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RESEARCH, ANALYSIS AND EVALUATION OF ROUNDABOUTS CONSTRUCTED IN LITHUANIA

Daiva Žilionienė[1], Rolandas Oginskas[2], Kazys Petkevičius[3]

[1, 2, 3]*Dept of Roads, Vilnius Gediminas Technical University, Saulėtekio al. 11, 10223 Vilnius, Lithuania*
E-mails: [1]daizil@vgtu.lt; [2]rolog@vgtu.lt; [3]kk@vgtu.lt

Abstract. It was in the year 2001 when Lithuania first started constructing roundabouts on the rural roads of national significance with the heavyweight transit traffic and creating conditions for sustainably safe traffic. A data of statistical analysis shows that Lithuania aims at designing and constructing small roundabouts where the diameter of central island in most cases is higher than the average diameter of 25 m. Design and construction of roundabouts on Lithuanian roads often face the problem of territories. For this reason, the inner and outer radii as well as the entry and exit radii of roundabouts are minimum and do not meet the current requirements. Having studied, analyzed and assessed detail designs of roundabouts it could be stated that the structural defects could be caused not only by the deficiencies of some design standards or recommendations but also by the inaccurate use of current standards what results in taking improper design solutions and technological violations during construction of roundabouts and author and technical supervision create favourable conditions for the initiation of defects.

Keywords: roundabout, inner radius, outer radius, carriageway width, structural defects.

1. Introduction

As mentioned by Antov *et al.* (2009), Čygas *et al.*(2009), Ēalışkanelli *et al.* (2009), Skrodenis *et al.* (2009) and in *Roundabouts: an Informational Guide*, roundabouts may improve intersection safety by:

– eliminating or altering conflicts;
– decreasing speeds into and through the intersection;
– decreasing speed differentials.

Daniels *et al.* (2008; 2009), Elvik (2003) and Persaud *et al.* (2001) states that roundabouts are able to reduce injury crashes considerably, although not for all user groups. The crash severity is strongly dependent of the involved types of road users. Bicyclists represent almost the half of all the killed or seriously injured in multiple-vehicle collisions at the investigated roundabouts. Fatalities or serious injuries in multiple-vehicle crashes for drivers of four-wheeled vehicles at roundabouts are relatively rare (Daniels *et al.* 2010a). The variation in crash rates is relatively small and mainly driven by the traffic exposure. Vulnerable road users are more frequently than expected involved in crashes at roundabouts and roundabouts with cycle lanes are clearly performing worse than roundabouts with cycle paths. Some variables turned out to be no meaningful predictors for the number of crashes in the studied sample, in particular the ones that describe the roundabout dimensions: inscribed circle diameter, central island diameter, road width or the number of lanes (Daniels *et al.* 2010b).

2. Lithuanian roundabouts and their characteristics

It was in the year 2001 when Lithuania first started constructing roundabouts on the rural roads of national significance with the heavyweight transit traffic and creating conditions for sustainably safe traffic. Over the past four years (2005–2008) the number of newly built roundabouts has increased three times compared to 2001–2004. Construction quality of this type of junctions is very important in the aspect of development and reorganization of the Lithuanian road network, also in the aspect of assessing the significance of main and national roads, providing mobility and access services, as their significance is determined by the certain specific features, characteristic to the roads of respective functionality, and by the requirements for ensuring traffic safety on the roads of various functions. Dynamics in the construction of roundabouts is given in Fig. 1.

