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ENGINEERING DIRECTIVE

Patricia Leavenworth (signature on original)

CHIEF ENGINEER

Protection of Bridge Piers and Abutments

The purpose of this Engineering Directive is to introduce updated MassDOT guidelines for the protection of bridge piers and abutments. The guidelines on the following pages supersede the corresponding guidelines contained in Part I of the *2013 MassDOT LRFD Bridge Manual*.

These guidelines are based on *NCHRP Report 892, Guidelines for Shielding Bridge Piers*, which updates the pier protection requirements found in the *AASHTO LRFD Bridge Design Specifications*.

The following standard drawings are also issued as part of this Engineering Directive and will be incorporated into a future edition of the *MassDOT Bridge Manual*:

D1	Structural Pier Protection, Clearances Under Bridge
D2	Limits of Structural Pier Protection, Clearances Under Bridge
D3	Pier Shielding for Occupant Protection, Clearances Under Bridge

This Engineering Directive is effective immediately.

3.3.1.7 Pier Protection for Bridges over Roadways. In 2018, NCHRP Report 892, *Guidelines for Shielding Bridge Piers*, was published, which was intended to update the pier protection requirements found in the *AASHTO LRFD Bridge Design Specifications* Article 3.6.5.1. The report identifies two specific cases when some form of pier protection is needed: 1) to protect the pier itself from impacts by heavy vehicles that can compromise the pier's structural integrity; or 2) to protect the occupants of vehicles, primarily passenger vehicles, that may impact the pier.

The report also notes that the peak load from the heavy vehicle impact that inflicts the most damage comes from the engine of the tractor. Finally, the report presents a risk-based approach for determining the need for shielding the pier for structural protection based on the probability of it experiencing such an impact. This approach includes consideration of site-specific factors, such as roadway curvature, grade, speed limit, etc., and would replace the procedure found in the *AASHTO LRFD Bridge Design Specifications* Commentary C3.6.5.1. The Bridge Manual pier protection requirements that follow are based on NCHRP Report 892.

1. Determine the Need for Structural Pier Protection. The Designer shall use the procedure given in NCHRP Report 892 Section 3.3 to calculate AF_{BC}, the Annual Frequency of Bridge Collapse for an Unshielded Pier System. The actual AADT for the road being investigated shall be used in the analysis. If the AF_{BC} is less than 0.0001 for Critical/Essential bridges or 0.001 for all other bridges, the piers do not require shielding for structural protection but should be evaluated for shielding for occupant protection. If the AF_{BC} is greater than these values, then the Designer shall provide structural pier protection as outlined below.

2. Structural Pier Protection: for both new construction and existing piers.

    a. If, in a multi-column reinforced concrete pier, the diameter of a round pier column or the least dimension of a rectangular pier column is greater than or equal to 36", a 42" high TL-5 barrier shall be used to shield the pier. It shall be placed preferably in line with approach guardrail however, if there is insufficient offset between the edge of roadway and the pier, the barrier may be placed up against the face of the pier columns. This is permitted because the 42" high barrier will take the peak impact load from the engine block and any intrusion of a truck component behind the barrier will either be the cab or the trailer box, which does not have the same impact severity as the engine block and can be resisted without significant damage by the pier column due to its size.

    b. If, in a multi-column reinforced concrete pier, the diameter of a round pier column or the least dimension of a rectangular pier column is less than 36", a 42" high TL-5 barrier shall be placed so that the top edge of the traffic face of the barrier is 39" or more from the traffic face of the pier component being protected. If there is not enough room to accommodate this 39" offset, then a 54" high TL-5 barrier shall be placed so that the top edge of the traffic face of the barrier is preferably no closer than 20" from the traffic face of the pier component being protected. However, the 54" high barrier may be placed up against the face of the pier columns if there is no other practical option.

c. For barriers placed in accordance with requirements 2a or 2b, the barrier shall preferably extend a minimum of 60 feet upstream of the pier to prevent a truck from penetrating behind the guardrail and still impacting the pier. For a median, if the approach barrier is narrower than the width of the pier, the barrier shall flare to meet the barrier in front of the pier.

