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Tank Bridge Crossing Capability Analysis

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INTRODUCTION

The Military Load Class (MLC) is a number assigned to both military vehicles and military bridges. For military bridges, the MLC represents the load carrying capacity of the structure, while for military vehicles, the MLC represents the effect it has on a bridge that it is crossing over. The vehicle's MLC is determined through comparison of the bending moments and shear forces induced by the vehicle at reference spans between 1 and 100 m, inclusive, and bending moments and shear forces for hypothetical vehicles, as published in [1], at the same reference spans. The final MLC reported from this process is the maximum value resulting from this comparison over all reference spans. The MLC provides a quick way for the User to determine if a vehicle can cross a bridge or not. However, reporting of the MLC as the maximum value over all reference spans may also unnecessarily restrict a vehicle from crossing a bridge which, based on statics, could otherwise cross the bridge safely. A study was previously performed, using several Abrams tank and Heavy Equipment Transporter (HET) configurations, to investigate the differences in crossing capability determined using the vehicle's MLC versus using statics, specifically a comparison of bending moments and shear forces calculated at the bridge's maximum span. The results of this study are documented in [2]. A reassessment was recently performed for the Abrams tank crossing the Dry Support Bridge (DSB) using an estimated tracked caution crossing rating. The analysis was also extended to investigate the crossing capability of NATO partner main battle tanks, specifically the German Leopard 2 and United Kingdom Challenger 2. Presented in this report is the study's results, as well as the analytical procedure used for the study and procedure to estimate the tracked caution crossing rating of the Dry Support Bridge. Also presented in this report is information on the vehicles and bridges used for the study and the study results.

VEHICLE INFORMATION

The reassessment of the crossing capability of the Abrams tank over the DSB was performed using the same 8 tracked vehicle configurations evaluated in [2]. The Leopard 2 and Challenger 2 assessment consisted of a total of 5 Leopard 2 configurations and 2 Challenger 2 configurations, with characteristics shown in Table 1. Weight and geometric information for the Challenger 2 were provided in [3], while information on the Leopard 2 was obtained from Mr. Thomas Boehm, a German exchange engineer working for the TARDEC Bridging Team. MLCs for these configurations were calculated using the official software as mandated by [1], using the characteristics provided for the vehicles.

Configuration	Weights (Short Tons)	MLC	Track Length (in)	Vehicle Width (in)	Single Track Width (in)
Leopard 2 A4	60.79	60	194.173	134.646	25
Leopard 2 A5	65.59	66			
Leopard 2 A6	68.01	69			
Leopard 2 A6M	68.89	70			
Leopard 2 A7V	74.41	77			

Table 1: Leopard 2 Configurations Used for Study

Configuration	Weights (Short Tons)	MLC	Track Length (in)	Vehicle Width (in)	Single Track Width (in)
Challenger 2 (Basic)	69.424	71	188.6	132.677	23.62
Challenger 2 (Uparmored)	82.673	98			

Table 2: Challenger 2 Configurations Used for Study

BRIDGE INFORMATION

The Leopard 2 and Challenger 2 study was performed on the same 6 bridge configurations used in [2]. At the time the study in [2] was performed, a tracked caution crossing rating was not provided for the DSB. A tracked caution crossing rating was recently estimated for the DSB, for the purposes of this study, using the following procedure:

1. Calculate the bending moment and shear force at maximum span due to the hypothetical vehicle, with characteristics published in [1], representative of the tracked normal rating of the DSB. An impact factor of 1.15 (bending) and 1.2 (shear), as specified in [4], was applied, as well as an eccentricity factor, calculated using the same procedure as described in [2].
2. Calculate the bending moment and shear force at maximum span due to the hypothetical vehicles in [1]. Impact and eccentricity were not applied for this calculation to simulate caution crossing conditions.
3. Compare the values calculated in Step 2 with the values calculated in Step 1 to determine the equivalent bending moment and shear force MLC rating. The equivalent rating is equal to the MLC of the hypothetical vehicle with bending moment and shear force closest to the value calculated in Step 1 without exceeding it.
4. Compare the equivalent bending moment rating to the equivalent shear force rating calculated in Step 3. The lower of the two values represents the tracked caution crossing rating for the bridge.

