Minnesota Department of Transportation
Engineering Services Division
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Technical Memorandum

To: **Electronic Distribution Recipients**

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Subject: Interchange Ramp Terminal Configuration

Expiration

This is a new Technical Memorandum and will remain in effect until January 16, 2024 unless superseded or published in the MnDOT Road Design Manual prior to that date.

Implementation

The design guidance contained in this Technical Memorandum is effective immediately and should be incorporated in the design of MnDOT projects at any stage of development to the extent reasonable and feasible. Incorporation will be required for projects currently in the preliminary design phase or for which a geometric layout is completed but final design has not yet commenced.

Introduction

This Technical Memorandum pertains to the design of ramp junctions with highway mainlines where merging and diverging maneuvers are performed, in particular the use of taper- versus parallel-type geometry. Background reference information – including MnDOT's preexisting design criteria – can be found in Road Design Manual (RDM) Section 6-2.0.

Whereas the taper design diverges from / converges with the highway at a gradual, uniform angle, the parallel design provides a uniform-width auxiliary lane of sufficient length for deceleration/acceleration as well as for gap acceptance in the case of the merging maneuver. Advantages of the parallel design include the ability to tailor the auxiliary lane lengths to site-specific needs and the opportunity for drivers to use their rear-view mirror to identify gaps in highway traffic when merging.

Minnesota has utilized taper-type ramp terminal geometry as a primary design configuration since the middle 1960's, before which both parallel and taper designs with various geometric features had been employed. The current version of RDM policy states that acceleration and deceleration lanes may be of either the taper or parallel types, but the taper design is referred to as MnDOT's standard design, to be provided wherever possible. This guidance reflects national design policy at the time it was originally written, which was the First Edition of the American Association of State Highway and Transportation Officials' (AASHTO's) *A Policy on Geometric Design of Highways and Streets* (aka the AASHTO "Green Book"), issued in 1984. In it, the figures depicting the taper designs are labeled as "preferred." In the Second and all subsequent editions of the Green Book (1990 to present), the "preferred" labeling is absent.

It has become accepted through experience that both taper and parallel design types perform sufficiently well to present them both as standard options in design, although each has attributes making them more effective in certain situations. In general, per the AASHTO Green Book, the taper-type entrance usually operates smoothly in traffic demands up to the design capacity of the merging area. Weaknesses have been noted in the taper design's performance, however, most notably the fixed gap acceptance length associated with the entrance taper rate. (The MnDOT standard tapered entrance provides 300 feet of gap acceptance length, which is the minimum AASHTO Green Book value.) The parallel-type design is more versatile in allowing for longer deceleration, acceleration and gap acceptance lengths and presents the merging task to the driver as a simple lane change. There is also anecdotal evidence that parallel exit geometry is more conducive to deceleration into loops and low-speed ramps than taper geometry. National Cooperative Highway Research Program (NCHRP) Project 15-31 examined safety and operational performance and driver behavior at mainline ramp terminals. NCHRP Report 730 (2012) presents the following findings and recommendations related to the issue of taper versus parallel design geometry:

- In general, vehicles merge later and at speeds closer to freeway operating speeds at tapered terminals than at parallel terminals
- Drivers generally choose to not use the full length of the entrance terminal / acceleration lane when gaps are abundant and merging is not difficult
- If parallel entrance terminals are used, they are most appropriate for ramps expected to experience constrained- or forced-merge conditions (i.e. merging areas that are near or over capacity)
- Constrained-merge conditions appear to be the most difficult for drivers to negotiate
- Deceleration rates are substantially higher with parallel exit geometry than with taper geometry
- Deceleration rates are greater into loops than into high-speed ramps
- Providing deceleration lanes longer than the minimum values in the AASHTO Green Book (and the MnDOT Road Design Manual) may promote casual deceleration by exiting drivers
- Since many vehicles are capable of accelerating at higher rates than those assumed in the standard design criteria, reducing minimum acceleration lane lengths by 15 percent would not be expected to result in operational problems
- Passenger cars should remain the principal design vehicle for mainline ramp terminals, but where truck volumes on ramps are high, consideration should be given to fully accommodating them in the design

NCHRP Report 730 generally recommends that mainline ramp terminals be designed based upon free-flow traffic conditions and further recommends that tapered acceleration lanes be preferred over parallel designs because traffic using tapered terminals tends to merge later and at higher speeds under such conditions. However, the report does recognize the advantage parallel geometry has in provision of greater gap acceptance lengths and the resulting operational benefits to facilities during constrained-merge conditions as well as the difficulty drivers experience dealing with those conditions.

Purpose

The purpose of this Technical Memorandum is to amend MnDOT design criteria, establishing parallel ramp-mainline terminal geometry as a standard design along with taper-type geometry as well as providing guidance for design practitioners as to which should be utilized in various circumstances.

Guidelines

Mainline ramp terminals are key features in the design of highways and freeways, particularly as they affect operational performance. Under-designed or otherwise inadequate acceleration and deceleration lanes often stand as the weak points or constrictions in a highway's capacity and traffic flow. Providing adequate ramp terminal design is relatively inexpensive when measured against operational benefit; therefore, providing robust designs and incorporating traffic operations analysis where appropriate in higher-demand locations are highly recommended. This constitutes a low cost, high benefit approach.