During the above mentioned period only small roundabouts were built where the average radius of inner circle (central island) was 13.8 m, and in certain roundabouts varied from 7 to 20 m. The absolute frequency histogram and empirical distribution function of inner radius of roundabouts are given in Fig. 2. The ab-

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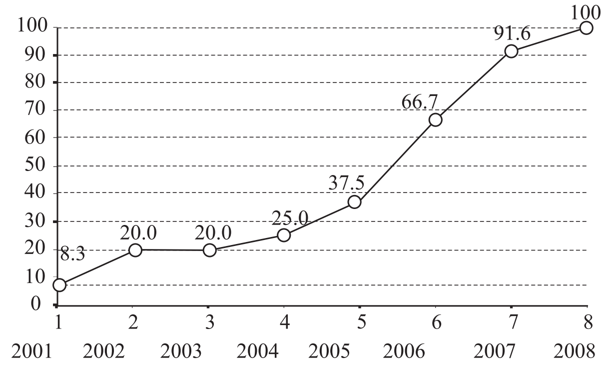

Fig. 1. Dynamics in the construction of roundabouts on the Lithuanian rural roads of national significance in 2001–2008

solute frequency histogram and empirical distribution function of outer radius of roundabouts are given in Fig. 3.

The data of statistical analysis shows that Lithuania aims at designing and constructing small roundabouts where the diameter of central island in most cases (almost 80%) is higher than the average diameter of 25 m.

The results of statistical analysis show that the dimension of outer radius, similarly to that of the inner radius, is often larger than the average dimension calculated for all junctions constructed since 2001. Based on *R 36-01 Automobilių kelių sankryžos* [Automobile Road Roundabounts], the outer circle diameter determines the carriageway width of the circle, including a paved part of inner circle (Fig. 4).

Fig. 4 shows that in most cases the carriageway of roundabouts is narrower than the recommended one. Distribution of roundabouts by the carriageway width is given in Fig. 5.

The absolute frequency histogram and empirical distribution function of the measured carriageway width of small roundabouts are given in Fig. 6.

Fig. 6 shows that the average carriageway width, calculated for all roundabouts, is 5.4 m. The carriageway width is lower than 5.4 m in more than 2/3 rounda-

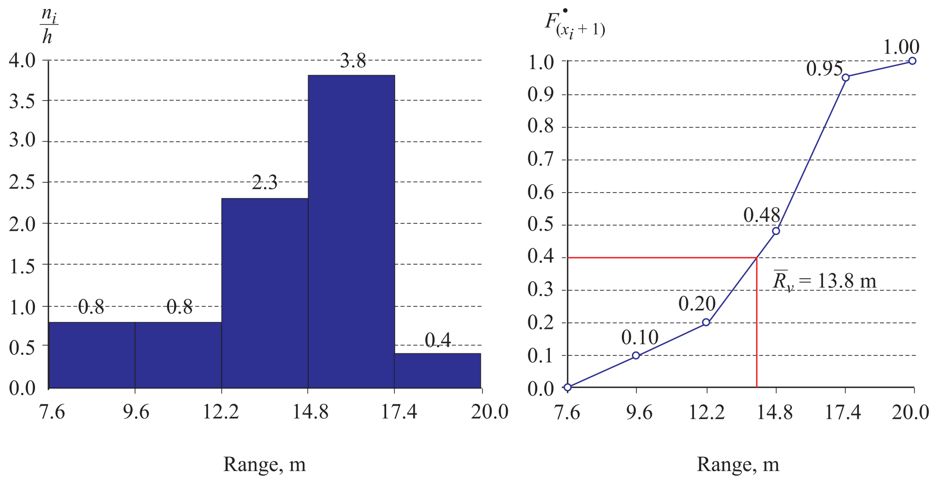

Fig. 2. Absolute frequency histogram and empirical distribution function of the variation in the inner radius of small roundabouts

