shoulders require better maintenance.

Road shoulder properties are described as: exact delineation between road line and shoulder, proper gradient for good drainage, sufficient width for emergency parking, installation of guardrails and structural stability, low construction costs.

The shoulders could be erected from soil, stabilized mineral materials or concentrated materials (Butt *et al.* 1997).

Granular shoulders are usually used on low-volume roads. Material grading, compaction method and type of the structure are the main factors to ensure a better quality of the shoulder (Butt *et al.* 1997). The officers of accident investigation of Iowa State (USA) say that the shoulder of insufficient quality is the cause of many accidents. The most frequent

causes of shoulder worsening are: ruts and pavement edge breakage (Souleyrette *et al.* 2001). Rutting and pavement edge breakage are determined by the following reasons:

- settlement of shoulder pavement,
- worsening of grading of the mineral material of shoulder pavement,
- erosion caused by water discharge,
- large traffic volume,
- wide vehicles passing the edge.

Price (1990) says that the problems are noticeable in places where road pavement edge joins the granular shoulder. The problems include water discharge from the pavement causing “soft” spots on the shoulder and occurrence of ruts.

## 2. Characteristics of low-volume roads

Stability of the road structure depends on the structural strength of pavement, strength of subgrade and deformations of road elements (Vorobjovas, Žilionienė 2008).

Shoulder deformations are initially caused by the deformations in the subgrade and its slopes. Therefore, a properly prepared and erected subgrade should be provided with the shoulder of corresponding structure where inadmissible deformations would not occur. It is important that the road shoulder serve its function, i.e. would improve traffic safety, protect carriageway edges from breaking, serve for emergency parking and for the installation of guardrails, warning and informatory signs.

The roads up to 10 000 vpd form the main network of Lithuanian low-volume roads. On these roads the width of carriageway is 6.0 or 7.0 m, of both shoulders – 2.0 m (Fig. 1).

In Fig. 1 given structure of the shoulder consists of a frost blanket course placed on the erected subgrade with the cross fall of 3% (in banked turns – 4%). Usually the shoulder is formed from course-grained soil. The cross fall of the shoulder pavement is 6%.

A frost blanket course is laid from aggregates and has a certain task to prevent the structure of shoulder pavement from the hazardous frost impact. For a frost blanket course of the shoulder structure like for that of the road pavement structure the frost-unsusceptible soils or mixes of natural mineral materials are used which, if properly compacted, are water permeable. When determining the coefficient of filtration  $K_{10}$  or the water permeability index  $k$ , the coeffi-

cient or the index shall correspond to those established by the project and is the same for the structure of road pavement and shoulder pavement. On the low-volume roads, the coefficient of filtration  $K_{10} \geq 1.0$  m/day or the water permeability index  $k \geq 0.5 \times 10^{-5}$  m/s. Thickness of a frost blanket course depends on the structure of shoulder pavement and is varying since in the slope the thickness is reduced to 20 cm. A frost blanket course shall have such a structure and be of such an erection that during road operation it would prevent the structure of shoulder pavement from heaves and guarantee its durability and stability (of course, if the strength of pavement structure is sufficient).

The strength of the erected frost blanket course, characterized by the deformation modulus  $E_{v2}$ , shall have at least 80–100 MPa. The required strength is guaranteed by the sufficient thickness, suitable course-grained soils and a degree of compaction.

Thickness of the frost blanket course of the shoulder is usually  $\frac{1}{4}$  lower if compared to its thickness in the structure of road pavement. Therefore, the min deformation modulus on the top of a frost blanket course of the shoulder should be at least 60 MPa. However, the strength on the top of a soil layer, used for the shoulder, and of the erected shoulder with gravel or other pavement should be not less than the strength on the top of a frost blanket course.

The frost blanket course is covered with gravel or crushed stone base course, which is also characterized by the deformation modulus  $E_{v2}$ . Depending on the class of road pavement structure, it shall be at least 120–180 MPa. The required strength is guaranteed by the sufficient thickness of the course built from proper course-grained soils at a sufficient degree of compaction.

