PARTNERSHIP FOR GEOTECHNICAL ADVANCEMENT

IOWA STATE UNIVERSITY

Best Practices for Bridge Approaches

tech transfer summary

RESEARCH PROJECT TITLE
Identification of the Best Practices for the Design, Construction, and Repair of Bridge Approaches (TR-481)

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backfill material gradation, moisture content, compaction, settlement, and erodibility—bridge approach design, construction, and maintenance—bump—drainage and water management—joints and joint sealing—pavement notch

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Objective and Scope

The objective of this research project was to investigate bridge approach problems and develop new concepts for design, construction, and maintenance that will reduce this costly problem. This was accomplished through the following research activities:

- Perform a literature search to identify state-of-the-art practices for design, construction, and maintenance of bridge approaches to reduce the bridge approach settlement problem.
- Investigate bridge approach problems at existing bridges with poor performance to better understand conditions that lead to formation of the bump.
- Investigate new bridge approach construction practices and problems.
- Evaluate various maintenance and rehabilitation practices for bridge approaches, and develop bridge approach maintenance rating criteria to establish a threshold to initiate corrective maintenance/repair.
- Test backfill material properties and characterize abutment backfill materials with emphasis on compaction and erosion properties.
- Analyze the failure potential of the pavement notch region and approach slab.
- Recommend design alternatives for newly constructed bridges and repair of poorly performing approaches.

Problem Statement

The bump, resulting from bridge approach settlement, contributes to added expense and repair time, added risk to maintenance workers, reduction in transportation agency's public image, distraction to drivers, reduced steering control, damage to vehicles, and damage to bridge decks from snowplows.

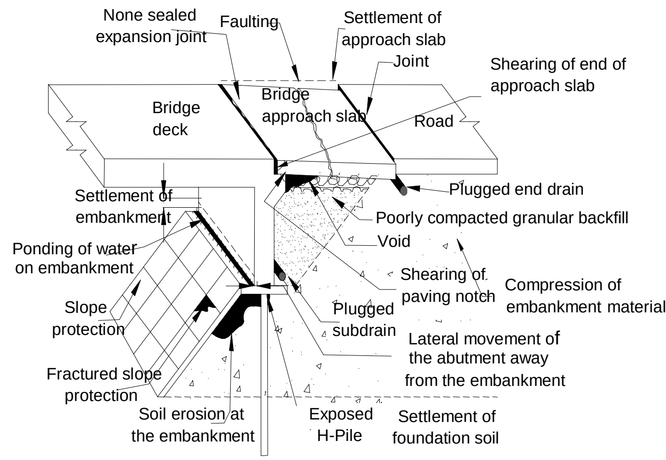
Bridge approach settlement can be caused by a number of factors, including settlement of foundation soils, loss of backfill material by erosion, poor construction practices (e.g., poor compaction of backfill materials and poor joint and drainage system construction), seasonal temperature change causing horizontal abutment movements, failure of the pavement notch and/or approach slab, and high traffic loads.

Various design alternatives, construction practices, and maintenance methods exist to minimize bridge approach settlement, but each has its own drawbacks such as cost, limited effectiveness, or inconvenience to the public. The present study evaluates common bridge approach problems and causes and recommends improvements to bridge approach design, construction, and maintenance.

Existing Bridge Approach Problems

An investigation of bridge approach problems at existing bridges with poor performance produced the following observations:

- Backfill materials under poorly performing approach slabs were often loose and undercompacted.
- Settlement of the foundation soil or embankment fill was evidenced at many of the bridges inspected.
- The majority of the bridge approach elevation profiles obtained had slopes higher than 1/200, which is recommended as an acceptable maximum gradient for bridge approaches and a benchmark for initiating maintenance.
- Void development under the bridge approach was commonly observed on bridges within one year of construction, indicating insufficiently compacted and erodible backfill material.
- Inadequate drainage, or otherwise poor water management, was a major problem at most of the bridges inspected. Erosion leads to void development under the approach slab, faulting of the approach slab, and failure of slope protection, and exposes the H-pile supporting the abutments, which can contribute to corrosion.
- A variety of water management designs exist for bridges. Some drainage details perform better than others. Most of the abutment subdrains inspected were not functioning properly. Many subdrains were either dry with no evidence of water, blocked with soil fines and debris, or had collapsed.
- Measurements of an expansion joint at one bridge site showed about 1 inch of total movement, much less than the 4-inch design width. This suggests that the design joint width may be overly conservative.
- Most of the expansion joints of the bridges inspected were not sufficiently filled, allowing water to flow into the underlying fill materials. Flexible foam and recycled tire joint fillers were not effective in sealing the expansion joint (The current Iowa DOT design detail does not require the joints to be waterproof).



