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Guide for Mechanistic-Empirical Design

OF NEW AND REHABILITATED PAVEMENT STRUCTURES

FINAL REPORT

PART 3. DESIGN ANALYSIS

CHAPTER 2. SHOULDERS

NCHRP

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DISCLAIMER

PART 3—DESIGN ANALYSIS

CHAPTER 2
SHOULDERS

3.2.1 GEOMETRIC CONSIDERATIONS

Wide, surfaced shoulders provide a suitable, all-weather area for stopped vehicles to stand clear of the travel lanes, and they should be provided on all high-volume facilities. Paved shoulders are required on all Interstate routes, and the outside shoulder is typically 10 ft wide and the inside shoulder 4 ft wide (*1*). Shoulders also provide an immediate recovery area for errant vehicles. When used, shoulders must have an all-weather surface and sufficient structural capability; turf or sod-filled shoulders should only be used on very low-volume roadways (typically those roadways with a two-way average daily traffic [ADT] less than 500).

In addition to serving as emergency parking areas, shoulders lend lateral support to the travel lane pavement structure, provide a maneuvering area, and increase sight distance on horizontal curves. Shoulders vary in width from 2 ft or so on minor rural roads to about 12 ft on major roads, where they may be used as a traffic lane in emergencies or during maintenance closure of the regular traffic lanes. Recommendations on shoulder widths are contained in *A Policy on Geometric Design of Highways and Streets* (*2*).

Shoulders should be flush with the roadway surface and with the edge of the traffic lane. All shoulders should be sloped sufficiently to drain water away from the traveled way, but not to the extent that vehicular use should be restricted. Asphalt concrete and portland cement concrete surfaced shoulders should be sloped from 2 to 6 percent, gravel or crushed-rock shoulders from 4 to 6 percent, and turf shoulders about 8 percent. Shoulder slopes that drain away from the paved surface of the outside of superelevated sections should be designed to avoid too great a cross slope. *A Policy on Geometric Design of Highways and Streets* contains recommendations on the geometric cross section elements for shoulders (*2*).

The use of full-width paved shoulders is desirable. However, the additional cost of this design may not be warranted on all projects. In those cases, the use of widened lanes should be given strong consideration (i.e., widened portland cement concrete slabs and widened asphalt concrete paving but the lane edge traffic stripe remains at 12 ft). Widened lanes significantly reduce edge stresses, strains, and deflections (thus reducing structural damage) and the potential for dangerous edge drop-offs by increasing the distance from the truck wheels to the edge of pavement. In short, they increase pavement load carrying capacity, safety, and reduce maintenance costs. A monolithic widening of 2 ft (maximum) outside of the regular painted edge stripes is recommended. Slabs wider than 14 ft could be prone to longitudinal cracking. Widened lanes are only effective when the travel lanes are striped at standard lane widths (12 ft) to help guide vehicles within the traffic lane and not on the widened area. Consideration should be given to the placement of rumble strips on the shoulder portion of the widened lane (*3*, *4*).

3.2.2 STRUCTURAL DESIGN

3.2.2.1 Traffic Loadings on Shoulder

Shoulder pavement thickness design should be predicated upon the magnitude and frequency of loads to which the shoulder will be subjected. However, there are a large number of variables that affect the number of loads a shoulder will receive. Encroachment of trucks, the use of shoulders as temporary lanes during rehabilitation, and the incorporation of shoulders as additional lanes have significant impacts on the performance of shoulder pavements. In addition, large numbers of trucks often park at night on shoulder pavements at interchanges and rest areas, and this static loading must be considered in the design. The designer should consider past performance of shoulder pavements on similar sections, expected traffic usage of the shoulder, and future plans for the route when selecting a pavement structure for the shoulder.

The following recommendations should be considered in the design of shoulders:

General (*1*, *4*, *5*, *6*, *7*)