On roads with 3000 vpd, the base of shoulders, part of which as the marginal safety lane gets into the carriageway, the most frequently used material is crushed dolomite and, depending on the category, the deformation modulus shall be 120–150 MPa.

The erected crushed stone base courses shall conform to the required geometric parameters, grading of mixes, size of crushed stone fractions (when erected by wedging), deformation modulus  $E_{v2}$ .

On the remaining part of the shoulder, on the frost blanket course the soil is laid which shall be water resistant, insensitive to cold and distinguished for its good filtration properties.

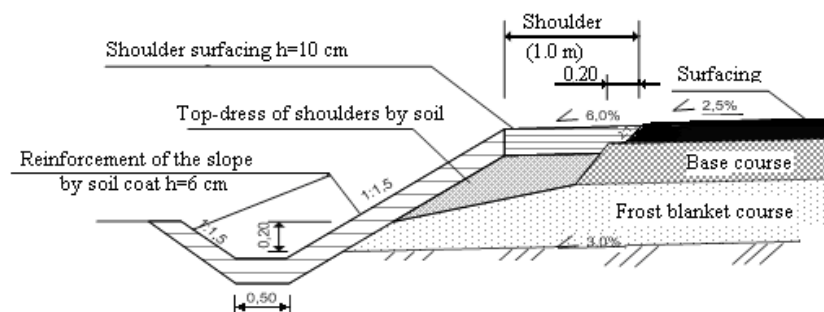


Fig. 1. The structure of the low-volume road shoulder

**Table 1.** Data of the investigation statistical evaluation of the shoulders on low-volume roads (Vorobjovas, Žilionienė 2008)

Measured or determined values, indices	Units	Statistical indices				
		Average value	Mean square deviation, $s$	Variation coefficient, %	Limits of the change of average value (probability $p = 0.95$ )	Dispersion of results (probability $p = 0.95$ )
Width	m	1.1	0.15	13.6	1.05–1.15	0.81–1.39
Cross falls	%	3.8	2.2	57.9	3.1–4.6	2.3–5.3
Pavement thickness	cm	7.0	3.0	42.8	6.0–8.0	1.0–13.0
Structural strength ( $E_{v2}$ )	MPa	53.1	18.4	34.7	46.3–59.9	17.0–89.2
Structural strength of a base ( $E_{v2}$ )	MPa	78.7	20.8	26.4	70.9–86.5	37.9–119.5

The *Rules for Designing the Standardized Road Pavement Structures (KPT SDK 07)* do not define the design of shoulder structures. When designing and erecting shoulders it is necessary to follow the *List of Technical Requirements for Mineral Materials Used for Roads (TRA SBR 07)* and the *Rules for the Construction of Structural Road Pavement Layers without Binders (IT SBR 07)*.

On low-volume roads the pavement of shoulders is mostly constructed from gravel. Defects in the low-volume road pavement occur when gravel of unsuitable composition is used for the shoulder pavement, the structure is of insufficient thickness and strength, top of the subgrade becomes damp due to the lack of proper drainage or road maintenance is of unsatisfactory level (wrong cross falls or unsuitable steepness of subgrade slopes, etc.). The occurrence of some of defects depends on climatic factors and vehicle impact, of other defects – on design solutions or road maintenance level (Calvert *et al.* 1999; Ranieri 2002; Tighe *et al.* 2001).

Road drainage influences the road performance. One of the negative factors is water penetration into the road structure and its degradation. Therefore, it is important to ensure water discharge from the road and from the shoulders, since shoulders is part of the road drainage system. One of the functions of the shoulder is to ensure water discharge from the road pavement and to prevent water from getting into the structure of the road and its shoulders. A selection of materials for the shoulder is also important. The materials shall be similar to those used for the road pavement and yet more durable and permeable. In road construction and maintenance the aim is to prevent water accumulation between the road pavement and the shoulder, as this is the main reason why water gets into the road structure (Zegeer *et al.* 1994).

The improperly erected shoulders on the low-volume roads reduce speed and increase accident risk. In order to find out the condition of the low-volume road shoulders experimental investigations were carried out.

