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SOME ADDITIONAL ASPECTS FOR THE REGULATION OF THE MILITARY LOAD CLASSIFICATION OF EXISTING ROAD BRIDGES (STANAG 2021)

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Abstract: This study examines some of the details of the regulation of load capacity assessment for military traffic on road bridges. The author gives a proposal for modification of the standard. Suggestions include: definition of a new crossing condition, introduction of a uniform marking system, modification of the safety factor, improvement of the bending moment table of the standard and revision of the speed limit. These suggestions have certainly arisen in the application of local codes in some NATO countries. Maybe this open-source paper could be the fist step to the professional discussion. In case of technical consensus, it is possible to incorporate the proposals (e.g. a new crossing condition) directly into STANAG.

Keywords: Military transport; Road bridges; Load capacity; Standards; STANAG 2021; AEP-3.12.1.5.

1 INTRODUCTION

The Achilles heel of military strategy is the logistics. Logistics is based on transport, which requires a good transport network. The most critical points in the network are typically bridges. The usability, adequacy and load-bearing capacity of bridges are therefore of paramount importance.

In Hungary, after joining NATO in 1999, the NATO standard AEP-3.12.1.5 [1] was introduced with STANAG 2021 [2], which provides for the load classification of bridges, ferries, rafts and military vehicles. The convention and the standard are in English, there is no official Hungarian translation.

The standard lays down a procedure for the classification of military vehicles according to their load and geometry, both wheeled and tracked. The second part of the standard provides for the classification of the load capacity of bridges, ferries and rafts. The purpose of the standard: if the classification number of a bridge or ferry or raft is greater than that of the military vehicle, there is no load obstruction to crossing [3].

The aim of the research is to develop the parameters and procedures necessary to extend the standard to Hungary. This is necessary because the standard gives national scope for the definition of partial factors, dynamic factors and other parameters that influence the assessment of load capacity (e.g. intensity of simultaneous civil traffic loads). This needs to be investigated on a national scale because their definition depends on the bridge design regulations of the country concerned. The aim of our work is to develop in detail a military load capacity conversion procedure derived from old Hungarian bridge design regulations [4].

On the basis of this studies we have carried out so far, we will provide some suggestions for supplementing and amending the existing standard. Among these, the main recommendations are the definition of a new crossing condition and the elaboration of a standard notation of military classification. We then make three further suggestions for the standard.

According to the most commonly used design standards in NATO countries (e.g. EN, ASCI), a bridge is defined as any structure with a clear opening greater than 2 m. The study applies to all bridges (culverts, viaducts, overpasses, frames, ...).

2 ANALYSIS OF THE PROBLEM

The STANAG 2021 standard covers a very wide area. (Hereafter, we will refer to the Agreement and the underlying standard together as STANAG 2021. The text of the standard refers to itself as STANAG 2021.) It includes the classification of vehicles and the classification of bridges. A vehicle may cross a bridge if its classification number is less than the classification number of the bridge.

The Annex A of STANAG 2021 gives the ideal 16+16 vehicles for crawler (tracked) and tire cases (wheeled), which are the basis for military loads. The method of determining the load capacity may vary from country to country. In all cases, a dual load rating of road bridges should be carried out, giving the classification for tracked and wheeled vehicles separately. In the case of a simple one-span bridge structure, the tables and graphs for the classification of vehicles (Annexes B and C) may be used to calculate the classification of bridges.

We only deal with the classification of bridges. This is a big topic in itself, because it includes the methods that can be applied, from the simplest estimation (remote reconnaissance) to the most detailed investigation (even by test loading or destructive testing). We have limited our field of research to the A3c method according to the K.6.3 of the STANAG 2021.

The A3c method (correlation method) is sufficiently fast and reliable. The conversion procedure compares the bending moments and shear forces according to the bridge design standard with the values according to STANAG 2021. To use this method, we need to know the construction, design load capacity of the bridge and use the old standard to which it was designed. The new aspects and proposals determined by the large number of calculations carried out are set out in Chapters 3-8.

3 PROPOSAL FOR A NEW CROSSING CONDITION

STANAG 2021 provides four different ways (cases) for civil and military vehicles to cross a road bridge (normal case with one lane of military traffic, normal case with two lanes of military traffic, caution case and risk case). Under normal loading, the ideal military vehicles are modelled as a convoy, with a distance of 30.5 m between successive vehicles. In the normal case, the military vehicles travel in one or two lanes and there is civilian traffic on the other lines of the bridge at the same time.