Using this assessment procedure, the tracked caution crossing rating of the DSB, based off of a tracked normal crossing rating of MLC 80, was determined to be MLC 100. Use of this estimated rating also necessitated the reassessment of the DSB crossing capability for the Abrams tank configurations assessed in [2].

ANALYTICAL PROCEDURE

Vehicle crossing capability was assessed for both normal crossing conditions and caution crossing conditions. Normal crossing conditions allow for unrestricted use, while caution crossing conditions place restrictions on vehicle speed, number of vehicles on the bridge and vehicle position along the roadway width. The caution crossing restrictions enable heavier vehicles to cross with the same safety as would be allowed under normal crossing conditions. The bridge crossing capability analysis for the vehicles in Tables 1-2 and reassessment of the crossing capability of the Abrams tank configurations assessed in [2] over the DSB was performed using the same two methodologies as were described in [2]. These methodologies were 1) a strict comparison of vehicle and bridge MLC and 2) a static analysis consisting of a comparison of maximum bending moments and shear forces induced by the actual vehicle and hypothetical vehicle representative of the bridge’s MLC.

The analytical procedure does not take a look at the local effects of the vehicles on the bridge, such as deck cracking. More detailed analysis will be necessary to evaluate local effects.

RESULTS AND DISCUSSION

Table 3 shows the original results for the crossing assessment of the Abrams tank over the DSB, as presented in [1], and the results of the reassessment using the first methodology and the estimated caution crossing rating. Using the estimated caution crossing rating, the crossing capability of the Abrams improves slightly using the first methodology, as 2 Abrams configurations are now able to safely cross, 1 as a normal crossing and 1 as a caution crossing.

Configuration	DSB (Original Assessment)	DSB (Reassessment)
Abrams SEPv3 + Class I/II/III/V	NORMAL	NORMAL
Abrams SEPv3 + Class I/II/III/V + FP Kits	NOGO	CAUTION
Abrams SEPv3 + Class I/II/III/V + FP Kits + APS + Ballast	NOGO	NOGO
Abrams SEPv3 + Class I/II/III/V + FP Kits + Mine Plow**	NOGO	NOGO
Abrams (notional 85 tons)	NOGO	NOGO
Abrams SEPv3 + Class I/II/III/V + FP Kits + APS+ Ballast + Mine Plow**	NOGO	NOGO
Abrams SEPv3 + Class I/II/III/V + FP Kits + Mine Roller**	NOGO	NOGO
Abrams SEPv3 + Class I/II/III/V + FP Kits + APS+ Ballast + Mine Roller**	NOGO	NOGO

Table 3: Reassessment results in slight improvement in DSB Crossing Capability Using Methodology 1.

As Table 4 shows, the Abrams crossing capability also improves using the second methodology and the estimated caution crossing rating, as all Abrams configurations are found to be capable of crossing the Dry Support Bridge, 1 as a normal crossing and the remaining 7 as a caution crossing.

Configuration	DSB (Original Assessment)	DSB (Reassessment)
Abrams SEPv3 + Class I/II/III/V	NORMAL	NORMAL
Abrams SEPv3 + Class I/II/III/V + FP Kits	CAUTION	CAUTION
Abrams SEPv3 + Class I/II/III/V + FP Kits + APS + Ballast	CAUTION	CAUTION
Abrams SEPv3 + Class I/II/III/V + FP Kits + Mine Plow**	CAUTION	CAUTION
Abrams (notional 85 tons)	CAUTION	CAUTION
Abrams SEPv3 + Class I/II/III/V + FP Kits + APS+ Ballast + Mine Plow**	CAUTION	CAUTION
Abrams SEPv3 + Class I/II/III/V + FP Kits + Mine Roller**	CAUTION	CAUTION
Abrams SEPv3 + Class I/II/III/V + FP Kits + APS+ Ballast + Mine Roller**	NOGO	CAUTION

Table 4: All Abrams Configurations are Determined to Capable of Crossing DSB using Bending Moment/ Shear Force Comparison

