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Professional paper

Application of the MKS EN1317 on the roads of the Republic of North Macedonia

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Abstract – **The paper contains a comparison of the previous standard for use of elastic guardrail with the newly applied. The comparison will identify the advantages and disadvantages of both standards regarding the type of the materials, installation, designer approach and maintenance. In addition, comparison will be conducted regarding the safety aspect via constructed test sections.**

Keywords – **Disadvantages, Materials, Guardrail, Advantages, Comparison.**

I. INTRODUCTION

The guardrail, as part of the vehicle restrain system, is the most frequently applied element of the traffic equipment on the roads, which directly and considerably influences the achievement of passive safety of traffic.

The initial application of the new guardrail standard in Macedonia started as a recommendation in the road safety audits (Road Safety Audit – RSA) where the auditors gave initial directions to the designers on how to increase road safety by applying EN 1317. Of course, the experts did not initially considered these directions as serious because an applicable road safety standard had already existed in Macedonia and was considered than more than reliable.

The background for the introduction of the recommended standard opened only recently, with the increased number of road accidents where the inspection identified shortcomings in the guardrail. The application started with the elaboration of the Technical instruction on the application of the vehicle restrain on the roads in Macedonia, enabling for overall application of the MKS EN1317 standard, adopted as far behind as in 2011. A short comparative analysis of the two standards will be presented in this paper.

II. CHARACTERISTICS OF MKS U.S4

The MKS U.S4 standard in Macedonia was inherited by the previous JUS U.S4 one which was initially taken from the German standard of DIN.

- U.S4.100 – The technical conditions for the fabrication and delivery of steel guardrails (A and B profile). These conditions refer to the material of which the guardrail is fabricated and its general structural characteristics, as well as of their making and form, joints, surface protection, packing and delivery. This standard is based on the German document of RAL-RG 620: 1972, however allowing for certain modifications in view of adjustment to the than Yugoslav market. Those modifications refer to the IPE 100 pillar and the sigma (RAL), with the possibility to replace it by a U 1200 profile and a profile C spacer, with the features nearest to the profiles available on the domestic market. All tin-made parts are fabricated of C0361 steel, whereas the hardness of the bolts is of 8.8. The surface protection refers to class 2 steel constructions (other open air constructions) finally precised by the steel standard. The final parts, pillars and spacers are marked with the sign of the manufacturer, as per U.S4.108 the year and the month of fabrication [1].
- U.S4.104 – Guardrail and concrete bumpers - terms, definition and classification. This standard includes the basic terms regarding railings, general classification of railings, classification and marking of guardrails.

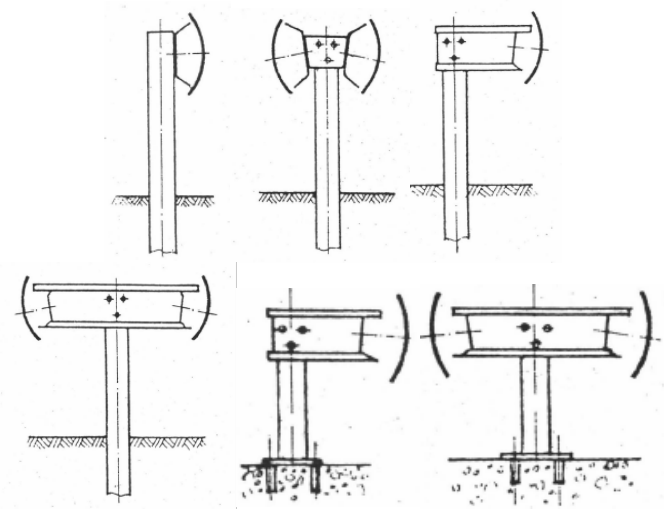

Figure 1. Classifications of steel guardrails
Source: MKS U.S4

This standard gives an detailed explanation of the steel guardrail type and of the concrete bumpers and presents the abbreviated terms that would be used upon design and effectuation. [2].