The standard defines the caution crossing and the risk crossing too. In the case of a caution crossing, there is a single vehicle on the bridge structure instead of a military convoy, with no simultaneous civilian traffic. The arrangement for a risk crossing is the same as for a caution crossing, but in this case minor damage to the bridge structure is allowed. The cases according to STANAG 2021 are shown in Figure 1.

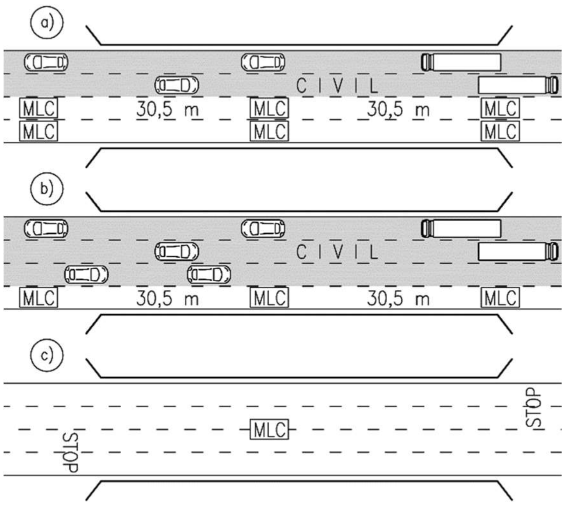

Fig. 1 Crossing conditions of the STANAG 2021
Source: author.

The difference between the normal cases and the other cases (caution and risk) is striking. This large difference naturally results in a large additional load capacity for caution and risk, but at the same time significantly limits military mobility due to the fact that the military convoy cannot move continuously.

Based on a detailed study of the standard and a number of test calculations, we propose to define and introduce a new crossing condition in the standard [5]. The new case is when the military convoy is continuously moving on the bridge axis and there is no parallel civilian traffic (see Figure 2).

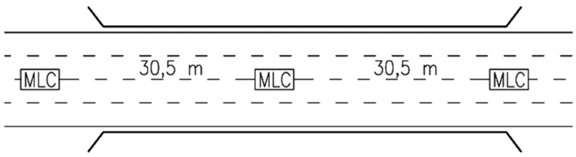

Fig. 2 Proposed new crossing conditions: Axis
Source: author.

It could be seen that this new case is very important for larger bridges, where several vehicles in a convoy can load the bridge at the same time. This is particularly important and useful for routes with many bridges.

We could take an example: if there are several long bridges on a route, the military vehicles can only cross them one at a time. This prevents the convoy from moving continuously and creates queues in the vehicle column that dramatically reduce the speed of the overall convoy.

For optimal military mobility, we propose to introduce the new case. We propose the term „Axis“ as the name of the new crossing condition. We was looking for a word that also has a different initial letter from the most important words used in the STANAG 2021 (Caution, Risk, Weheccle, Trucked, One, Two, Normal). This is important so that it cannot be confused with other important marker words and can easily be used as a short form or marking.

4 MARKING SYSTEM FOR BRIDGE LOAD CAPACITY

Under STANAG 2021, classified bridges are to be used by the entire NATO community. Therefore, it is of utmost importance that the load rating of the bridge is clear. Typically, a bridge will have more of load ratings. It should define the load capacity for wheeled vehicles and tracked vehicles separately. It should be defined for each crossing condition case. There are four types of crossing conditions in the standard, and we suggested a fifth in the previous chapter.

Two types of vehicles and five crossing conditions give us a total of 10 different load capacities for a single bridge. These 10 possible cases need to be clearly distinguished from each other. Unfortunately, we also encounter bad examples. The practice of specifying the load capacity of a bridge with a single number, for example MLC100, is wrong. We does not know which of the 10 possible cases the MLC100 value is used for.

Equally important is the methodology for the classification of the load capacity, which is regulated in detail in STANAG 2021. The classification methodology and the qualification of the person performing the classification will influence the result and the usability of the classification.

We see that it is very important to accurately mark the load capacity of the bridge. For the marking system we have chosen the standard marking system for concrete as a model, [6]. We have developed a marking system for the load capacity of bridges [5], which we have improved with the new crossing condition case proposed in the previous chapter (see Figure 3).

The precisely marked load capacity indicates, in addition to the nominal value of the load capacity, the vehicle type, the concurrency and the reliability of the determination (person and procedure). Without these parameters, the numerical value of the bridge load rating cannot be interpreted on its own.