### 3. Experimental investigations of low-volume road shoulders and statistical evaluation

Characteristics of low-volume road shoulders are indicated by the construction quality (the used materials and their characteristics, the strength achieved). In this respect 8 road sections were selected in Vilnius and Panevėžys counties. From each of them the samples of soil, used to form

the shoulders, and the samples of gravel, used to erect the pavement, were taken. In random locations of the shoulders of each of the studied road sections the measurements were carried out of width of shoulders, cross falls, thickness of pavement layer, deformation moduli on the top of the shoulder structure and a frost blanket course.

In gravel and soil samples the grading was determined and the content of fines in soil. Table 1 gives the statistical analysis and evaluation of the data of measurements and investigations.

The characteristics of low-volume road shoulders are their width, cross falls and pavement thickness. Table 1 shows that the shoulder width is the least varying characteristic (variation coefficient – 13.6%) and the mean value is never lower than that established by the norms – 1.0 m. Investigations showed that the shoulder width varies within the limits of 0.85–1.50 m (Fig. 2).

Investigations showed that only in 15% of cases the shoulder width is lower than that required by the norms, however, it is never less than 0.85 m, except in cases where the road width is 7.0 m.

The cross fall of the shoulders is the most varying characteristic. The average cross fall of the shoulders comes to 3.8% and never reaches 6% established by the norms (Fig. 3). For this reason the draining characteristics in the shoulders become worse, water is prevented from fast flowing out of the shoulders, it gets into the structure of shoulders and reduces their strength. The structural strength of shoulders is influenced by the change in the thickness of shoulder pavement. Sometimes happens that the same material is used for the shoulder pavement and for the shoulder structure.

Measuring results of the base and the pavement strength of low-volume road shoulders are given in Table 2. The below data shows that the average value of deformation modulus  $E_{v2}$  for the base is 78.7 MPa and for the pavement structure is by 32.5% less and makes 53.1 MPa. It is typical that the structural strength of the shoulder is usually lower than the strength measured under the pavement. The pavement layer of the shoulder should increase the shoulder's deformation modulus, though, on the road the opposite effect is obtained. Investigation of gravel material, used for the shoulders, showed that the material could not be compacted due to its grading (low content of fines, inadequate structure) (Figs 4, 5). Data on the grading of gravel, used for the low-volume road shoulder pavement, is given in Table 3.