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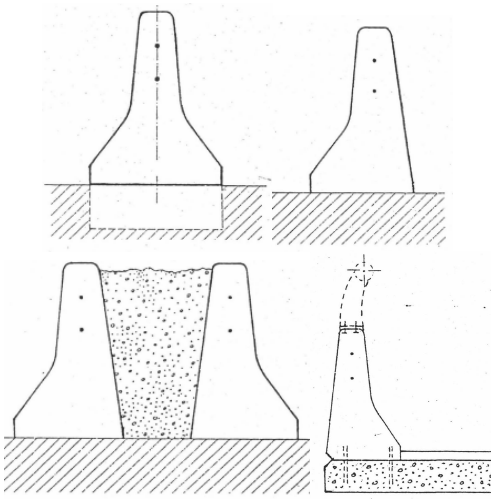

Figure 2. Classification of protective concrete bunkers (New Jersey) Source: MKS U.S4

- U.S4.108 – Form and dimensions of the steel guardrail (profile A and B). This includes the exact dimensions of each separate elements, the connection and the assembly, and a presentation of the dimensions of the constructed guardrail [3]

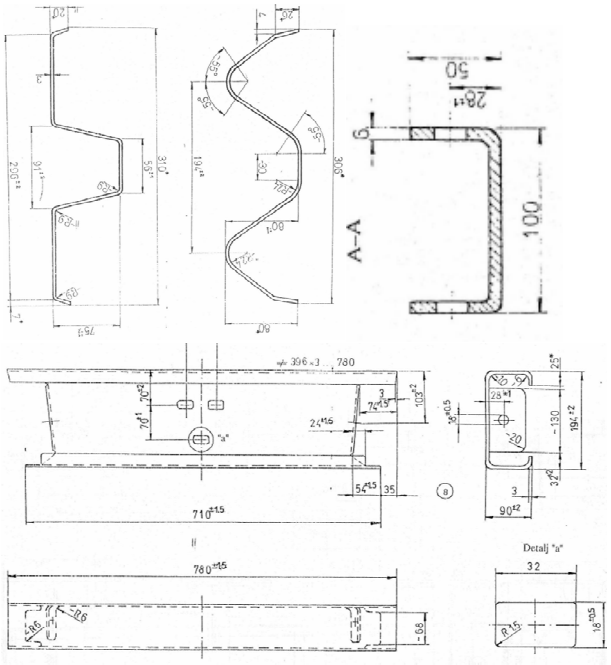

Figure 3. Form and dimensions of guardrail parts. Source MKS U.S.4.

- U.S.4.110 – Technical conditions and method of placement. This standard refers to the conditions and method of placement on locations that have to be protected in situation and in cross-section [4].

Table 1. Guardrail lengths before/after the point of danger

Road type	Before the danger point (m)	After the danger point (m)
Motorways and first category roads	min. 48 (60)	min. 12 (18)
Second category roads	min. 36 (48)	min. 24
Third category roads	min. 24 (32)	min. 18
Fourth and fifth category roads	min. 16	min. 12
Note: The values in brackets are the priority lengths:		

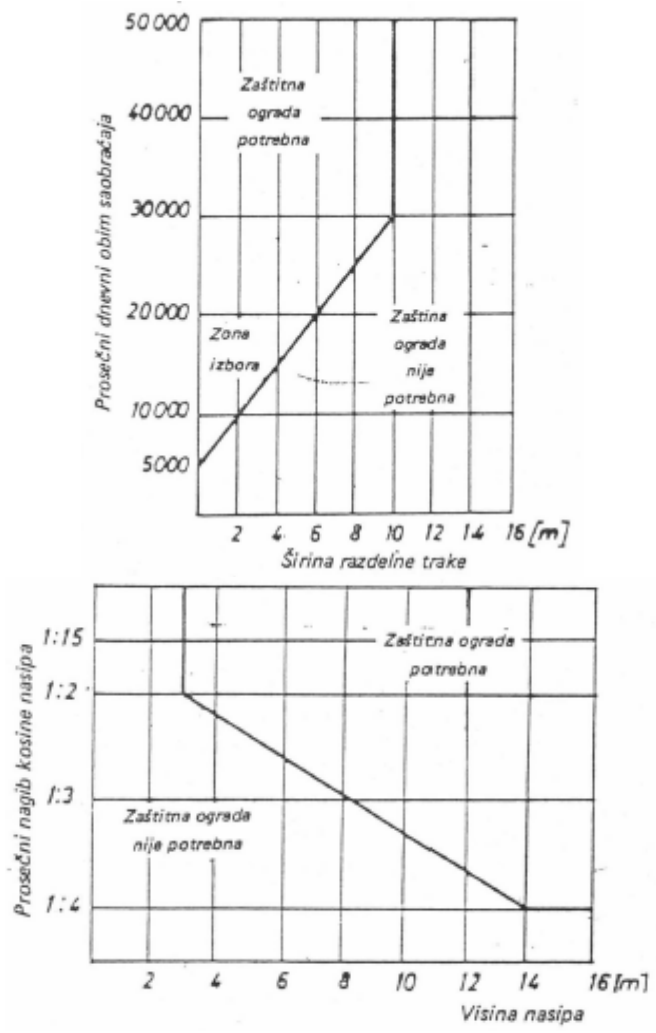

Figure 4. PGDS diagram/dividing lane and Inclination/Embankment height. Source: MKS U.S4

III. MKS EN 1317

In relation to MKS U.S4, and led by the latest standard of 110 treating the placement of the guardrail, a comparison has been made with the newly applied standard od EN1317 in which the guardrail is generally placed according to the same principles in cross-section and in a layout plan. Therefore, the description

of EN1317 shall not refer to placement part, but only analyze the structural, safety and administrative preconditions.

