JOINT TRANSPORTATION RESEARCH PROGRAM

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Performance Assessment of MSE Abutment Walls in Indiana

Introduction

This report presents a numerical investigation of the behavior of steel strip-reinforced mechanically stabilized earth (MSE) direct bridge abutments under static loading. Finite element simulations were performed using an advanced two-surface bounding plasticity model based on critical state soil mechanics. Results of the simulations were found to be in good agreement with published laboratory and field measurements, including horizontal-facing displacements and tensile forces in the reinforcement.

A parametric study was then conducted to investigate the behavior of a full-scale direct MSE bridge abutment. The parameters considered were the horizontal distance of the footing behind the wall facing, backfill compaction, reinforcement length and spacing, and magnitude of bridge load. Results indicate that these parameters have a significant influence on the horizontal-facing displacements, bridge footing settlements, and axial strains in the reinforcements.

A survey questionnaire on the current state-of-practice of direct and mixed MSE abutments was prepared and distributed to all departments of transportation (DOTs) in the United States. Results obtained from the survey shed light on

- percentage of use of direct and mixed MSE abutments by various DOTs;
- abutment height, type and dimensions of the facing element;
- type of reinforcement, proportioning of footing and pile in direct and mixed MSE abutments, respectively; and
- common problems experienced by DOTs with respect to construction and performance of MSE abutments in the field.

Findings

- Results from the parametric study indicate that the horizontal distance from the back of the facing to the front edge of the footing, backfill compaction, reinforcement length and spacing, and bridge load have significant influence on the horizontal-facing displacements, bridge footing settlements, and axial strains in the reinforcements. For a given bridge load, abutment movements can be reduced by properly compacting backfill soil (especially within the 1 m distance behind the wall facing), decreasing reinforcement spacing, and increasing reinforcement length.
- Based on the results obtained from the finite element simulations performed in this study, it is recommended that the clear horizontal distance from the back of the wall facing to the front edge of the footing be within 0.15 to 0.2 times the height H of the wall facing measured from the ground surface to the top of the facing, with a minimum of $0.1H$.
- The depth of embedment of the footing is suggested to be within 0.2 to 0.25 times the width of the footing. The minimum vertical clearance between the base of the footing and the top level of reinforcement should be 0.3 m. A reinforcement length of $0.7H$ is suggested as a reasonable starting point for preliminary design and internal stability analysis of a direct MSE abutment.
- A DOT survey was carried out to obtain information on the current state-of-practice of MSE abutments in various US states. An email solicitation was distributed to all 50 DOTs, and responses were received from 31. It was found that 83.9% of the DOTs have constructed MSE abutments in their respective states, while 16.1% reported on the contrary, and 63.9% and 69.2% of the

DOTs have constructed direct and mixed MSE abutments, respectively, with heights of 21 to 30 ft.

- 50% of the DOTs use only precast concrete panels as the facing element for both direct as well as mixed MSE abutments. Steel strips are the preferred choice of reinforcement by most DOTs (used by 40% of them) for both direct and mixed MSE abutments.
- 46.4% of the DOTs reported the clear horizontal distance from the back of the wall facing to the front edge of the footing to be within 2 ft., while 39.3% of the DOTs reported it to be within 2.1 to 4.0 ft. The minimum requirement specified by FHWA (2009) is 0.5 ft.
- 37.5% of the DOTs reported the depth of embedment of the footing to be between 1.1 and 2.0 ft. However, no guidelines have been specified by FHWA (2009) for the depth of embedment of the footing in a direct MSE abutment.
- 46.2% of the DOTs reported the vertical clearance between the base of the footing and the topmost reinforcement layer to be within 0.6 to 1.0 ft. The minimum requirement specified by FHWA (2009) is 1 ft.
- 50% of the piles used by DOTs in mixed MSE abutments are partial-displacement piles, 31.25% are displacement piles, and 18.75% are non-displacement piles. 78.1% and 21.9% of partial-displacement piles are H-piles and open-ended pipe piles, respectively, whereas 80% and 20% of displacement piles are closed-ended pipe piles and prestressed concrete piles, respectively. The non-displacement piles consist of drilled shafts.
- 53.8% of the DOTs reported the clear horizontal distance from the back of the wall facing to the front edge of a driven pile to be between 2.1 and 4.0 ft., while 28.2% reported it to be between 4.1 and 6.0 ft. The minimum requirement specified by FHWA (2009) is 1.5 ft.
- 61.5% of the DOTs reported the clear horizontal distance from the back of the wall facing to the front edge of a drilled shaft to be between 2.1 and 4.0 ft. while 23.1% reported it to be between 4.1 and 6.0 ft. The minimum requirement specified by FHWA (2009) is 3 ft.
- The top five problems experienced by DOTs with respect to construction and performance of MSE abutments are
  1. loss of backfill material through the joints of the facing (18.1%);
  2. inadequate drainage system (12.5%);
  3. unsatisfactory workmanship and QA/QC (12.5%);
  4. growth of vegetation in the joints of the facing (11.1%); and
  5. inconsistent backfill compaction (11.1%).

Implementation

Based on the results obtained from the finite element simulations performed in this study, the recommendations provided for (a) the clear horizontal distance from the back of the wall facing to the front edge of the footing, (b) the depth of embedment of the footing, and (c) the length of the reinforcement can be taken into account during design and construction of direct MSE abutments in Indiana.

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