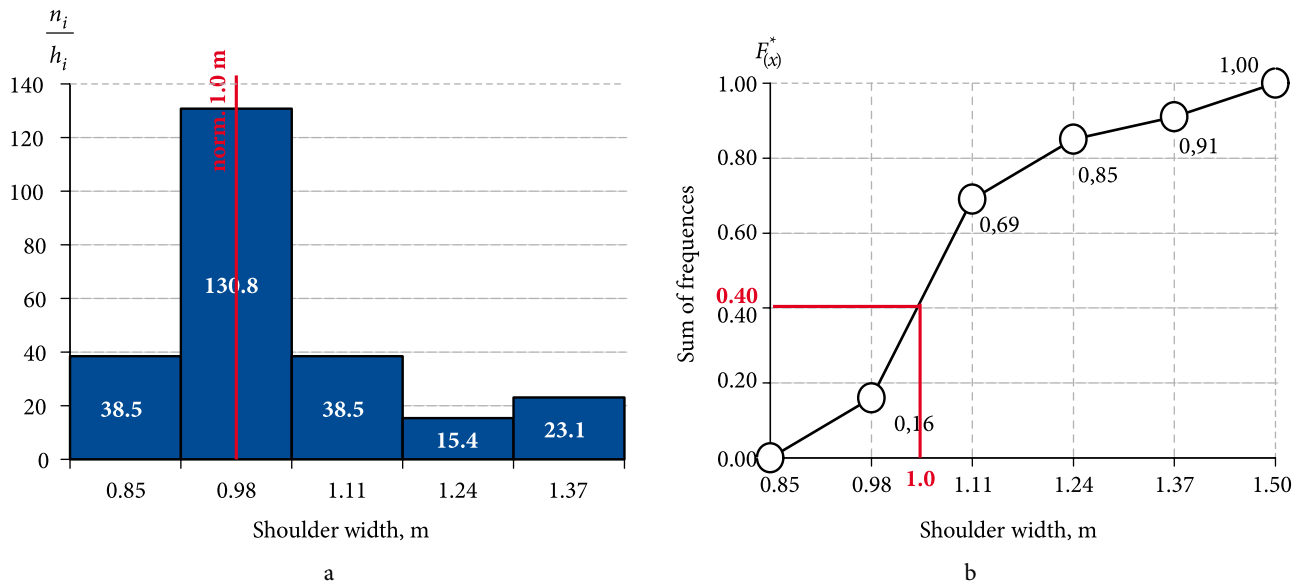


Fig. 2. The histogram (a) and the section function (b) of shoulder width (Vorobjovas, Žilionienė 2008)

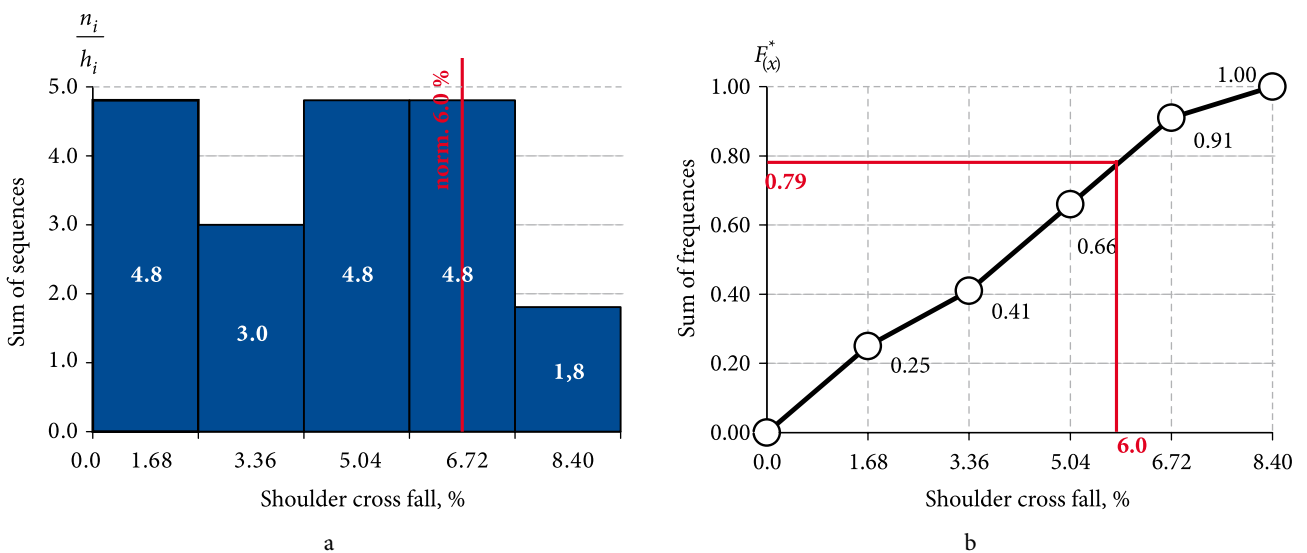


Fig. 3. The histogram (a) and the section function (b) of shoulder cross falls

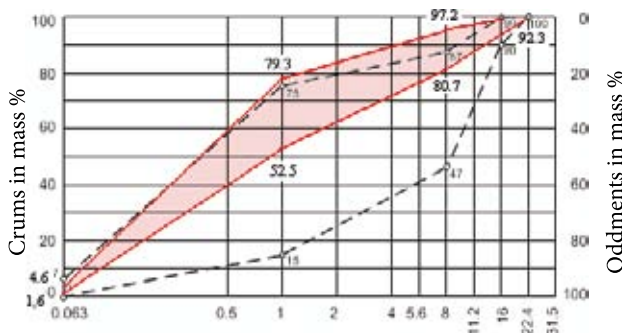
Table 2. Statistical characteristics for the strength of shoulder base and the shoulder structure ( $E_{vd}$  ir  $E_{v2}$ ) on regional roads

