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FAMILY OF THE ROAD SIGNS MASTS VALIDATION IN ACCORDANCE TO EN 12767

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Abstract: *Occupant safety during car accidents is to a large degree dependent on road infrastructure behavior. For safety reasons, this type of infrastructure is designed taking into account legal requirements. The paper presents part of the process of certification of the road signs masts family accordingly to EN 12767. In the work, experimental results and numerical calculations of the crash test are presented. A comparison of numerical and experimental data is used in the validation process of developed methodology for preparing numerical models.*

Keywords: LS-Dyna, Road infrastructure, EN 12767, Crash test.

1. Introduction

Due to constantly growing traffic and as the highways with a high-speed limit are widely available the probability of road accidents increases. In such ways, the safety of the vehicle occupants is highly dependent on the road infrastructure. Nowadays all objects which are placed in the vicinity of the road must meet certain requirements. Some of them have been introduced in 2007 within the standard EN 12767 (2007). Increasing the passive safety of passengers by adapting or designing the road infrastructure accordingly to requirements of EN 12767, among other legal regulation and activities in road safety measures, can significantly reduce injuries in the event of a crash From 2007 to 2016 according to the Annual Accident Report of the European Commission (2018), the number of fatalities caused by car accidents decreased by about 20 %. The annual number of injury accidents in the Czech Republic in 2007 was 23 060 and this number decreased to 21 386 in 2016. For the whole of Europe, the decrease was from 1.3 to 1 mln. In work (Vilan et al., 2005) the study aimed to develop a new non-energy-absorbing anchorage system. The results presented there indicate a decrease in primary injuries with the employment of this system. The design processes of such innovative structures are usually supported by the use of numerical calculations. In the work (Soltani et al., 2017), numerous numerical calculations were carried out to test various concepts of guardial system.

The main goal of this work is to present part of the process of certification of road infrastructure accordingly to EN 12767. The authors explain the concept of the family of products in relation to road signs masts. Then indicate the most important parameters, which are decisive in the certification process. Against this background, present results of the experimental tests for selected family members. The authors performed numerical calculations on the basis of experimental data. A comparison of the numerical and experimental results allows validating the developed methodology for preparing numerical models. Based on the validated methodology, numerical analyzes were conducted prepared for all family members.

2. Test object and conditions

By the word the family is meant that all constructions within the family are the same type, build with the

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same material based on the same project but different dimensions. The whole family has to have the same mechanism of deformation or part separation. The family under investigation was designed to support road signs of different sizes. There were four members of the tested family. The main difference between them was the area of the road sign: 2.25 m^2, 4.6 m^2, 7.3 $m^{2,}$ and 9.7m^2. Therefore the diameter of the rods of the supporting mast could be reduced. If we consider the diameter of the rods of the biggest mast as 1, the rods of the other members are smaller by the ratio respectively 0.9, 0,8 and 0.75. That helped to reduce the mass of particular family members from 430 kg for the mast 9.7 m^2 to 70 kg for the mast 2.25 m^2. This led to the design of the structure not being oversized and cost reduction. The aim for the whole family was to reach a high level of passive safety. The structures tested were manufactured by Tioman Sp z o.o. Sp. k. in Poland.

3. Test parameters and classification requirements

The velocity of the vehicle during the test depends on where the structure will be used and what speed limit applies there. The manufacturer specifies the appropriate velocity class for the construction. Due to that class crash tests are conducted with two velocities selected accordingly. There are three velocity classes in the norm: 50, 70 and 100 km·h^{-1}. For the presented family of products, the highest velocity class was selected. Therefore the experiment was conducted with a velocity of 35 and 100 km·h^{-1}.

Support structures are classified accordingly to the energy absorption class during impact. There are three categories of energy absorption for the constructions. High energy absorption (HE), low energy absorption (LE), and No energy absorption (NE). In order for the structure to qualify for a specific class, the vehicle speed after a collision v_e should be within a strictly defined range. All categories and allowable velocity drops for the 100 km·h^{-1} velocity class are shown in Tab. 1.

Tab. 1: Energy absorption class for 100 km·h^{-1}velocity class.

