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Denisa CIHLÁŘOVÁ[1], Tomáš SEIDLER [2]

ANALYSIS OF DYNAMIC THROUGH MOVEMENT ON ROUNDABOUT

ANALÝZA DYNAMICKÉHO PRŮJEZDU OKRUŽNÍ KŘIŽOVATKOU

Abstract

Dynamic roundabout vehicle path is according to U.S. standards one of the parameters used to prove the validity of roundabout design. Under Czech law is roundabout design verification based on possibility of roundabout design vehicle path. But the question is whether the only a verification is enough especially if traffic is increasing [1]. The article is devoted to the analysis of dynamic roundabout vehicle path. Article dealt with the speed of through movement on roundabout, depending on the radius of the characteristic roundabouts points. In situ measurements were made on selected single-lane, four-leg roundabout. The aim of this work is to evaluate selected roundabout in terms of the dynamics vehicle path and then find out how much corresponds theoretical dynamic vehicle path to the real one.

Keywords

Roundabout, radius, speed, geometric parameters, roundabout design, dynamic vehicle path.

Abstrakt

Dynamický průjezd okružní křižovatkou je podle USA standardů jeden z parametrů, kterým se prokazuje správnost jejího návrhu. Dle českých předpisů stačí pouze návrh okružní křižovatky ověřit na prostorovou průjezdnost požadovaným návrhovým vozidlem. Ovšem otázkou zůstává, zda je pouze ověření prostorové průjezdnosti při stále zvyšujících se intenzitách provozu dostačující [1]. Tento článek se věnuje právě analýze dynamického průjezdu okružní křižovatkou. Řešena je rychlost průjezdu okružní křižovatkou v závislosti na poloměru v charakteristických bodech okružní křižovatky. Měření in situ probíhala na vybrané jednopruhové čtyřramenné okružní křižovatce. Cílem této práce je posoudit vybranou okružní křižovatku z hlediska dynamiky průjezdu a následně zjistit, jakou měrou odpovídá reálný dynamický průjezd teoretickému dynamickému průjezdu.

Klíčová slova

Okružní křižovatka, poloměr, rychlost průjezdu, geometrické parametry, návrh okružní křižovatky, dynamický průjezd.

1 INTRODUCTION

Still popular roundabouts contribute to safer and smoother road traffic. Design procedure of roundabout isn't clearly defined. Standards, technical specifications and design manuals of different countries describe various procedures [1] [3] [4] [5] [6] [7]. Worldwide studies mostly analyse

[1] Ing. Denisa Cihlářová, Ph.D., Department of Transport Constructions, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 33 Ostrava, tel.: (+420) 597 321 981, e-mail: denisa.cihlarova@vsb.cz.

[2] Ing. Tomáš Seidler, Ph.D., Department of Transport Constructions, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 33 Ostrava, tel.: (+420) 597 321 981, e-mail: tomas.seidler@vsb.cz.

accidents on roundabouts according to their geometrical parameters [8] [2]. We can find roundabouts mostly in urban areas so the spread of emissions isn't negligible factor to [9]. Roundabout design should be also adapted to the movements of pedestrians and cyclists [10]. These groups of road users are more vulnerable in terms of severity of injury [11]. It is also important to ensure a comfortable and safe driving through the roundabout; it means roundabout should be modelled for required performance for example by interpolation methods using geostationary estimation methods [12]. Respecting all input factors should not be violated principles assuming a slow entrance and fast exit of roundabout in the spirit of "safety/performance principle" [13].

As above the functional design of roundabout is dependent on various parameters. Their mutual dependence is the subject of many studies and their results should be reflected in standards, technical specifications or design manuals.

2 ANALYZED OBJECT

For solution was chosen single-lane four-leg roundabout. Four-leg roundabout was chosen because the three-leg roundabouts are considered riskier according to [10]. It can be concluded that the size and arrangement represents the most commonly used type of roundabout in Czech Rep. Roundabout is located in the city of Ostrava, Pustkovec district, at the intersection of 17. Listopadu street (road II/469) and Bedricha Nikodema street. Roundabout inscribed circle diameter is 35 m and central island diameter is 10 m. Roundabout was put into operation in September 2008. Before the roundabout construction were reported 13 accidents per year at the site. After roundabout realization there were in the period 2009-2011 reported 4 accidents. It is obvious that the roundabout implementation greatly increased safety.