3. Shielding for Occupant Protection: for both new construction and existing piers. For multi-column reinforced concrete piers, which do not require structural pier protection but are located within the clear zone as defined by the *AASHTO Roadside Design Guide*, occupant protection shielding shall be provided. This protection shall consist of the standard MassDOT W-beam guardrail found in the MassDOT *Construction Standards* as long as the offset distance from the face of the guardrail to the traffic face of the pier being protected is not less than the offset distance to a fixed (non-breakaway) object specified for the guardrail. If the offset distance is less than this, then a solid 42" high TL-5 barrier shall be provided. It shall be placed preferably in line with the approach guardrail, however, if there is minimal room between the edge of roadway and pier, the barrier may be placed up against the face of the pier columns. The location and length of this protection shall be designed in accordance with Chapter 5 of the *AASHTO Roadside Design Guide*.

4. For substructures consisting of non-redundant reinforced concrete pier columns, such as single column hammerhead piers or individual columns supporting steel cross girders, structural pier protection shall be provided in accordance with requirements 2a and 2c above if these substructures are located within the clear zone as defined by the *AASHTO Roadside Design Guide*. While these members may be designed for the 600 kip load specified in the *AASHTO LRFD Bridge Design Specifications* Article 3.6.5, providing structural pier protection ensures a redundant level of protection for these substructures.

5. For substructures other than multi-column reinforced concrete piers, such as pile bent substructures or steel frames, for both new construction and existing piers, if they are located within the clear zone as defined by the *AASHTO Roadside Design Guide*, structural pier protection shall be provided in accordance with requirements 2b and 2c above.

6. If occupant protection shielding is being provided for a solid wall pier, it is still preferred to install a MassDOT *Construction Standards* barrier in front of the solid wall. This is in consideration of the fact that the crash testing of tall wall barriers has demonstrated the potential for the head of a vehicle occupant to hit the wall during impact, resulting in serious injury. Providing an offset that is the thickness of the top of the barrier is intended to mitigate this possibility.

7. When designing a new pier consisting of reinforced concrete elements and if, based on the procedure outlined in requirement 1 above, the pier requires structural pier protection, the Designer has the option of designing the pier for the 600 kip impact load as specified in *AASHTO LRFD Bridge Design Specifications* Article 3.6.5 in lieu of providing structural pier protection. In this case, the pier shall be investigated for the need to provide occupant

protection shielding in accordance with requirement 3 above. Also, in the case of non-redundant reinforced concrete pier columns, requirement 4 above will still apply.

3.3.1.8 Structural Protection for Abutments. Full thickness reinforced concrete abutments, either cast in place or assembled from precast concrete bridge elements, do not require structural protection. However, if they are located within the clear zone as defined by the *AASHTO Roadside Design Guide*, occupant protection shall be provided in accordance with Paragraph 3.3.1.7, requirements 3 and 6.

For MSE and other wall types which function as abutments by directly supporting a spread footing of a bridge stub abutment and they are located within the clear zone as defined by the *AASHTO Roadside Design Guide*, structural protection shall be provided in accordance with Paragraphs 3.3.1.7 requirements 2b and 2c, so that a vehicular impact does not fail the panel, thereby compromising the backfill and consequently the bridge structure that relies on it for support. If the MSE or other wall type only retains the embankment soil and the bridge abutment has a separate foundation that does not rely on the MSE or other wall type for support and these walls are located within the clear zone as defined by the *AASHTO Roadside Design Guide*, then only occupant protection shall be provided in accordance with Paragraphs 3.3.1.7 requirements 3 and 6.

