Minnesota's MH Shape: The Development of Efficient Shallow-Depth Prestressed Concrete Beams

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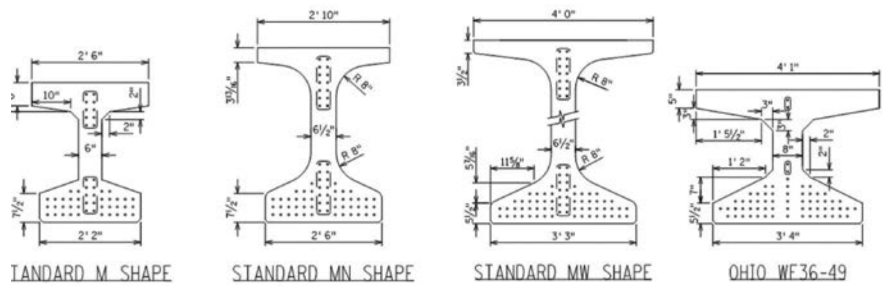
The Minnesota Department of Transportation (MnDOT) has been designing and building bridges using precast, prestressed concrete beams since the late 1950s. Currently, these types of structures make up 70% to 80% of the state's new bridges annually. MnDOT has worked with local fabricators to continue improving the quality and efficiency of these beams.



Girder cross sections considered during development of the MH girder. All Figures: Minnesota Department of Transportation.

As new two-span bridges are scoped to replace existing four-span bridges with side piers, project leaders often choose between including a grade raise of up to 18 in. or constructing the bridge with steel girders to accommodate vertical clearance requirements. Shallow concrete beams could be a more cost-effective solution. An analysis of MnDOT-owned bridges designed since 2001 and state-funded local highway bridges designed between 2009 and 2016 showed that a significant portion of bridges spanned 75 to 105 ft, with beam depths between 27 and 45 in. Through this analysis, MnDOT identified efficiency gaps in the shorter spans, and that finding led to the development of new 30-, 35-, and 40-in.-deep "MH" girders.

Shape Geometry

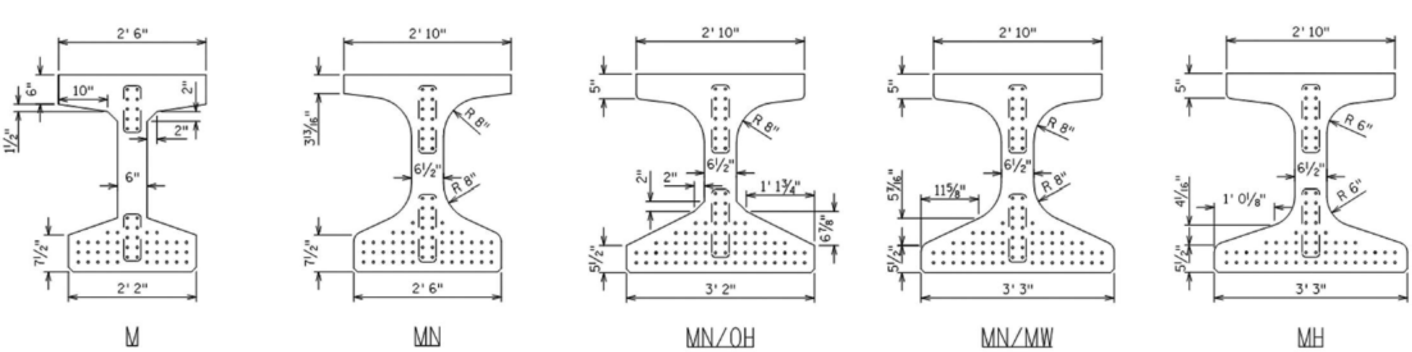
The study began by analyzing MnDOT's 36-in.-high prestressed concrete beam against those standardized by other states.[1] For example, Ohio uses a WF36-49 beam.[2] Combined with a typical MnDOT strand configuration, this type of beam would span 12 ft farther than MnDOT's 36M shape. The next step was to understand which features allowed the WF36-49 beam to span so much farther than MnDOT's same-height shape. After investigating several combinations of top- and bottom-flange shapes, MnDOT selected a beam shape with the following attributes:

- Top flange: A tip depth of 5 in. was chosen to facilitate deck replacement. A 34-in. width was determined to be the best option to resist stresses at transfer.
- Web: A width of 6½ in. provided ample shear capacity and the ability to place shear reinforcement.
- Bottom flange: A width of 39 in. was selected to match the bed width of current precast producers. This option also minimized the flange area where strands could not practically be used and flattened the slope of the top face to reduce weight.

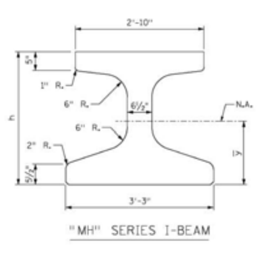
The new MH cross section also provides softened flange-to-web radius transitions to enhance form release and increase aesthetic appeal. For comparable depths, the MH shape provides maximum span lengths within 2% of the modified Ohio beam and is 30% lighter per foot. MNDOT chose the depths of the MH shape to fill gaps between existing beam shapes and provide the minimum depth required for typical railroad crossings.

Design Method

Full design criteria can be found in the *MnDOT LRFD Bridge Design Manual*.[1] For the selection table, maximum span length was determined at 5, 7, 9, 11, and 13 ft beam spacing. At each spacing, the MH shape was the most efficient, either by spanning farther or providing comparable span lengths with a lighter section. The MH and MN/OH shapes span farther than other shapes at the same depth. The MH shape was chosen because it weighs 6% less than the MN/OH section.



Iteration of cross-section geometry before finalizing the MH shape.



Beam Properties

BEAM	h (in)	AREA (in^2)	W ① (lb/ft)	$\bar{y}$ (in)	I (in^4)	S_B (in^3)	A_c ② (in^2)
30MH	30	639	688	13.66	70,416	5,155	403
35MH	35	672	723	15.85	105,570	6,661	419
40MH	40	704	758	18.07	149,002	8,246	435

① Based on 155 pounds per cubic foot.
② Based on a 9" slab with 1/2" of wear and 1 1/2" stool. See LRFD 5.8.3.4.2 for A_c definition.

Cross-section properties for the shallow-depth MH beams (from reference 3).

Fabricators' Input

As part of the design process, MnDOT incorporated fabricators' input. For hold-down during transportation, the 30MH and 35MH are strapped over the top flange, while the 40MH allows for optional 2-in.-diameter sleeves through the web. For shear reinforcement, MnDOT utilizes no. 5 stirrups at 2½ in. spacing at the ends of the M shapes and no. 6 stirrups at 3 in. spacing at the ends of the MN shapes. There was concern that no. 6 reinforcing bars may be too large and the 2½ in. spacing too tight; therefore, the splitting reinforcement was designed as no. 5 stirrups at 3 in. spacing. Finally, the radius of the web-to-flange chamfers was changed from 4 to 6 in. to allow for better concrete flow and form removal.