Besides it basic function of protection of vehicle passengers against hard consequences of deviation from the lane because of the possibility of a crush into a dangerous obstacle or dashing off the road, this standard also refers to the necessary special protection of third persons or areas along the road as well as on the motorways for protection against traffic from the opposite direction.

The main criteria for evaluation of the efficiency class of the protective systems pursuant to the MKS EN 1317-2 are the following:

- Restrain level,
- Action area,
- Crush intensity level.

The restrain level refers to the durability of a system of protection of vehicles against crush depending on the vehicle mass, the crush angle and velocity.

Table 2: Protective devices – crush test criteria (MKS EN 1317–2)

Analysis	Crush velocity	Crush angle	Total vehicle mass	Vehicle type
TB 11	100 km/h	20º	900 kg	Pass. vehicle
TB 21	80 km/h	8º	1300 kg	Pass. vehicle
TB 22	80 km/h	15º	1300 kg	Pass. vehicle
TB 31	80 km/h	20º	1500 kg	Pass. vehicle
TB 32	110 km/h	20º	1500 kg	Pass. vehicle
TB 41	70 km/h	8º	10000 kg	Heavy vehicle
TB 42	70 km/h	15º	10000 kg	Heavy vehicle
TB 51	70 km/h	20º	13000 kg	Bus
TB 61	80 km/h	20º	16000 kg	Heavy vehicle
TB 71	65 km/h	20º	30000 kg	Heavy vehicle
TB 81	65 km/h	20º	38000 kg	Tow truck

Table 3: Protective devices – restrain levels (MKS EN 1317 – 2)

Restrain levels	Adequate testing
Normal restrain capacity N1 N2	 FV 31 FV 32 and FV 11
Higher restrain capacity N1 N2 N3	 FV 42 and FV 11 FV 51 and FV 11 FV 61 and FV 11
Very high restrain capacity H4a H4b	 FV 71 and FV 11 FV 81 and FV 11

The standard defines three basic levels of restrain resulting from the appropriate crush test of the adequate vehicle.

In order to provide for the basic level of protection and define the safety areas behind the guardrail upon the choice of a protective system it is also necessary to determine the action area, W, which is the distance between the front of the protective system and the maximal lateral position of each physical obstacle.

Figure 5. Action area. Source: MKS EN1317

Table 4: Protective devices – action area levels (MKS EN 1317–2)

Classes of action area	Level of action area
W1	W ≤ 0,6 m
W2	W ≤ 0,8 m
W3	W ≤ 1,0 m
W4	W ≤ 1,3 m
W5	W ≤ 1,7 m
W6	W ≤ 2,1 m
W7	W ≤ 2,5 m
W8	W ≤ 3,5 m

Crush intensity level is a theoretical feature to evaluate the body strain, the injury level or the mortal danger of the car passengers upon crush into a vehicle restrain system. The value of the ASI index is a given crush of a certain weight in a percentage of the driver's weight suffered through a metal rail.. It is calculated by the following formula:

$$ASI = \max[ASI(t)]$$

$$ASI(t) = \sqrt{(\bar{a}_x / \hat{a}_x)^2 + (\bar{a}_y / \hat{a}_y)^2 + (\bar{a}_z / \hat{a}_z)^2}$$

$$\hat{a}_x = 12\ g,\ \hat{a}_y = 9\ g,\ \hat{a}_z = 10\ g \qquad (1)$$

$= 50 m/s^2$ – mean value of the measured acceleration components

Table 5: Protective devices – crush intensity level (MKS EN 1317–2)

Crush intensity level	**ASI: Acceleration Severity Index THIV: Theoretical Head Crush Velocity**		
A	ASI ≤ 1,0	and	THIV ≤ 33 km/h
B	1,0 < ASI ≤ 1,4		
C	1,4 < ASI ≤ 1,9		

Depending on the danger level, speed of vehicles, AADT and the third persons risk level on a certain section, the first procedure to be effected is to determine the basic restrain level and the action area before specifying the crush intensity level. This is a general approach, most frequently referring only to the protective appliances [5].