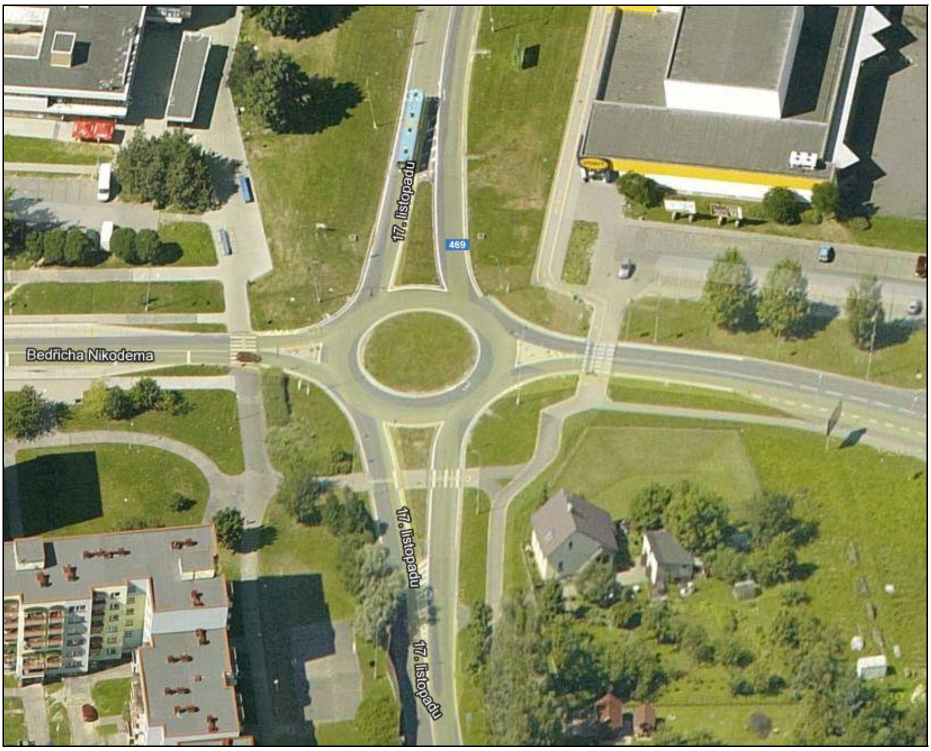

Fig. 1: Solved roundabout situation (source: maps.google.com)

2 SOLUTION DESCRIPTION

Assessment of theoretical dynamics of vehicle paths

Dynamic vehicle path proves by compliance of vehicle speed comparing with the fastest (ideal) vehicle path. For this need was assumed solution of ideal vehicle path from [3]. This standard defines five characteristic radii on three basic manoeuvres in roundabout.

Roundabout was processed using CAD software, for ideal vehicle path determination in all basic manoeuvres. These radii were converted into speed in particular characteristic points. Radii and parameters of ideal vehicle paths are shown in fig. 3. Conversion of the radius to the speed of vehicles was performed according to [3].