Detailing Considerations

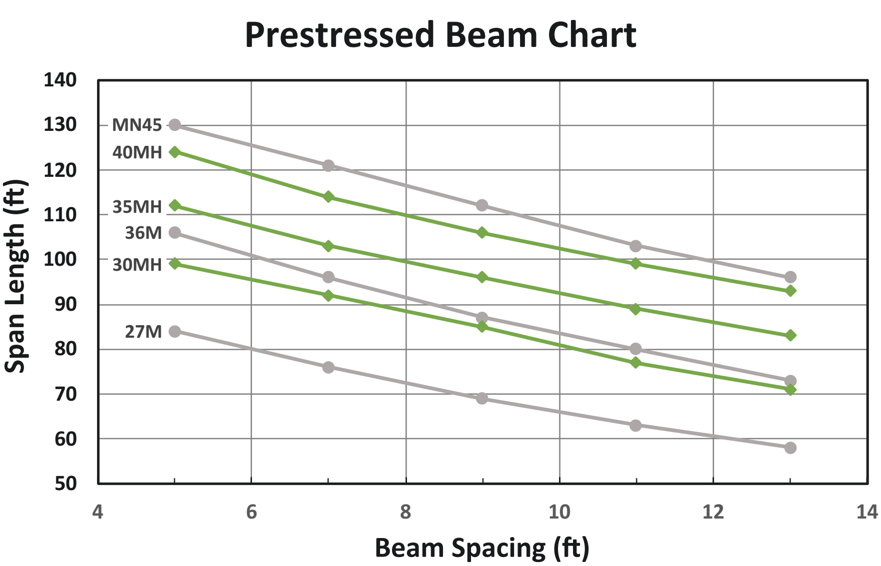
Like all other MnDOT shapes, the MH beams are detailed with the outside 6 in. of the top flange troweled smooth, and an approved bond breaker is applied to facilitate future redecking.

Intermediate diaphragms are not required for the 30MH and 35MH beams. The flat portion of their webs is too small to accommodate channel or bent-plate diaphragms. The diaphragm spacing for the 40MH beam will follow guidelines consistent with those for other MnDOT shapes. Likewise, beam-end dimensions, camber prediction, overhang criteria, and material properties will be consistent with specifications for other shallow- to medium-depth beams. Standard bearing, intermediate-diaphragm, and end-diaphragm details were all modified to include the MH shapes and modified as needed to include MH beam dimensional requirements.

Availability Timeline and Future Developments

On December 20, 2018, MnDOT issued a memo to designers[3] announcing the ability to use the new 30MH and 35MH beams for projects with a letting date on or after July 1, 2019. To allow fabricators adequate time to procure forms, the 40MH beams will be permitted for projects letting on or after November 1, 2019.

These new MH shapes are being used for upcoming MnDOT projects and on the local highway system. Cost savings, fabricator concerns, and contractor comments will be analyzed to determine whether additional changes are needed. MnDOT has not typically used strand debonding, but it is utilizing debonding with both the MH and previously developed shapes in upcoming projects.



Preliminary beam selection chart, with the beam spacing and span lengths for the new MH shapes and some of the other shallow beams currently in use in Minnesota, from the Minnesota Department of Transportation's *LRFD Bridge Design Manual* (from reference 1).

Conclusion

MnDOT's new MH-series beams should prove to be an efficient beam type for use in the 75 to 105 ft span range. Success developing the beams would not have been possible without collaboration between MnDOT and fabricators. The experiences of other agencies that have developed shallow beams, as well as the past performance of MnDOT's smaller beams, has led to a more efficient option in the shallow-beam category. MnDOT continues to view prestressed concrete beams as the preferred low-maintenance and cost-effective design option for typical bridges. The MH beams add another shape to the toolbox.

References

1. Minnesota Department of Transportation (MnDOT). 2018. *MnDOT LRFD Bridge Design Manual*. https://www.dot.state.mn.us/bridge/lrfd.html.
2. Ohio Department of Transportation (ODOT). 2007. *ODOT Bridge Design Manual*. http://www.dot.state.oh.us/Divisions/Engineering/Structures/standard/Bridges/Pages/BDM2007.aspx.
3. MnDOT. 2018. Memo to Designers #2018-01: New 30 MH, 35MH, and 40MH Prestressed Concrete Beams. https://www.dot.state.mn.us/bridge/lrfd.html.

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EDITOR'S NOTE

The editors of ASPIRE® wish to congratulate another department of transportation for looking at the shallow-beam sections and optimizing these short-span concrete bridge solutions to remain competitive. See a related article by the Illinois Department of Transportation in the Fall 2015 issue.