Velocity class, km·h^{-1}	100
Energy absorbtion class	**Exit velocity, v_e, km·h^{-1}**
HE	$5 < v_e \leq 50$
LE	$50 < v_e \leq 70$
NE	$70 < v_e \leq 100$

Road infrastructure is supposed to be classified in terms of occupant's safety based on Acceleration Severity Index (ASI) and Theoretical Head Impact Velocity (THIV) parameters. ASI is the value calculated on the basis of car acceleration in three axis due to EN 1317-1. THIV is the value of velocity in km·h^{-1} at which a hypothetical passenger hits the surface of the hypothetical passenger compartment. The values of these parameters are crucial and may indicate how much the consequences of an accident will be felt for passengers (Pawlak, 2016). Those indexes are measured at reference points that are located in the vehicle, which assumes that passengers are permanently tied to the vehicle by fastened seat belts (Eppinger et al., 1999). Occupant safety classes are shown in Tab. 2.

Tab. 2: Occupant safety class.

Energy absorption class	**Occupant safety class**	**Velocity**			
		Low-velocity test 35 km·h^{-1}		High-velocity test 100 km·h^{-1}	
		Maximum values		Maximum values	
		ASI	**THVI, km·h^{-1}**	**ASI**	**THVI, km·h^{-1}**
HE / LE / NE	E	1	27	1,4	44
HE / LE / NE	D	1	27	1,2	33
HE / LE / NE	C	1	27	1	27
HE / LE / NE	B	0,6	11	0,6	11
NE	A	No test	No test	Without ASI and THIV data	

4. Experimental test

For the certification process, only the smallest and biggest members of the family have to be tested experimentally. The velocity class of 100 km·h^{-1}. was selected, so for each structure two tests with a velocity of 35 and 100 km·h^{-1} were conducted. In summary, four tests were performed. Exemplary results of the experimental test for the biggest mast with the highest velocity are presented. Experimental tests were conducted at the accredited road safety test facility Transpolis located in Lyon, France.

Fig. 1 depicts the vehicle before and after the crash test of the mast 9.7 m^2 with a velocity of 100 $km \cdot h^{1.}$ Fig. 2 depicts the recorded values of ASI and THIV for the same mast. During the test, the vehicle velocity decreased from 100 $km \cdot h^{-1}$ to 77.6 $km \cdot h^{-1}$.

a) b)

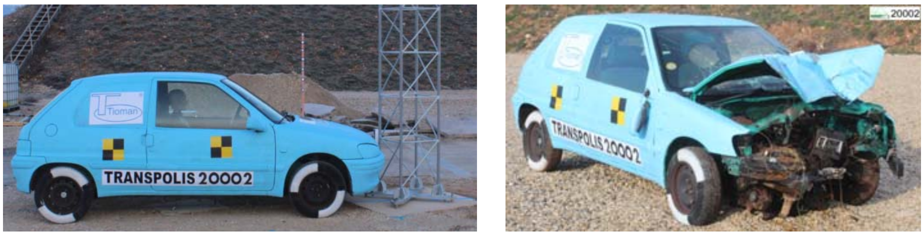

Fig. 1: Experimental test of the mast 9.7 m^2 with a velocity of 100 $km \cdot h^{-1}$: a) initial state;, b) final state.

a)

b)