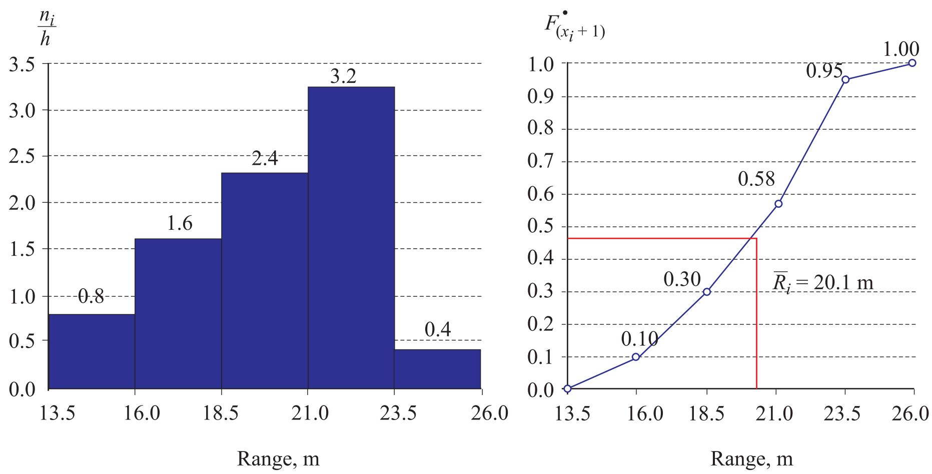

Fig. 3. Absolute frequency histogram and empirical distribution function of the variation in the outer radius of small roundabouts

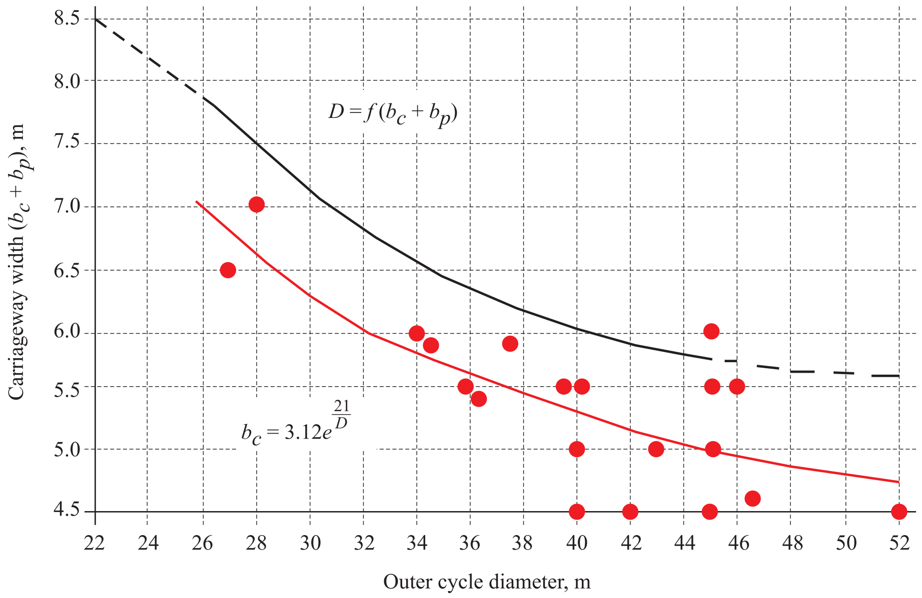

Fig. 4. Relationship between the carriageway width (including a paved part) and the outer cycle diameter: b_c – carriageway width; b_p – paved part of carriageway by chopping-block; D – diameter of outer cycle

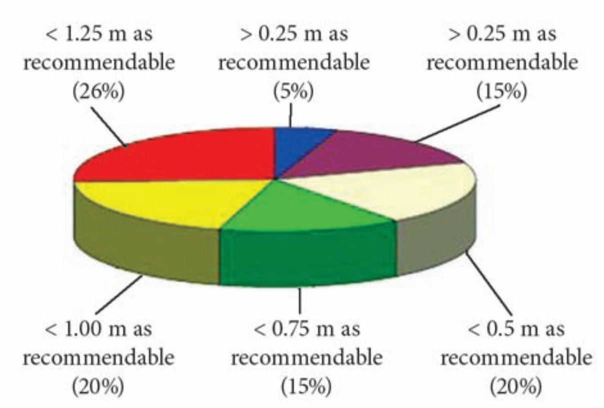

Fig. 5. Distribution of roundabouts by the carriageway width

bouts, and when probability $p = 0.95$ the width varies from 4.5 m to 6.4 m at the variation coefficient of 9%. Tendencies for the decrease in the carriageway width are also indicated by the absolute frequency histogram. If the carriageway is too narrow, it is more complicated to pass through the roundabout, the heavyweight oversize vehicles are forced to ride up on the block pavement, and sometimes even on the road kerbs or pedestrian paths.