1. The shoulder should be constructed of the same materials as the mainline pavement to reduce maintenance problems at the mainline shoulder joint.
2. The same type and general thickness of base and subbase material should be used under the shoulder as under the mainline, especially on high volume facilities. Care must be taken in designing the base and subbase cross slope under concrete shoulders to avoid pocketing of water under the lane/shoulder joint and at the shoulder edge. Problems are often encountered at this location due to changes in material type, resulting in non-uniform support or difference in drainage characteristics. Base and subbase materials should be properly “daylighted” to encourage water flow out of the pavement and to prevent water buildup. In addition, in deep frost areas, a shoulder with different thickness and materials may frost heave more than the adjacent traffic lane, creating a safety problem (and, after thawing occurs, a rapid deterioration problem).
3. Avoid the use of aggregate base courses having more than 6 percent minus 200 mesh sieve materials to provide at least some slow seepage of water out of the base to minimize pumping and clogging of the shoulder drainage system.
4. On urban freeways and other routes carrying high truck volumes, the shoulders should be constructed to the same structural section as the mainline pavement to ensure adequate load capacity at the interface between the mainline and shoulder, to provide for ease and economy of construction, and to prevent a "bathtub" condition under the pavement. This will also allow the shoulder to be used as a temporary detour lane during rehabilitation or reconstruction.
5. The expected number of parked trucks on the shoulder should be considered in the shoulder design. This occurs often at night on off ramps of interchanges and rest areas and can cause significant damage if the shoulder is not designed for this loading. Note that this static loading can be approximated through use of a low speed of loading input whenever asphalt bound material is used in the shoulder structure.

Portland Cement Concrete (*1,5,6*)

1. Widened PCC slabs have been shown to be an effective design. As previously recommended, the maximum widening is 2 ft beyond the regular lane edge strip. The width of the PCC slab should not be greater than 14 ft to minimize the possibility of longitudinal cracking.
2. As an option for other than urban freeways and expressways, a tapered shoulder may be considered. Adjacent to the mainline, the shoulder PCC slab should be the same thickness as the mainline PCC slab to permit mid-depth tiebar placement and to provide structural support for truck wheel encroachments. The shoulder slab may then be tapered to no less than 6 inches at the outside edge. Care must be exercised with a tapered section since a "bathtub" type condition can result, with ponding water in the area of the lane/shoulder interface.
3. Concrete shoulders should be tied to the mainline with properly spaced and sized tiebars. Tied concrete shoulders that maintain a tight joint and good load transfer will reduce pavement stresses and edge deflections. Tied concrete shoulders will also result in a tighter, easier to seal longitudinal joint that, when properly maintained, will effectively reduce water infiltration into the pavement structure. Tiebars are needed between the mainline pavement and concrete shoulders to keep the longitudinal joint tight to provide the necessary load transfer and avoid opening of the joint and a safety problem.
4. Traditional design procedures (e.g., the 1993 AASHTO Guide [*3*]) are inadequate in modeling stresses and strains in tie bars. Therefore, tiebar-related recommendations should be based on successful practices of highway agencies. Tiebars with a diameter of 5/8 in are typically placed on 30-inch centers at mid-slab depth. If tiebars are to be bent and later straightened during construction, Grade 40 steel is recommended, as it better tolerates the bending. When using Grade 40 steel, 5/8-in by 30-in tiebars should be used. When using Grade 60 steel, 5/8-in by 40-in or 1/2-in by 32-in tiebars should be used. Some agencies use ¾-in tiebars with a 30-in spacing to provide improved capability to hold the joint together and good load transfer for heavy traffic.
5. Tiebars should not be placed within 15 inches of transverse joints. When using tiebars longer than 32 inches with skewed joints, tiebars should not be placed within 18 inches of the transverse joints.
6. Another option is to use jointed hook bolts when keyways are constructed. Some agencies specify a two-piece threaded tie bar to avoid bending of a bar. One part is cast into the PCC slab, and the other part is threaded into the first part after paving.
7. Mainline transverse joints should be extended continuously across the shoulder. All transverse shoulder joints should be sawed to a depth of one-third the slab thickness.
8. Where plain jointed concrete shoulders are used adjacent to continuously reinforced mainline pavement, the shoulder joints should be sawed at 15-ft intervals. Plain jointed concrete shoulders should not be constructed integrally with continuously reinforced concrete pavement. Transverse saw cuts in the *integrally constructed shoulders* will propagate cracks across the mainline CRCP.
9. Keyways are not recommended for use due to construction difficulties. They definitely should not be used for pavements less than 9 in, thick as shearing of the top or bottom of the slab may occur. If used for pavements 9 in or greater in thickness, keyways should be

placed at mid-slab depth to ensure maximum strength. Proper concrete consolidation both above and below the keyway is essential, and the joint must be tied with reinforcing steel as previously recommended.

Asphalt Concrete (*1*,*5*,*6*)

1. If full-width paving is not used, consideration should be given to widening the paved AC material to reduce edge loading conditions. Even a small widening (e.g., 1 ft) can be beneficial.
2. For other than urban freeways and expressways, a structural section less than that of the mainline may be warranted for the shoulder. It is recommended that the thickness be based on an evaluation of life cycle costs and past performance under similar conditions.
3. It is recommended that plant-mixed asphalt concrete be used for shoulders of heavy trafficked highways, as opposed to bituminous surface treatments, which may not support the loads and require substantial maintenance.

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