Statistical indices	Measuring units	Statistical characteristics of the base of shoulders		Statistical characteristics of the structure of shoulders	
		for $E_{vd}$	for $E_{v2}$	for $E_{vd}$	for $E_{v2}$
Number of measurements	units	29	27	28	28
Average value of strength	MPa	36.8	78.7	28.3	53.1
Dispersion ( $s^2$ )	MPa <sup>2</sup>	89.1	430.8	43.4	336.8
Mean square deviation ( $s$ )	MPa	9.4	20.8	6.6	18.4
Variation coefficient ( $C_V$ )	%	26.0	26.4	23.3	34.7
Change in the average value of the strength of shoulder base at the probability $p = 0.95$	MPa	29.3–36.1	70.9–86.5	26.0–31.0	46.3–59.9
Change in the strength of shoulder base at the probability $p = 0.95$	MPa	14.2–51.2	37.9–119.5	15.6–41.4	17.0–89.2

**Table 3.** Grading of gravel used for the shoulder pavement (Vorobjovas, Žilionienė 2008)

Size of sieve meshes, mm	0.63	1.0	2.0	16	32
Change in the amount of particles passing through the sieve, %	1.7–2.4	33.1–49.6	44.6–59.6	72.8–90.3	92.9–97.9

For the formation of shoulders on regional asphalt roads and erection of their pavement the course-grained gravel and sand mixes 0/16 or 0/32 are used. Grading of these mixes is significantly varying. Characteristic fact is that these mixes have small amount of fines, i.e. particles smaller than 0.063 mm. The used sand mixes are fine (Fig. 4).



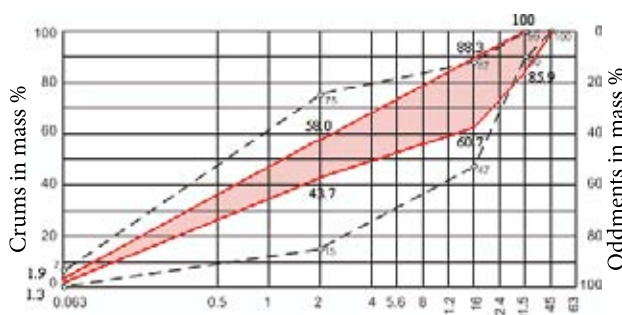
**Fig. 4.** Grading of 0/16 sand mix used for the shoulders

These mixes lack not only the gravel fraction 4/8, but also the fraction 0.5/1. To improve the sand mix 0/16 it would be necessary to add the gravel fraction (> 2 mm) and to increase the amount of fines.

The sand mix of the existing grading is water permeable. The shoulder structure erected from this mix could be slightly moistened by water getting on the shoulder. Variation in mix grading and in shoulder moisture has the influence on the variation in the strength of shoulder pavement and shoulder base.

Situation with the structure of shoulders becomes better if gravel 0/32 is used (Fig. 5).

However, in this case also the mixes have a very small amount of fines. For this reason the gravel mixes are water permeable, allowing water to easily get into the shoulder structure and to moisten it. When using gravel for the



**Fig. 5.** Grading of 0/32 gravel mix used for the shoulders

shoulders, due to the formed carcass and gravel particles, the strength of shoulders is higher if compared to the shoulders erected from sand.

The material, used for constructing the shoulder pavement, should increase the structural strength of the shoulder and prevent the occurrence of defects caused by the passing vehicles.

