A.1 Guidelines for the Barrier

The barrier, the coping, and moment slab should be safe against structural failure. A barrier should be designed to resist the impact load recommended in this report according to the information presented in Error! Reference source not found.- . Any section along the coping and the moment slab should not fail in bending when the barrier is subjected to an impact load. Two modes of stability failure are possible in addition to structural failure of the barrier system. They are sliding and overturning of the barrier-moment slab system.

1.1. Sliding of the Barrier

The factored static resistance (φ P) to sliding of the barrier-moment slab system along its base should be greater than or equal to the factored equivalent static load (γ L_s) due to the dynamic impact force.

0.80 1.0

$$\varphi P \geq \gamma L_s$$

The equivalent static load, L_s, is determined from Error! Reference source not found.-, ϕ resistance factor is 0.80 (AASHTO LRFD Table 10.5.5-1), and γ load factor is 1.0 (extreme event).

Table-1 Recommended equivalent static load (Ls) for TL-3 through TL-5

Test Designation	Dynamic Load (kips)	Equivalent[1] Static Load (kips)	Equivalent[1] Static Load per unit length (kips/ft)	Minimum Barrier Height (in.)	Effective Height, H_e (in.)
TL-3[2]	54	18	0.8	32	24
TL-4	80	20	0.67	36	30
TL-5-1	160	55	1.83	42	34
TL-5-2	260	77	2.57	>42	43

[1] Equivalent static load based on a rotation point B
[2] NCHRP Report 663, Figure 7.1

The static force P should be calculated as:

$$P = W \tan \phi_r$$

the current guidelines to have different designs loads based on height. Note that the TL-4 design load is applied 30 inches above the ground level.

On the other hand, the TL-4 barrier to be tested is 36 inches high. This is the minimum recommended height to contain and redirect the MASH 10000S test vehicle. This height was updated from the previously recommended minimum 32 inches height typically used under NCHRP Report 350 to contain and redirect the 8000S vehicle. The results of the TL-4 impact simulations are presented in the Table A2 and Figure A1 below. The measured dynamic load from the TL-4 crash test will be compared to the simulated 67.2 kips.

Design Forces and Designations	Barrier Height (in.)			
	36	39	42	Tall
F_t Transverse (kip)	67.2	72.3	79.1	93.3
F_L Longitudinal (kip)	21.6	23.6	26.8	27.5
F_v Vertical (kip)	37.8	32.7	22	N/A
L_L (ft)	4	5	5	14
H_e (in.)	25.1	28.7	30.2	45.5

N/A= not applicable

TTI recommends 1 design condition for TL-4 of MASH
80 kips @ 30" load height

Table A2: Summary of magnitude, distribution and application of the MASH TL-4 impact loads

4- **In Figure 28, it would be helpful to show the <u>width of the front sloped face</u>. In addition, additional barrier details should show an elevation view with spacing of vertical reinforcement at interior and end regions.**

The drawings are included in **Appendix-2-.** Kindly note that the critical length required to develop the end section failure mechanism (controlling failure mode) is about 4.3 feet. Considering that the barrier length is 10 feet, it is not practical to specify a variation in vertical reinforcement spacing between the interior and end regions.

5- **In Appendix 2, yield-line analyses were performed at end and interior regions, which demonstrated that the design configuration provided greater redirective capacity than the design load. For these analyses, compression steel was not considered in the calculations for Mw and Mc. If this additional steel were considered, the redirective capacity would be even greater. Would there be any benefit for including compression steel in the strength calculation and potentially further optimizing the barrier design?**

The steel reinforcement design was further optimized to minimize the reserve capacity. The updated reinforcement calculations are included in Figure A2 and Appendix -3-.