Taper-type mainline ramp terminals will continue to stand as MnDOT's base design, especially for rural and uncongested facilities. However parallel-type acceleration and deceleration lanes will henceforth be considered a standard design as well, to be used where advantageous from the performance standpoints of traffic operation, ease of use, and cost effectiveness. The following criteria should be regarded as guidelines rather than as design standards; context and situation specifics should be taken into account in the selection of an appropriate configuration.

Selection of Geometric Configuration

Parallel acceleration and deceleration lane design should generally be utilized in lieu of tapered design under the following circumstances:

1. Where the standard tapered design does not provide sufficient deceleration length as defined and specified in Road Design Manual Section 6-2.03.01 or provides less than 85 percent of the standard acceleration length in RDM Section 6-2.04.01. This will be the case for many low-speed ramps and practically all loops.
2. Where the standard tapered acceleration lane design does not provide adequate gap acceptance length for the merging maneuver. Needs for gap acceptance are discussed below.
3. Where the design hourly volume (DHV) of an entrance ramp exceeds 400 vehicles and where the mainline highway regularly operates near or over capacity, unless a gap acceptance analysis indicates that the 300 feet provided by the standard taper design is adequate.
4. Where the ramp terminal drops or adds an auxiliary lane or basic travel lane. This applies regardless of whether an escape lane is provided beyond an exit location.
5. Where parallel geometry is more geometrically advantageous or feasible than the standard tapered design due to constraints or other site specifics.
6. Where parallel geometry offers opportunity for economy or simplification of construction, for example where an acceleration or deceleration lane occurs across a bridge and parallel geometry results in a narrower or more rectangular structure.
7. Where the mainline design speed is less than 50 mph.

Parallel Lane Length

When parallel exit or entrance geometry is utilized, the following criteria for the length of the parallel section of auxiliary lane are applicable:

1. The design should provide the standard deceleration/acceleration length per RDM Sections 6-2.03.01 and 6-2.04.01 respectively. Deceleration lanes longer than the lengths specified therein may entail disbenefit and should only be considered under special circumstances – one being exits to loops or tight-radius ramps from downgrades exceeding 2 percent.
2. Where deceleration does not control the design, the absolute minimum parallel lane length for exit ramps is 200 feet.
3. A parallel acceleration lane should provide adequate gap acceptance length for the merging condition. Gap acceptance length is defined as beginning where the traveled ways of the mainline and ramp roadways are two lateral feet apart and ending where the full width of the parallel lane ends and the closing taper begins. Gap acceptance length is more likely to control the design in cases where mainline and ramp volumes are high. In these cases – as discussed in the Road Design Manual – an individual traffic analysis will be necessary to determine a design length. It is recommended that gap acceptance analyses always be performed for locations where the DHV of an entrance ramp exceeds 400 vehicles and where the mainline highway regularly operates near or over capacity.
4. Where acceleration or gap acceptance does not control the design, the recommended parallel lane length for entrance ramps is 600 feet – particularly in the case of high-speed mainline roadways. The minimum parallel entrance lane length is 300 feet, which provides the AASHTO minimum gap acceptance length. This minimum length is typically suitable only with lower traffic volumes (e.g. where a taper design would normally be constructed but a parallel design is selected due to considerations in Items 5, 6 or 7 above) or along low-speed mainline roadways.

Geometric Design Criteria for Parallel Geometry

The scope of this Technical Memorandum does not include geometric design details for parallel acceleration and deceleration lanes, which will be developed subsequently as Road Design Manual updates. Until such time, the following general direction and criteria will apply.

1. The geometry should generally observe the criteria in Chapter 10 of the AASHTO Green Book (7th Edition, 2018), particularly Figures 10-69 and 10-70 and accompanying verbiage.
2. The opening taper rate at the beginning of parallel deceleration lanes should be 1:20.
3. The closing taper rate at the end of parallel acceleration lanes should be 1:25 maximum and desirably 1:S_d/2, where S_d is the mainline design speed in mph. Flatter tapers may be considered where less than the recommended parallel lane length is provided.
4. Both entrance and exit conditions should feature a smooth traveled-way edge along the outside of the terminal where the last/first ramp curve ties into the parallel auxiliary lane. In other words, do not use tapers or other discontinuities to effect the width transition between the auxiliary lane and ramp traveled ways. The additional width will be created in the gore through the convergence/divergence of the roadways.

Consult the Geometric Design Support Unit (GDSU) of the Office of Project Management & Technical Support (OPMTS) for additional details and parameters in the design of parallel-lane terminals.

Questions

Any questions regarding the technical provisions of this Technical Memorandum can be addressed to either of the following:

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Any questions regarding publication of this Technical Memorandum should be referred to the Design Standards Unit, DesignStandards.DOT@state.mn.us. A link to all active and historical Technical Memoranda can be found at http://techmemos.dot.state.mn.us/techmemo.aspx.

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