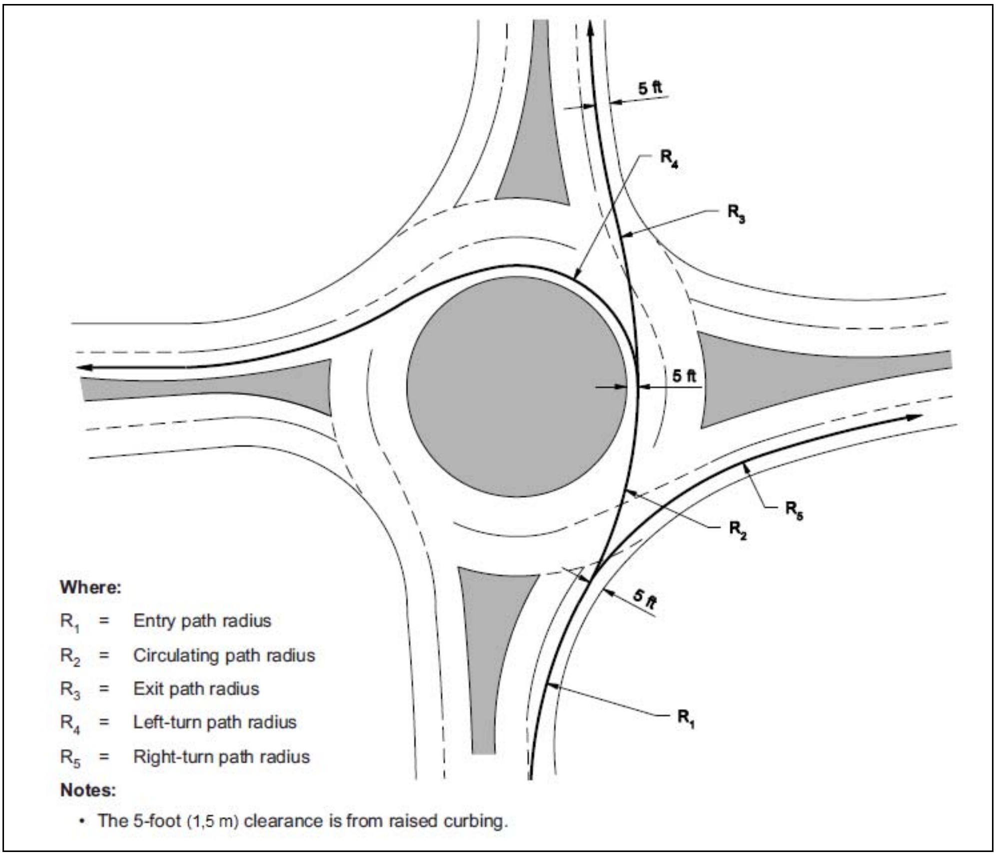

Fig. 2: Fastest path Radii [3]

$$V_i = \sqrt{(127 \cdot R_i \cdot (0,01 \cdot p + f))} \qquad (1)$$

where:

V_i – speed in characteristic point [km/h],

R_i – characteristic radius [m],

p – superelevation [%],

f – transverse friction coefficient.

Speeds were calculated for p = 2,5% and f were set according to the design speed of roundabout, where for R ≤ 25 m; f = 0,19

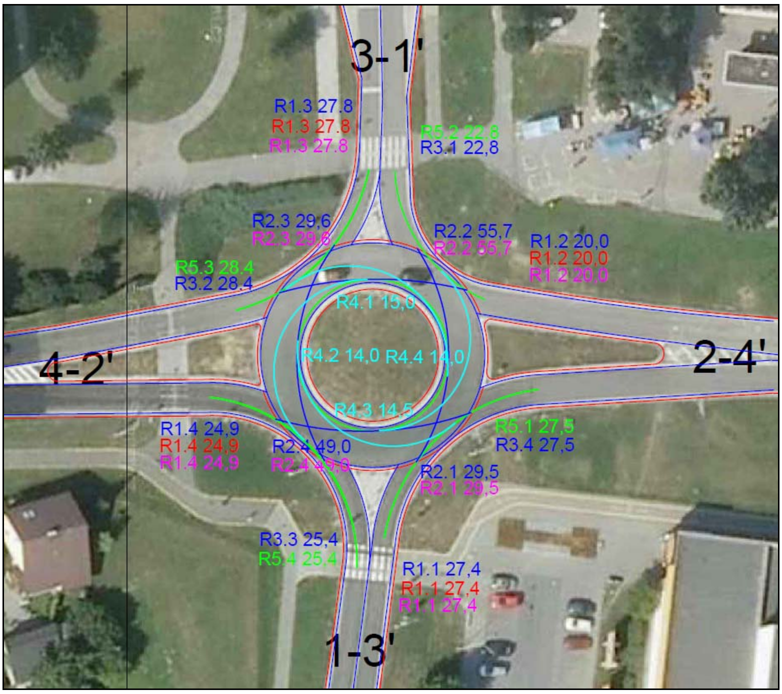

Fig. 3: Highlighted vehicle paths and characteristic radii

Real dynamic of through movement

In this case, were done in situ survey of measuring of characteristic points in the roundabout (see Fig 5). The survey was conducted on Monday, 21st May 2012 in time from 17:30 to 22:00. Survey interval was chosen to not be influenced by any daily rush hour. Since the aim of the survey was not vehicles counting or intensity, but only their speed passing through intersection (can be considered as the ideal vehicle path). Measurements were performed manually by radar Bushnell Speedster II.

For the survey were selected four basic observations on the roundabouts legs for passing vehicles speed measurement (see Fig 4). Each vehicle paths were marked by the entry roundabout leg marking and according to the performing manoeuvre:

- VP right turn,
- VL left turn,
- P straight direction.