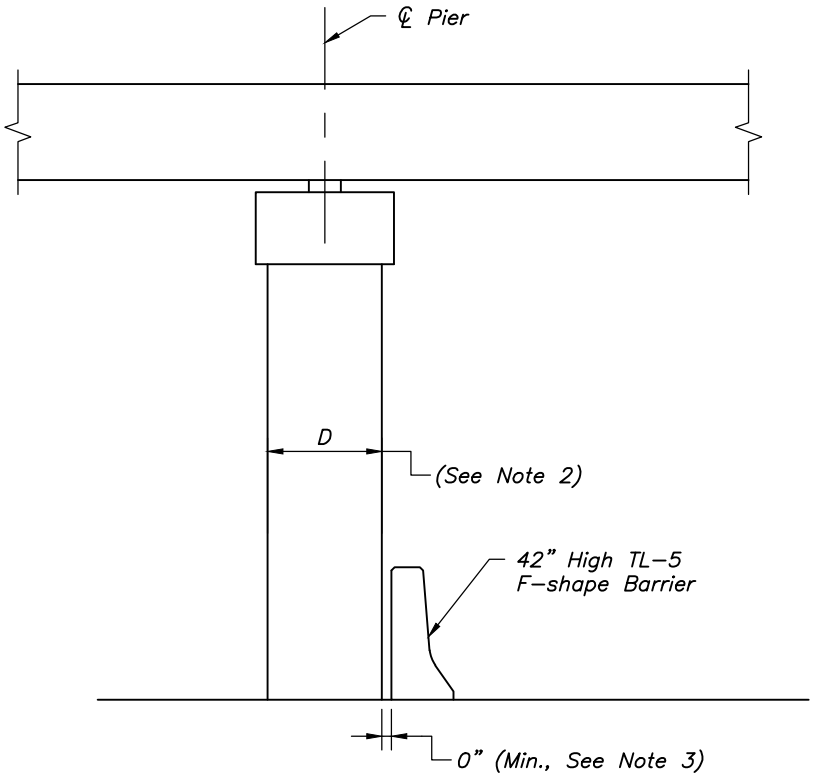
3.3.1.9 Pier Protection for Bridges over Railroads. A crash wall shall be provided in accordance with the latest AREMA code or in accordance with the standards of the railroad company the bridge is over, if they are more stringent than AREMA. These crash walls shall be designed to either the *AASHTO LRFD Bridge Design Specifications* Article 3.6.5 collision load, the loads specified in AREMA, or loads specified by the railroad company the bridge spans over, whichever is greater.

STRUCTURAL PIER PROTECTION REQUIREMENTS

PIER PROTECTION

YEAR OF ISSUE
2019

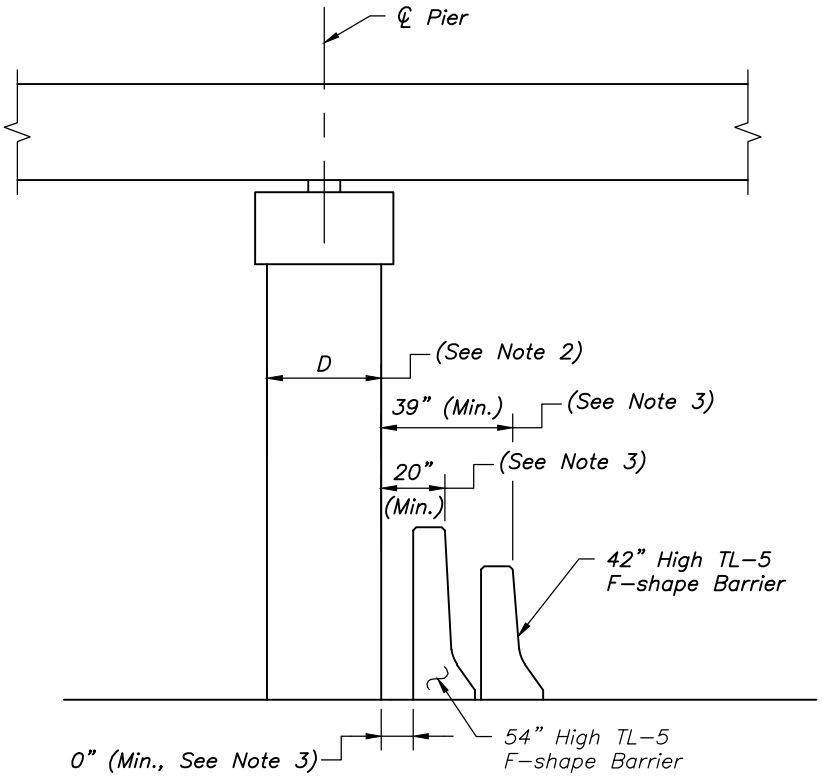
DRAWING NUMBER
D1



NOTES:

1. The need for Structural Pier Protection shall be determined using the procedure given in NCHRP Report 892 Section 3.3.
2. D is equal to a minimum diameter of 36" for a circular column or a least dimension of 36" for a rectangular column.
3. Preferably, the barrier shall be placed in line with the approach guardrail, however it can be placed against the face of the pier columns if there is insufficient offset between the edge of roadway and the pier.
4. All dimensions are for a square section.
5. Show actual dimensions on the Sketch Plans and Construction Drawings.
6. See Highway Drawings for all roadway dimensions.