Design and construction of roundabouts on Lithuanian roads often face the problem of territories. The areas are often built-up, the adjacent lands are owned by private owners, and therefore, when building new roundabouts or reconstructing traditional junctions into roundabouts the problem of taking of land really exists. Designers must sol-

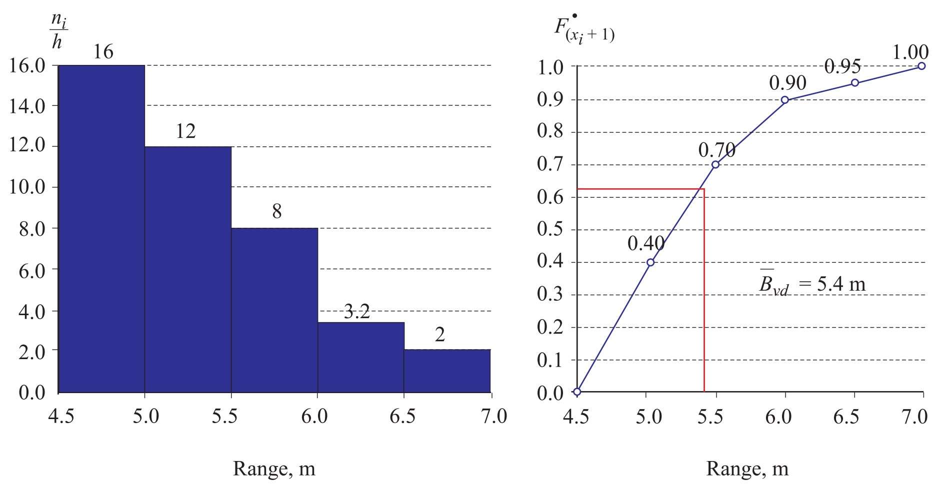

Fig. 6. Absolute frequency histogram and empirical distribution function of the variation in the carriageway width of small roundabouts

Fig. 7. The roundabout where the heavyweight vehicles are not able to make the right turn

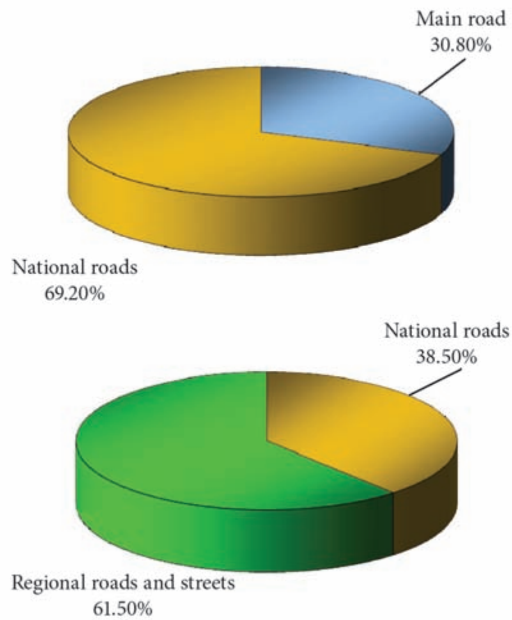

Fig. 8. The share of major and minor roads of roundabouts

ve the question on how to insert roundabouts into existing free territories. For this reason, the inner and outer radii as well as the entry and exit radii of roundabouts are minimum and do not meet the current requirements. One of such cases is shown in Fig. 7 where the heavyweight vehicles entering the roundabout are not able to make the right turn and have to go round the whole circle.

3. Defects of roundabouts and their causes

Importance of the quality of road structures and their elements at the roundabouts could be emphasized by the fact that at present roundabouts are built on the major main and national roads. Since 2001, the major roads of roundabouts consist of main (30.8%) and national roads (69.2%). The minor roads of roundabouts are represented by national (38.5%) as well as regional roads and city streets (61.5%) (Fig. 8).