The measurements were also divided according to the exit leg marking. Each radius is labelled by index, where first index determine characteristic point and the second index indicates the number of entry leg. I.e. at the observation 4' were measured speeds in these radii characteristics points:

- 4P – $R_{1,4}$, $R_{2,4}$, $R_{3,4}$
- 4VP – $R_{1,4}$, ($R_{5,4}$ - site 1´)
- 4VL – $R_{1,4}$, $R_{2,4}$, ($R_{4,4}$ - site 3´)
- 3VL – $R_{4,3}$
- 1VP – $R_{5,1}$

There were measured enough data in all direction to obtain representative sample.

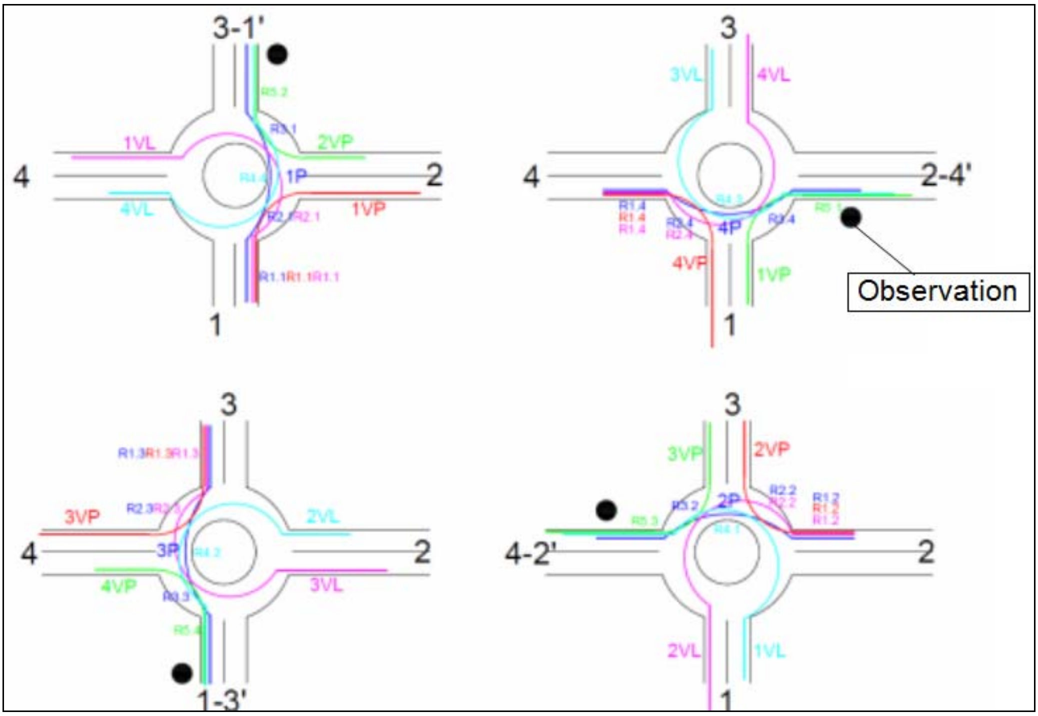

Fig. 4: Marking of survey observations and vehicle paths

Fig. 5: Stabilisation of characteristics points on roundabout

3 RESULTS

As already mentioned, the theoretical dynamic through movement as well as or real one is demonstrated by comparison of vehicle speed driving through ideal vehicle path. Defining relations between the speeds are listed in Table 1. To ensure compliance must be valid that the speed difference between the successive radii should not be higher than 20 km / h, preferably less than 10 km/h.

Assessment of theoretical through movement

Tab. 1: Evaluation of theoretical through movement

Vehicle direction	Speed difference Dvt	Leg 1	Leg 2	Leg 3	Leg 4
		[km/h]	[km/h]	[km/h]	[km/h]
Straight direction:	V1-V2	1	16	1	16
	V2-V3	3	11	2	9
Right turn:	V1-V5	0	2	0	0
Left turn:	V1-V2	1	16	1	10
	V2-V4	8	20	9	17

The results, (see table 1) shows that the legs 1 and 3 in terms of dynamics movement through meet, while the legs 2 and 4 meet only in right turn direction. At the same time it can be said that the opposite legs are structurally solved similarly.