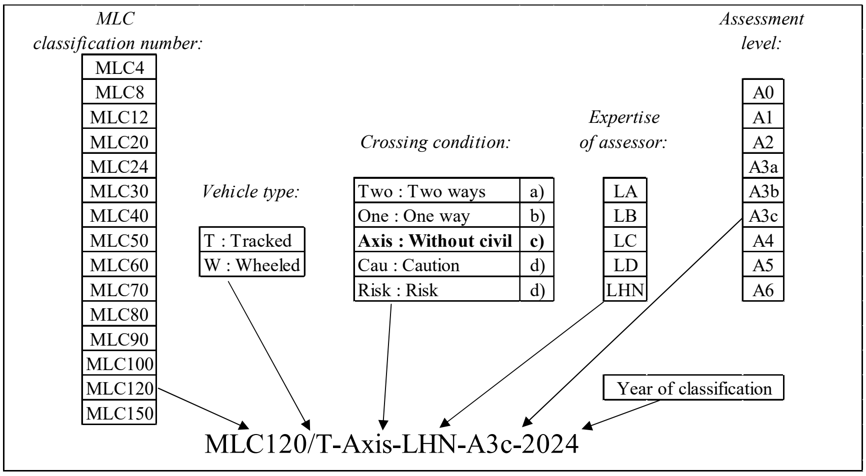

Fig. 3 Proposed making system of military load classification of bridges
Source: author.

The reliability part of the detailed marking gives you information on the usability. The general aim is that all bridges should have a specified load capacity of at least level A3c [5].

5 MODIFY OF SAFETY FACTORS

When classifying the load capacity of bridges, the safety factors, the dynamic factors, are national competences and can be defined by each country. The annex to the standard gives recommendations for these, giving values for the CC2 and CC3 importance classes, separately for the different military load groups (normal - caution - risk), and also distinguishing three short military design lifetimes (1 week, 4 weeks, 1 year) for the risk case - in clause K.8.6 [1]. This was published in the standard in 2017, see Tables 1 and 2 [1].

Tab. 1 Partial factors for assessment of CC3 bridges

CC3	Permanent Action	Variable Action
Normal	1.21	--
low dynamic	--	1.40
medium dynamic	--	1.50
Caution	1.21	1.26
Risk		
1 week	1.20	1.23
4 weeks	1.18	1.20
1 year	1.17	1.18

Source: [7].

Tab. 2 Partial factors for assessment of CC2 bridges

CC2	Permanent Action	Variable Action
Normal	1.19	--
low dynamic	--	1.33
medium dynamic	--	1.40
Caution	1.19	1.22
Risk		
1 week	1.18	1.19
4 weeks	1.16	1.16
1 year	1.16	1.16

Source: [7].

These factors were published in 2014 [7]. The theoretical derivation of the factors is discussed in detail in the thesis just quoted. One basis for the derivation is a graph from Eurocode [8]: Reliability levels for different reference periods in accordance (see Figure 4).

Figure 4 shows that a shorter design life is associated with a higher reliability level. This should be interpreted as being true for the same structure (resistance) and/or for the same load (impact). For example, a probability of failure of 50 years is calculated by summing the probability over one year as 50 consecutive independent events, of which if one occurs the bridge will fail. Thus, for longer durations, the probability of failure increases, and Beta (reliability level) decreases.

When judging the military load capacity, the reliability level should not be derived from the design life, but from the needs determined on the basis of probabilistic considerations. If these external conditions are the same and only the design life is different (because the operational plan requires a bridge to be in place for only one week or one year), then the reliability level will be the same.

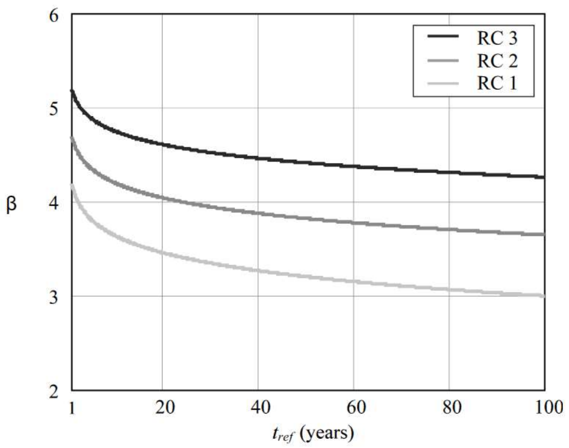

Fig. 4 Reliability levels for different reference periods
Source: [8].

The same can be found in the dissertation [7]. It states that Beta does not change the lifetime of the structure (see Table 3).