The process and the speed of structural degradation of roundabout pavements as and roads depend on the designed road structure, the quality of materials used, the condition of water discharge system, the impact of traffic and climatic factors, and on the level of maintenance (Fig. 9) (Grīslis 2010; Juknevičiūtė-Žilinskienė 2010; Petkevičius *et al.* 2010).

Having studied, analyzed and assessed detail designs of roundabouts it could be stated that the structural defects could be caused not only by the deficiencies of some design standards or recommendations but also by the inaccurate use of current standards what results in taking improper design solutions. Technological violations during construction

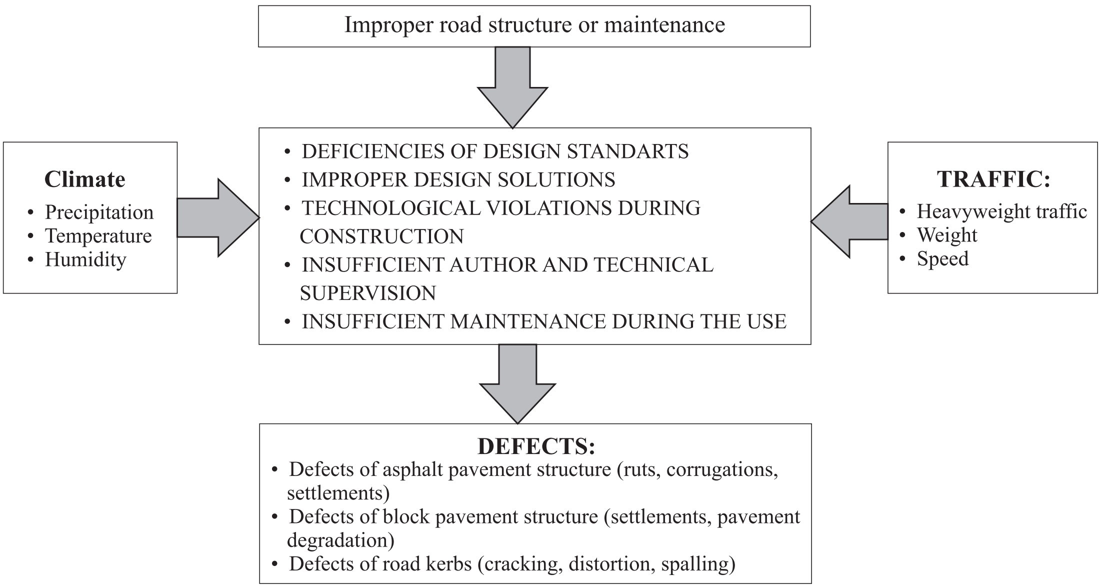

Fig. 9. Structural road defects and their causes

of roundabouts and author and technical supervision create favourable conditions for the initiation of defects.

Destruction of roundabout structures and their structural elements is mainly affected by heavy vehicles the traffic conditions of which differ in different roundabouts.

A different destructive impact of heavy vehicles depends on the size of roundabouts. Dimensions of roundabouts, the width of traffic lanes make influence on the driving speed when entering the roundabout, driving by the circle and exiting it. Traffic volume, driving speed and type of vehicle influence the driving trajectory, also the probability to ride up on the kerbs and the block pavement within the roundabout zone and affect their destruction intensity. In a number of cases vehicles even ride up on the kerbs of central island and destroy them.

The elements of roundabout roads could be destroyed by a poor quality of road structure and its structural elements.

Before reconstruction of a traditional junction into roundabout the pavement structure of intersecting roads shall be dismantled and the structure indicated in the detail design shall be laid. Materials used for the base layers of roads (crushed stone, gravel, sand, gravel sand mixtures) could be used for erecting roadbed or improving subgrade soils. The road structure shall be selected according to the defined loads, i.e. according to the equivalent axle loads of 10 tons.