Real through movement

During the survey, there were recorded 544 speeds. For each characteristic point of the vehicle path of a roundabout leg was determined average speed. Results of real dynamics through movement are listed in table 2. According to actual speed measuring, it was found that in terms of the dynamics through movement on the roundabout meet.

Tab. 2: Evaluation of real through movement

Vehicle direction	Speed difference Dvt	Leg 1	Leg 2	Leg 3	Leg 4
		[km/h]	[km/h]	[km/h]	[km/h]
Straight direction:	V1-V2	7	10	9	5
	V2-V3	4	1	2	4
Right turn:	V1-V5	1	5	2	3
Left turn:	V1-V2	9	9	9	8
	V2-V4	2	1	1	1

Assessment of both, real and theoretical dynamic of through movements shows figure 6. Here are shown the limits for acceptable speed difference. Out of these limits there are 6 theoretical speed differences. These results suggest that in case of a theoretical assessment has the radius of the vehicle path largest share of the exceeding the limit. The red curve describes the ideal condition, ie. a case where the theoretical values correspond to the real values.

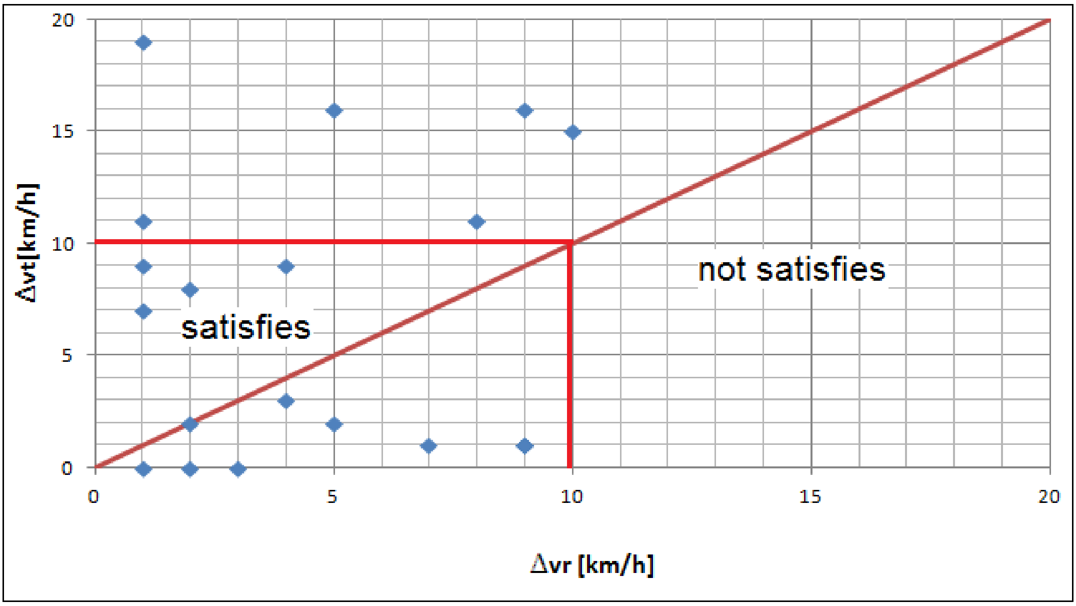

Fig. 6: Evaluation of real and theoretical dynamic of through movement

3 CONCLUSION

Solved roundabout failed in terms of theoretical dynamic through movement, but meet of real dynamic through movement. In case of design of this roundabout this result means the need for redesigning of the roundabout according to the conditions by [3]. Applying this procedure to Czech standards are currently appears to be unnecessary, even in [1] recommend this procedure. It should be noted that the conclusions of [1] are not derived from in situ observation. There could be many reasons why theory doesn't meet the reality. One of them may be the fact that the fastest track of driving through actually chosen by drivers, does not match to the designed one as described in [3] (goes through truck apron, does not meet the required clearances from curbs, etc.). To exclude or confirm this hypothesis should be done more observations in the next stage.

Another reason may be the time of observation, because there may not have been fully met the requirement for a condition when movement of car can't be affected by other movements of cars. It can be concluded that the roundabout design verification in terms of geometric through movement is sufficient.

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Reviewers:

Ing. Michal Radimský, Ph.D., Institute of Road Structures, Faculty of Civil Engineering, Brno University of Technology.

Ing. Michal Uhlík, Ph.D., Department of Road Structures, Faculty of Civil Engineering, Czech Technical University in Prague.