As for the remaining part of the MKS EN 1317 standard, referring to the initial and final constructions, transitional constructions and crush buffers, other factors are also taken into consideration (as the action effect, permanent lateral deviation, dynamic deflection etc.) helping to accurately specify the dimensioned device.

Besides the basic principles of definition of the protective system, MKS EN1317 is also specific in the method of manufacturing, performance and control of each type. The standard itself defines accurate factory production control (FPC) consisting of:

- Control of input materials and components (the control is carried out by a subcontractor on which special documentation is to be kept),
- Control of the production process influencing the quality of the product (the control is performed by the manufacturer and a certified independent body).

The finished product is subject to initial testing (ITT) ant to a Crash Test in the sense of determination of the efect of the system by a certified laboratory which issues the report.

The certification body carries out inspection control of the facilities, documentation keeping control, production control, permanent surveillance, evaluation and estimation of the manufacturer regarding the coordination of the product with the standard. What is controlled in the following:

- Responsibility and competence of human resources,
- Qualification of the employees influencing the coordination of the products,
- Measurement and control devices,
- Control of input material and the provided components,
- Gives instruction on the treatment of an inadequate product,
- Corrective measures,
- Storage and packaging,
- Possibility of retroactive monitoring and marking..

After the initial control, the certification body gives its final evaluation and assessment of the results, after which the manufacturer receives the SE certificate and the product can be used with the declaration on conformity with the MKC EH 1317 standard.

The CE certificate shall be obtained for each system separately in the name of the manufacturer with the appropriate number.

The manufacturer issues a declaration on the stability of features – that it releases its product as pursuant to the EN 1317 requirements. That declaration guarantees that the products have been manufactured in compliance with the provided documentation. Also, the manufacturer must accompany each batch of any certified system with assembly instructions, which are the same as those provided to the authorized laboratory before the performance of the crush test.

IV. DISCUSSION

The features described above reveal the advantages and the disadvantages of the two standards which are (were) applied in Macedonia.

The presented U.S4 bases leads to the observation that this is a solid standard, completely involving the protective lengths but without confirmation of any certain safety. It is based on previous crush tests with light vehicles and lower movement velocities. If this standard is not appropriately used, the guardrail will retain lighter freight vehicles at an exceptionally sharp angle and low movement velocity.

Nevertheless, the inconsistent use of this standard in our country resulted in considerable decrease in traffic safety.. The following situations were identified on our roads in the period of application:

- Short protective lengths (shorter than the analyzed one),
- Unprotected obstacles (non-standard boards, portals, chandeliers, concrete pillars, tunnel portals, trees etc.),
- Protection of third persons is not taken into account,
- Inadequate use of the U.S4.100 and 108 standard (application of aluminum instead of steel profiles, buffers of metal sheets thinner than prescribed by the standard, inadequate pillars, bolts of quality inferior to the prescribed one, greater distance between pillars, thinner anti-corrosion zinc layer etc.).

The new EN1317 standard dictates complete elimination of all the above mentioned shortcomings, regardless of whether they are positions that do not exist in the previous standard of design

or building omissions. Besides, this standard requires increased control both in the production of the protective system and in its installation, thus contributing to higher security of all project participants, which was not the case before. The application of this standard shall contribute to equality of all bidders in Macedonia, thus providing for standard quality of all applicable protective systems.

V. CONCLUSIONS

The above mentioned leads to the following conclusions:

- The previous MKS U.S4 standard applies two basic guardrail types, used on the roads, depending mostly on velocity, types but, due to weak guardrail characteristics, the appropriate protection level is not provided for on many sections, whereas the guardrail is over-dimensioned on points where the traffic load and the vehicle movement velocity are low,
- With MKS EN1317 all the protection systems applied are fully optimized and appropriate protection is provided at each dangerous point as per the actual need,
- A guardrail of MKS EN1317 is considerably more expensive, mostly due to the additional costs to provide an SE certificate, requiring increased production control and crush tests,
- MKS EN 1317 takes into consideration the protection of third persons, which is not the case with U.S4.

The practice so far demonstrates that in the countries where it is applied, the guardrail installed according to the EN1317 standard, achieves far better results than the one installed as per the MKS U.S4 standard, in every aspect of use. It must be mentioned that the vehicle restrain systems, designed and constructed as per the MKS EN1317 standard, do not provide for absolute protection of the traffic participants. The standard is designed as pursuant to the analysis of a large number of traffic accidents, but considering that they are an incidental phenomenon, there is also the possibility that the guardrail is not able to retain a vehicle. This standard reduces that possibility to a minimum.

For appropriate and consistent application of the MKS EN1317 it is necessary to provide for education and upgrading of all the participants in the project.

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