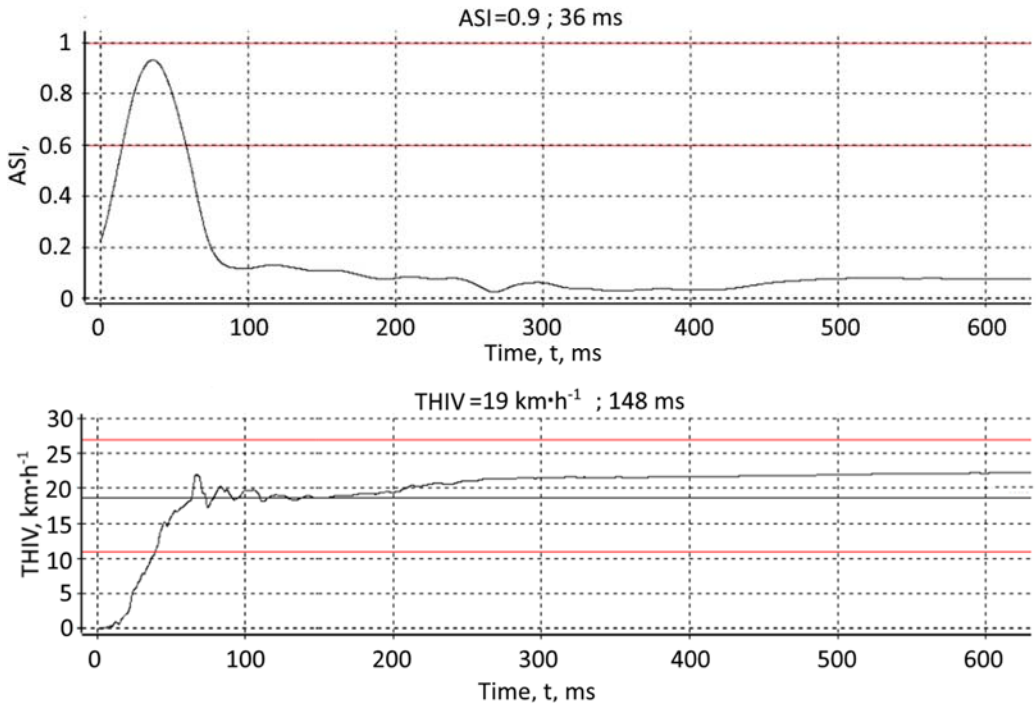

Fig. 2: Data collected during the crash test with mast 10 m^2 with a velocity of 100 $km \cdot h^{-1}$: a) ASI; b) THIV.

During the test velocity of the vehicle decreased by 2.1 $km \cdot h^{-1}$ and as in Fig. 2 depicts ASI index has reached a value of 0.9 and the THIV parameter value was 19 $km \cdot h^{-1}$. Therefore the result of the conducted research leads to the classification of the structure into NE class of energy absorption and C class for occupant safety (Tab. 2).

5. Numerical analysis

The model was prepared in LS-PrePost and solved with LS-Dyna R7.1 solver The process of preparing a numerical simulation of such an object may be complex, therefore should be divided into steps that allow recognizing different phenomena that can occur during the crash test. The process of bolts failure was crucial to construction behavior. In the paper (Stopel et al., 2017) the authors prepared an extensive analysis of modeling bolt connection and pre-loading. Other phenomena that were examined before whole model preparation was the change in material properties due to the high strain rate which occurs during impact structure (Stopel et al., 2018). Not considering these changes may have led to an oversized or too week. Not less important was the process of selecting the proper size of the mesh and element type in the model.

There are areas with high stress concentration for example on the edge of the holes in base plates (Cichański 2011).

The numerical model of mast 9.7 m^2 for a test with a velocity of 100 $km \cdot h^{-1}$ is shown in Fig. 3. In total there were 95 120 elements, 131 117 nodes, 8 materials models, and 13 contacts between parts. The total computation time for one case was 15 hours with the usage of 11 CPUs. Comparison of numerical and experimental results in, Figs. 2b and 3b show the similarities in the vehicle body deformation.

a) b)

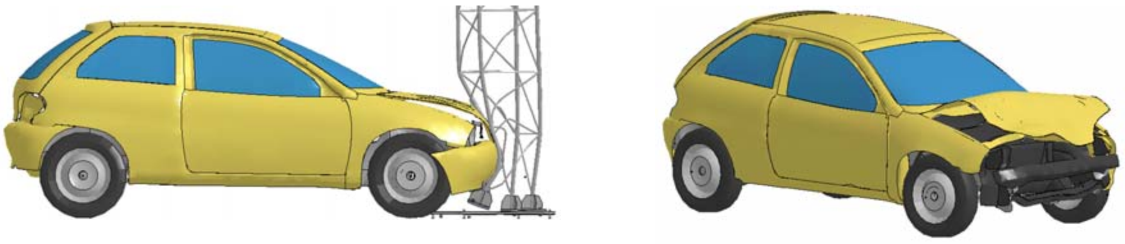

Fig. 3: Numerical model: a) during the crash; b) final state.

Based on a comparison of numerical calculations and experimental results for masts 2.25 m^2 and 9.7 m^2 validation of the developed methodology for preparing numerical models was carried out. In conformity with the formulated algorithm numerical models for the remaining masts: 4.6 m^2 and 7.3 m^2 were prepared. The analyzes carried out with the use of these models confirmed that also masts 4.6 m^2 and 7.3 m^2 can be classified into NE class of energy absorption according to the standard EN 12767.

6. Conclusions

All members of the family of road signs masts considered in the study showed a high degree of passive safety within the meaning of the standard EN 12767. The experimental tests are the most complex part of the certification process. The collected data during the experimental tests can be used in the process of evaluating the methodology of preparing a numerical model. The numerical calculations performed with use models developed based on the validated algorithm made it possible to evaluate the behavior of the masts for which not performed experimental tests. The numerical simulation of all construction can ensure hat the projected solution will work expectably in all structures without having to incur large expenses related to the experimental studies.

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