Tab. 3 Target reliabilities for Risk Crossing Condition

Consequ-ence class	Time reference	β_{hs} human safety	β_0 structural safety	max
CC3	1 week 4 weeks 1 year	3.4 3.0 2.0	2.8 2.8 2.8	3.4 3.0 2.8
CC2	1 week 4 weeks 1 year	2.9 2.4 1.3	2.4 2.4 2.4	2.9 2.4 2.4

Source: [7].

We could look at a simple example: We need a Beta=3 reliability level for Bridge ‚A' for only one week, and we also need a Beta=3 reliability index for Bridge ‚B' for a design life of one year. Obviously, the equal Beta and the safety factor derived from the cost optimisation result will be lower for Bridge ‚A' than for Bridge ‚B', because the probability of the effect occurring will be lower over the shorter time. And as a result, we can demonstrate an effectively larger military payload on Bridge ‚A' than on Bridge ‚B'.

This statement contains a lot of simplifications. The probability of a significant effect is not only a function of time. It is possible for a bridge to be used for only one week, but to have continuous and intense traffic. It is also possible for a bridge to be used for a year, but the expected traffic is close to zero. The statistically influencing parameters are uncertain and therefore we can simplify by using only the design time.

The example shown is contrary to the factors in the standard in the Risk case! Other contradictions are possible from the parameters in the standard: a bridge does not meet a design life of 1 week, but meets a design life of 1 year.

Our suggestion is to adopt the factors for the 1 year design life in the standard with the same value for shorter design lives. This way, the lack of correction of the factors remains in favour of safety. If one calculates with the wrong or old factors, one only errs in the direction of safety. The factors for 1 year can be accepted as factors independent of design life (see Table 4).

The factors for the payload were determined by taking 1.5 as the initial, original value (which appears in the table for CC3 as the maximum value). The safety factor for a payload vehicle in Hungary is 1.35 according to the Eurocode in force. We have therefore added the value of the original factor to the table. If the original factor was 1.35, then the values in the variable action* column should be used. In this column, we have entered the factors using a simple proportionalisation due to the difference between 1.5 and 1.35.

Tab. 4 Proposed safety factors for assessment of CC2 bridges

CC2	Permanent Action	Variable Action	Variable Action*
Original	1.35	1.50	1.35
Normal low dyn. medium dynamic	1.19 -- --	-- 1.33 1.40	-- 1.23 1.28
Caution	1.19	1.22	1.15
Risk ~~1 week~~ ~~4 weeks~~ 1 year	 ~~1.18~~ ~~1.16~~ 1.16	 ~~1.19~~ ~~1.16~~ 1.16	 -- -- 1.11

Source: author.

6 SMALL CORRECTION IN THE BENDING MOMENTS OF TRACKED VEHICLE

Annex B of STANAG 2021 gives the bending moments and shear forces in tabular form as a function of span. Annex C contains the same in graphical form. For wheeled vehicle data, the constant values for the small support spacing are shown, which is derived from the load on a single axle specified for loads. The same is not found at the tracked vehicles.

For tracked loads, STANAG 2021 Chapter 6.4.4.2 requires that the single axle load half value for the vehicle category shall be taken into account as the local load. The effect of this is significant for small support distances, similar to wheeled vehicles.

The table of bending moments for MLC30 - MLC150, improved by the solo axle effect as required by the standard, is shown in Table 5. It can be seen that the largest difference is for the MLC150, where the solo axle is the standard up to 2 m span. The graph corrected according to the table is shown in Figure 5, which can be used as a correction to the STANAG 2021 Annex C Figures C-6 and C-7.

In terms of shear force, the required solo axle does not cause any major stress in any load class.

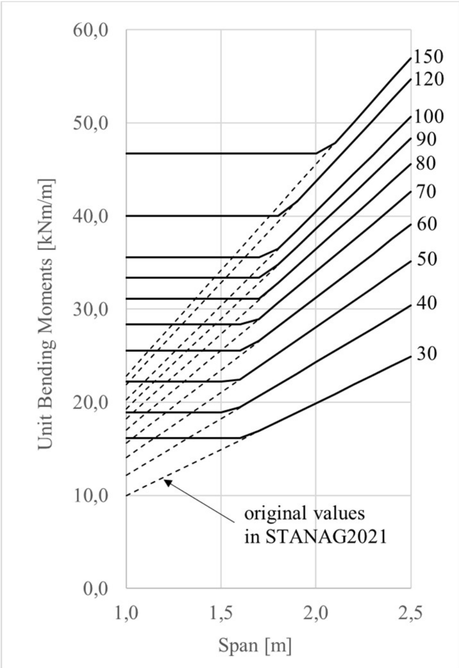

Fig. 5 Modified graph of bending moments
Source: author.