REQUIREMENT 2a



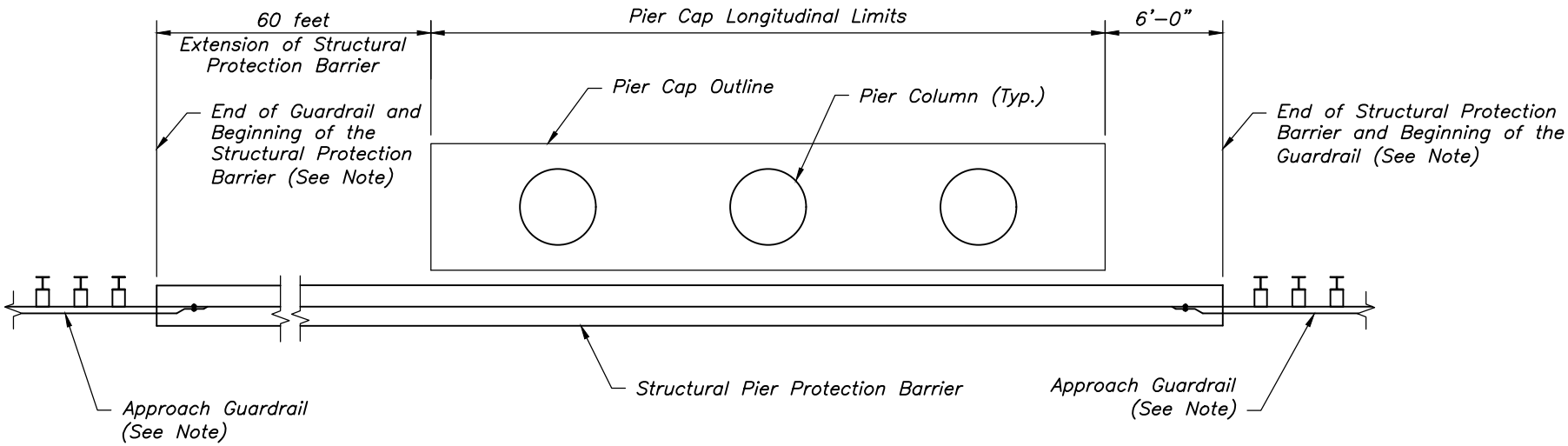
NOTES:

1. The need for Structural Pier Protection shall be determined using the procedure given in NCHRP Report 892 Section 3.3.
2. D is equal to a maximum diameter of less than 36" for a circular column or a least dimension of less than 36" for a rectangular column.
3. Preferably, the barrier shall be placed in line with the approach guardrail to the dimensions shown. If there is not enough room to accommodate the minimum 39" offset for a 42" high barrier, then a 54" high barrier shall be placed as shown above. If the 20" minimum dimension cannot be accommodated, the 54" high barrier may be placed against the face of the pier columns.
4. All dimensions are for a square section.
5. Show actual dimensions on the Sketch Plans and Construction Drawings.
6. See Highway Drawings for all roadway dimensions.