Investigations showed that most of roundabouts and their elements need no repair. There are 37% of roundabouts where no repair works are necessary. In other roundabouts the various types of repair shall be implemented, i.e.:

- to replace the damaged kerbs – in 15.8% of roundabouts;
- to repair the block pavement – in 5.3% of roundabouts;
- to strengthen base under the kerbs – in 5.2% of intersections.

The least damaged elements of roundabouts are carriageways, road structures and pavement. Pavement on 80% of roundabouts has no defects. It was determined that the road structures of 20% of roundabouts having ruts were designed according to the requirements of construction technical regulations and constructed before the year 2005.

The largest damages were identified on road kerbs. Only 38% of roundabouts have no defects of kerbs, whereas, 48 % of roundabouts have shown small defects of break. On 14% of roundabouts a part of the cracked and distorted kerbs shall be replaced. The block pavement has no defects on 75% of roundabouts. One can find the cracked concrete blocks on 6.2% of roundabouts. The largest problems are related to the quality of laying granite block pavement. The block pavement of 18.8% of roundabouts becomes distorted, uneven, settled, water discharge gets more and more poor.

It happened, though very occasionally, that the roundabout road structure was damaged due to its unconformity to traffic and operational conditions (Fig. 10).

In the course of detail investigations the structural defects of block pavements were determined in some roundabouts (in the outer part of inner circle, in the entry and exit zones) which were caused by the unconformity of designed structures to traffic and structural strength, by the laying of block pavement and selection of the class of block pavement structure. It was determined that in case of unreduced strength of pavement base the block pavements are more sensitive to damages. When vehicles travel on such pavements the joints are subjected to damages (the fine filler of joints is pumped out), the blocs are moved off and in some cases even thrown to the surface, the pavement is destroyed, the settlements occur, the pavement profile is distorted, the pavement depressions accumulate water and the lower pavement structural layers are more intensively dampen (Fig. 9).

Fig. 10. Road structures damaged due to their unconformity to traffic and operational conditions

Fig. 11. The damaged block pavement on the widened carriageway

The block pavement of sidewalks is damaged if it is laid on a weaker base without a crushed stone base layer. If the sidewalk of sufficiently strong block pavement is run on the blocks are not damaged.

The mostly damaged elements are road kerbs both in the outer and in the inner part of the roundabout. They happen to be damaged even in a case when the block pavement structure has a sufficient strength (Fig. 11). The road kerbs become distorted (mostly in a part of the inner circle, the cracked or broken kerbs also could be find). Almost on all roundabouts the kerbs showed degradation defects, the damages of edges and other concrete surfaces. It was determined that the less damaged are the kerbs of safety islands. Characteristic damages of road kerbs are given in Figs 12 and 13.

Fig. 12. Characteristic damages of road kerbs

Fig. 13. The damaged road kerbs by riding up on the block-paved circle, the broken inner road kerbs at joints

When laying road pavement structures one shall keep to the detail design in order to avoid cases when the newly laid crushed stone base is covered with a several centimetres thick sand layer.

The block pavement shall not be preceded by the sublayer of crushed stone siftings the thickness of which is more than 3 cm. The thicker sublayers could be the cause of unevenness and the occurrence of other defects in block pavement.

The road kerbs of roundabouts shall be installed on concrete base having the corresponding height support from both sides of the kerb. Otherwise, when vehicles ride up on the kerbs they move off, break or crack at joints.

It is necessary to not only properly lay concrete bases under the road kerbs but also to properly supervise the setting of concrete.

4. Conclusions

Having studied, analyzed and assessed the detail designs of the already constructed roundabouts, having made the analysis and assessment of defects, identified during visual inspection, it could be definitely stated that there are two causes of the roundabout structural defects: improper road structure or maintenance during the use of roundabout.

Investigations of roundabout defects and of their causes suggested a conclusion that it is necessary to give recommendations for designing and constructing the stable and long-term road structures of roundabouts. Based on the Lithuanian and foreign experience and taking into consideration the geological and hydro geological conditions of Lithuania, the impact of heavyweight vehicles and climatic factors the recommendations could be given for the structures of sufficient strength and for the use of materials on the roundabouts to be constructed in future.

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