Table 5 shows the results of the Leopard 2 and Challenger 2 crossing assessment using the MLC comparison method, while Table 6 shows the results using the bending moment/ shear force comparison method. As Tables 5 and 6 indicate, the crossing capability for the Leopard 2 and Challenger 2 does not change with respect to the methodology used for the assessment. Comparison of the results of the crossing assessment for the Leopard 2 with that for the Abrams tank in [1] and in Table 4 indicate that the Leopard 2 has greater mobility than the Abrams over the bridges evaluated in this assessment, regardless of the method of analysis. All Leopard 2 configurations are able to cross the Line of Communication Bridge (LOCB), Armored Vehicle Launched Bridge (AVLB), and DSB as a normal crossing. It was observed that the Leopard 2 configurations are generally lighter in weight than the Abrams configurations that were assessed. The heaviest Leopard 2 configuration assessed was slightly heavier than the lightest Abrams configuration that was evaluated. The Leopard 2 track length is also longer than that for the Abrams, thus allowing the weight to be distributed over a longer footprint and helping to reduce the overall effect of the vehicle on the bridge.

The basic configuration of the Challenger 2 is also able to cross LOCB, AVLB and DSB as a normal crossing, while the uparmored Challenger 2 is only able to cross the Commercial DR configuration of the LOCB (LOCB-CR) as a normal crossing. For the two remaining LOCB configurations, AVLB, and DSB, the uparmored Challenger 2 is able to cross under caution crossing conditions. A distinct conclusion cannot be made at this time regarding the overall mobility of the Challenger 2 over US military bridges compared to the Abrams tank. Additional Challenger 2 configurations would need to be evaluated to be able to make such a conclusion. It is noted that the Challenger 2 has a longer footprint than the Abrams tank, which enables it to distribute the load over a longer area, resulting in a less concentrated effect on the bridge.

Neither vehicle is able to cross over the REBS under any conditions. It is noted that none of the tanks assessed in this study or in [2] have widths that are smaller than the roadway width of the REBS, so, even if the analysis stated otherwise, crossings would not be physically possible without modifications being made to the bridge.

Configuration	LOCB-GOV	LOCB-ONS	LOCB-CR	AVLB	DSB	REBS
Leopard 2 A4	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NOGO
Leopard 2 A5	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NOGO
Leopard 2 A6	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NOGO
Leopard 2 A6M	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NOGO
Leopard 2 A7V	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NOGO
Challenger 2 (Basic)	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NOGO
Challenger 2 (Uparmored)	CAUTION	CAUTION	NORMAL	CAUTION	CAUTION	NOGO

Table 6: Leopard/ Challenger Tank Crossing Assessment Using MLC Comparison

Configuration	LOCB-GOV	LOCB-ONS	LOCB-CR	AVLB	DSB	REBS
Leopard 2 A4	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NOGO
Leopard 2 A5	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NOGO
Leopard 2 A6	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NOGO
Leopard 2 A6M	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NOGO
Leopard 2 A7V	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NOGO
Challenger 2 (Basic)	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NOGO
Challenger 2 (Uparmored)	CAUTION	CAUTION	NORMAL	CAUTION	CAUTION	NOGO

Table 7: Leopard/ Challenger Tank Crossing Assessment Does Not Change Using Bending Moment/ Shear Force Comparison

While it is not as apparent looking at the results for the Leopard 2 and Challenger 2, the results for the Abrams tank do show the adverse effect strict application of the MLC has on a vehicle’s crossing capability. Focusing on the actual effect the vehicle has on the bridge allows for greater mobility for military vehicles over military bridges and could potentially aid in mission performance by opening up routes that would otherwise be avoided using only the MLC as a guide.

CONCLUSION

An analysis was performed to reassess the capability of several Abrams configurations to cross over the Dry Support Bridge and assess the capability of the German Leopard 2 and United Kingdom Challenger 2 tanks to cross over different military bridging assets. The analysis was performed using the traditional way of comparing vehicle and bridge MLCs, as well as an alternative way of comparing bending moments and shear forces induced for a particular bridge span. Similarly to what was observed in [2], comparison of the results of the Abrams – DSB reassessment for the two methods indicates that the traditional comparison of MLCs is more restrictive to the mobility of a vehicle than the bending moment/shear force comparison. This increased restrictiveness can affect mission performance, as well as result in overdesigned bridges that are difficult to employ. Comparison of the results for the Leopard 2 and the Challenger 2 using the two methods do not show a similar difference, as the configurations assessed for these two tanks were found to be able to cross all of the bridges evaluated in this study except the REBS regardless of the method used for the analysis.

REFERENCES

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