7 REVIEW OF THE SPEED OF MILITARY VEHICLES

STANAG 2021 regulates the speed of military vehicles in two places, in Annexes H and Annex K. Unfortunately, the values given in Caution case are contradictory (see Table 6).

Speed is an important parameter in military transport. Another problem about the Table 6, apart from the contradiction, is that it general imposes a speed limit on bridges. Modern vehicles are capable of faster speeds. The requirement under STANAG 2021 thus results in a mandatory speed limit on all bridges.

The speed of the vehicle affects the dynamic effect. Many studies have looked at the dynamic effects of military vehicles, [9] [10]. Dynamic coefficient can be reduced for tracked vehicles and heavy equipment trailers. It has been shown that the dynamic effect decreases proportionally with increasing vehicle mass [11].

Overall, the speed limit will improve the load capacity of bridge slightly, but will slow down military traffic considerably. Speed restrictions for military traffic are not desirable.

We would recommend deleting the speed limit of normal crossing condition in Annex K of STANAG 2021. The Caution case requires detailed consideration. Further investigation is needed to determine whether the removal of the speed limit in the Caution case would significantly reduce the available load capacity. It would be desirable to remove the speed limit in the Caution case (similar to the Axis crossing condition proposed in Chapter 3).

In the case of Risk, there is no contradiction in STANAG 2021 and it is recommended to maintain the 5 km/h speed limit.

Tab. 5 Modified table of the bending moments for tracked vehicle

L [m]	MLC30	MLC40	MLC50	MLC60	MLC70	MLC80	MLC90	MLC100	MLC120	MLC150
1	16,12	18,90	22,24	25,57	28,35	31,14	33,35	35,59	40,04	46,70
1,1	16,12	18,90	22,24	25,57	28,35	31,14	33,35	35,59	40,04	46,70
1,2	16,12	18,90	22,24	25,57	28,35	31,14	33,35	35,59	40,04	46,70
1,3	16,12	18,90	22,24	25,57	28,35	31,14	33,35	35,59	40,04	46,70
1,4	16,12	18,90	22,24	25,57	28,35	31,14	33,35	35,59	40,04	46,70
1,5	16,12	18,90	22,24	25,57	28,35	31,14	33,35	35,59	40,04	46,70
1,6	16,12	19,45	22,47	25,57	28,35	31,14	33,35	35,59	40,04	46,70
1,7	16,93	20,66	23,87	26,56	28,96	31,14	33,35	35,59	40,04	46,70
1,8	17,93	21,88	25,27	28,13	30,66	32,81	34,78	36,46	40,04	46,70
1,9	18,92	23,09	26,68	29,69	32,36	34,64	36,71	38,49	41,57	46,70
2	19,92	24,31	28,08	31,25	34,07	36,46	38,64	40,51	43,75	46,70
2,1	20,91	25,52	29,49	32,81	35,77	38,28	40,57	42,54	45,94	47,85
2,2	21,91	26,74	30,89	34,38	37,47	40,11	42,51	44,56	48,13	50,13
2,3	22,91	27,95	32,29	35,94	39,18	41,93	44,44	46,59	50,32	52,41
2,4	23,90	29,17	33,70	37,50	40,88	43,75	46,37	48,61	52,50	54,69
2,5	24,90	30,38	35,10	39,07	42,58	45,58	48,30	50,64	54,69	56,97

Source: author.

Tab. 6 Speed limit in the STANAG 2021

Annex	Crossing Condition		
	Normal	Caution	Risk
H.1. and H.2. (in text)	--	5 km/h	5 km/h
K.8.3. (part of Table 5.)	MLC ≤ 30 : 40 km/h MLC > 30 : 25 km/h	MLC ≤ 30 : 25 km/h MLC > 30 : 15 km/h	5 km/h

Source: [1].

8 SUMMARY

The use of a common standard, STANAG 2021, is necessary for the uniformity of the military load rating of road bridges. The classification of the load capacity of bridges is influenced by the inclusion of certain parameters.

We have formulated five suggestions for modifications to the use of the standard, which we propose for further analysis and consideration.

In case of a professional consensus, we propose to improve the standard by adding the amendments discussed here. The most important of our proposals, and the one that would be of most practical help in using STANAG 2021, would be the introduction of a uniform detailed marking system, for which we have developed a detailed proposal.

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