REQUIREMENT 2b

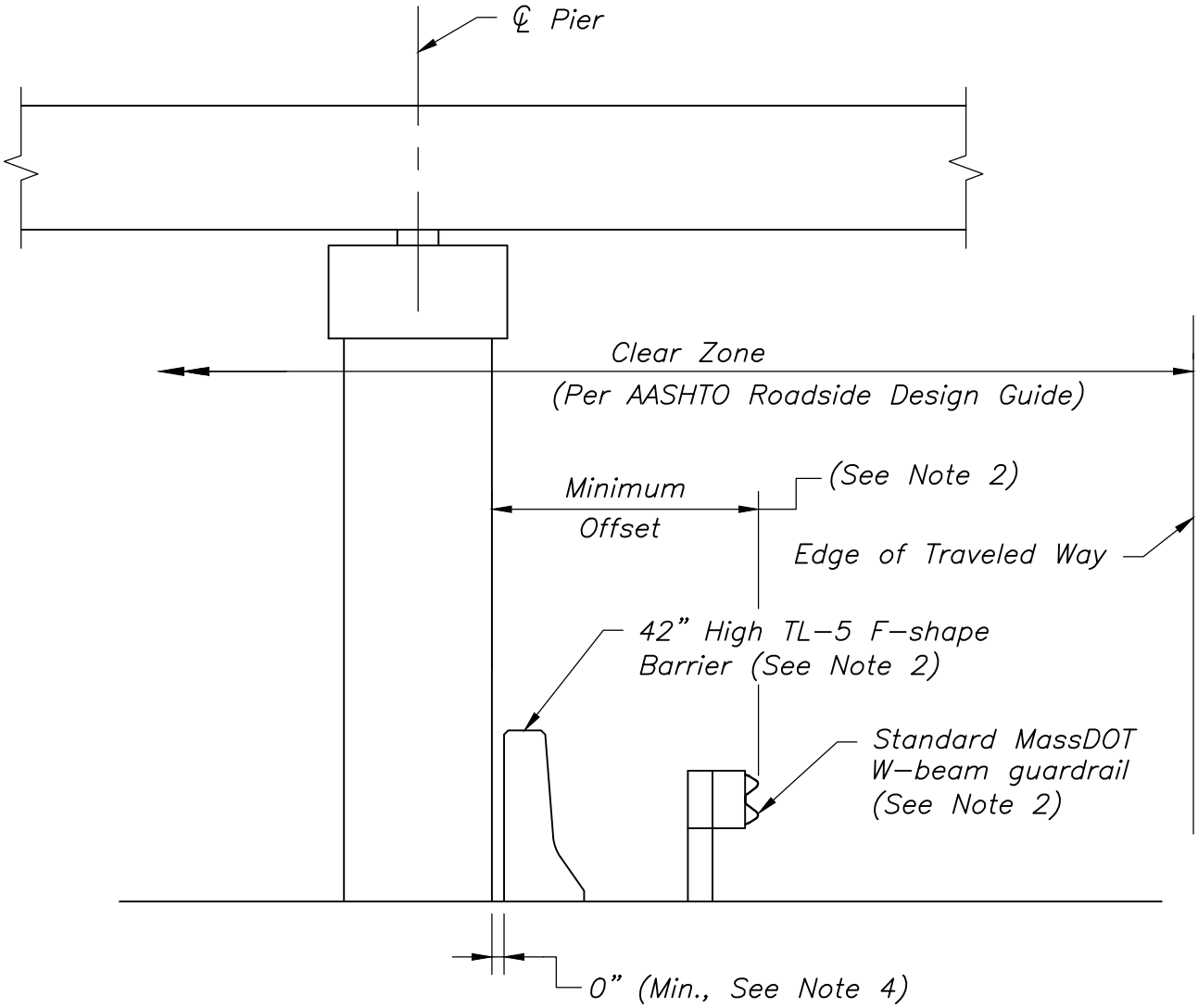
LIMITS OF STRUCTURAL PIER PROTECTION

PIER PROTECTION



NOTE:
For details of the guardrail and guardrail transitions to the Structural Protection Barrier, see MassDOT Construction Standards.

REQUIREMENTS 2a and 2b – Plan



NOTES:

1. The above shielding is for piers that do not require Structural Pier Protection but are located within the Clear Zone.
2. The MassDOT Construction Standards guardrail shall be used where ever possible for Occupant Protection shielding. If the minimum offset is less than the offset distance to a fixed (non-breakaway) object specified for the guardrail, a 42" high barrier shall be provided. Preferably, the barrier shall be placed in line with the approach guardrail, however, it can be placed against the face of the pier columns if there is insufficient offset between the edge of roadway and the pier.
3. All dimensions are for a square section.
4. Show actual dimensions on the Sketch Plans and Construction Drawings.
5. See Highway Drawings for all roadway dimensions.

REQUIREMENT 3

MassDOT Highway Division BRIDGE MANUAL PART II	PIER SHIELDING FOR OCCUPANT PROTECTION PIER PROTECTION	YEAR OF ISSUE 2019 DRAWING NUMBER D3