#### 4. Conclusions

1. When solving the problem of traffic quality on low-volume roads, it is necessary to ensure reliability and stability not only of the carriageway but also of the shoulders. The inadequately erected shoulders reduce speed and increases accident risk.
2. Since the cross falls of the shoulders do not reach the established value of 6%, the draining characteristics of the shoulders are getting worse.
3. Investigation of gravel material, used for the shoulder pavement, showed that the material is unsuitable and could not be compacted due to its grading. Thus, the pavement of road shoulders should be constructed from the material which is able to increase the structural strength of the shoulder and to prevent the occurrence of defects.
4. The investigation showed that the deformation modulus on the top of the base course of the shoulder varies from 37.9 MPa to 119.5 MPa on the test sections of regional roads (variation coefficient 20%), while on the top of the shoulder structure – from 17.0 MPa to 89.2 MPa (variation coefficient 18.4%). The structural strength of the shoulder should be higher than the strength of shoulder base. It is very important for the shoulders of low-volume roads to use a proper material for increasing the structural strength of the shoulder.

#### References

Butt, A. A.; Carpenter, S. H.; Selim, A. A.; Zimmerman, K. A. 1997. *Evaluation of South Dakota department of transportation's shoulder surfacing in new construction*. Pierre, SD: South Dakota Dept of Transportation; Savoy, IL: ERES International, Incorporated. 153 p.

Calvert, E. C.; Haiar, K.; Wilson, E. M. 1999. Development of a field evaluation guide for unpaved rural roads, *Transportation Research Record* 1652(1): 86–89. DOI: 10.3141/1652-11.

Gintalas, V.; Čygas, D.; Žilionienė, D.; Puodžiukas, V. 2005. Problems of road plan designing when implementing Paving of Gravel Roads Program in Lithuania, in *Proc of the 6<sup>th</sup> International Conference "Environmental Engineering"*: selected

- papers, vol 2. Ed. by Čygas, D.; Froehner, K. D. May 20–27, 2005, Vilnius, Lithuania. Vilnius: Technika, 691–694.
- Gintalas, V.; Čygas, D.; Žilionienė, D.; Puodžiukas, V. 2007. Longitudinal profile of the objects included in the Gravel Roads Paving Programme of Lithuania, *The Baltic Journal of Road and Bridge Engineering* 2(2): 53–59.
- Hedmen, K. O. 1990. *Road design and safety*. VTI Rapport 351A. Swedish Road and Traffic Research Institute, Linköping, Sweden, 225–238.
- Plessis-Fraissard, M. 2007. Planning roads for rural communities, *Transportation Research Record* 1989(1): 1–8. DOI: 10.3141/1989-01.
- Price, D. A. 1990. *Experimental gravel shoulders*. Final report. Report No. CDOH-DTD-R-90-2. Denver, CO: Colorado Dept of Transportation; Washington DC: Federal Highway Administration. 39 p.
- Ranieri, V. 2002. Runoff control in porous pavements, *Transportation Research Record* 1789: 46–55. DOI: 10.3141/1789-05.
- Souleyrette, R.; McDonal, T.; Hans, Z.; Kamyab, A.; Welch, T.; Storm, B.; Anderson-Wilk, M. 2001. [on-line]. *Paved shoulders on primary highways in Iowa: an analysis of shoulder surfacing criteria, costs, and benefits* [cited 5 Sep, 2008]. Available from Internet: <<http://www.ctre.iastate.edu/reports/paved-shoulder.pdf>>.
- Tighe, S.; He, Z.; Haas, R. 2001. Environmental deterioration model for flexible pavement design: an Ontario example, *Transportation Research Record* 1755: 81–89. DOI: 10.3141/1755-09.
- Vorobjovas, V.; Žilionienė, D. 2008. Investigations of low-volume road shoulders, in *Proc of the 7<sup>th</sup> International Conference "Environmental Engineering"*: selected papers vol. 3. Ed. by Čygas, D.; Froehner, K. D. May 22–23, 2008, Vilnius, Lithuania. Vilnius: Technika, 1242–1246.
- Zegeer, C. V.; Stewart, R.; Council, F.; Neuman, T. R. 1994. Accident relationships of roadway width on low-volume roads, *Transportation Research Record* 1445: 160–168.
- Žilionienė, D.; Čygas, D.; Dundulis, K. 2003. Solutions of gravel road renovation based on certain local conditions in Lithuania, *Transportation Research Record* 1819: 267–274. DOI: 10.3141/1819b-34.

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