Common problems at bridge sites

A 9-inch void under the approach slab and spalling of concrete from the paving notch and the approach slab

Failure of concrete slope protection due to erosion

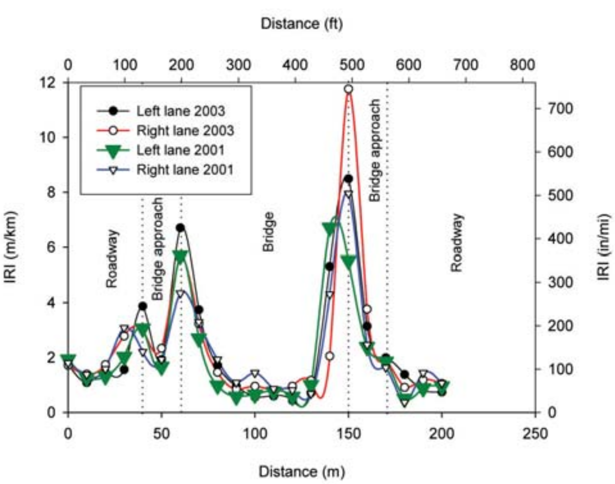
New Bridge Approach Construction Practices and Problems

An analysis of bridge approach construction practices and problems at new bridges under construction resulted in the following findings:

- The granular backfill (classified as SP) being used had relatively good compactibility. However, most granular backfill being used as abutment fill at new bridge sites is not being sufficiently compacted.
- Measured moisture content within the bulking moisture content range (i.e., 3% to 7%) was shown to be inhibiting compaction. Backfill materials were being placed at the bulking water content, leaving the material susceptible to collapse upon saturation.
- Several abutment subdrains were observed to be plugged with soil during and after construction. Porous backfill was not used around the subdrain at most bridge sites. On average, 70% of granular backfill particles and 1% of porous backfill materials were smaller than the perforated openings in the subdrain pipe.

Exposed H-pile caused by soil erosion under the abutment

Inclined paving notch observed during construction of a new bridge



Increase of IRI with time

Bridge Approach Maintenance Practices

Various bridge approach maintenance practices were observed and evaluated:

- Asphalt overlays and grouting were the most commonly used maintenance practices.
- At one bridge site, the URETEK, Inc., maintenance method was used to inject expansive polyurethane under the approach slab and successfully lift the pavement back to its original profile. Further monitoring of this method is required to verify long-term performance.

Need-of-Maintenance Rating System Based on Bridge Approach Settlement

International Roughness Index (IRI) and Bridge Approach Performance Index (BI) data were used to develop maintenance rating criteria that could be used to establish a threshold to initiate maintenance. The BI is defined graphically as the area between the current bridge approach elevation profile and the original elevation profile normalized by the bridge approach length. The maximum value of IRI around the bridge and the BI of several bridge approaches were used to develop the final rating criteria. Findings include the following:

- Maximum values of IRI were observed at the transition between the bridge and the approach slab, and the approach slab EF joint.
- IRI values at the bridge approach increased with time, indicating progressive bridge approach settlement problems.

Soil Backfill Materials and Bridge Approach Settlement

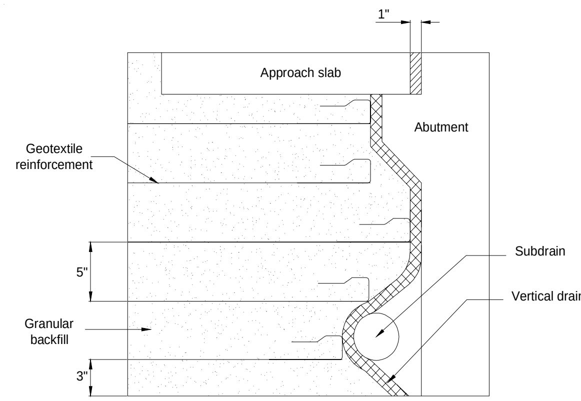
Soil backfill materials, believed to be contributing to bridge approach settlement problems at some bridge sites, were isolated and tested.

- Most granular backfill materials are being compacted at the bulking water content (3% to 7%). Granular backfill placed at the bulking water content undergoes up to 6% collapse (settlement) when saturated. Granular backfill placed at moisture content greater than 8% experiences no collapse. Saturating granular backfill can reduce settlement; however, the material is still highly erodible.
- Porous backfill does not experience collapse even if compacted at an initial compaction moisture content between 0% and 12%. The gradation for porous backfill does not fall within the range of most erodible soils.
- Based on scaled laboratory testing, using porous backfill helps to minimize slab settlement and void formation, and can increase flow capacity about 3 times that for granular backfill.
- Adding a geocomposite drain increases flow capacity about 7 times.
- The geocomposite drainage system STRIPDRAIN 75 increases the drainage capacity about 12 times
- Using recycled tire chips reduces settlement, prevents void formation, and increases the drainage by about 17 times.

Pavement Notch Analytical Investigation

Pavement notch failures can contribute to bridge approach settlement. Analysis of pavement notch failure potential resulted in the following findings:

- Steel reinforcement details used for pavement notch by the Iowa DOT are sufficient.
- The failure analysis of unreinforced concrete segments in a pavement notch and an approach slab indicated that shear failure of these segments is likely to occur when dynamic effects are included. Failure of these unreinforced segments should be possible under static loads when concrete strength is below 4 ksi.
- Poor workmanship and/or poor quality of concrete can lead to premature failure of the pavement notch and the approach slab at reduced loads.



Schematic diagram of drainage details incorporating vertical drain

Drainage capacity results from scale model abutment tests

Drainage Option	Maximum flow rate (cm^3/second)
Granular backfill fill with porous backfill around subdrain	32
Granular backfill fill with geotextile covering porous backfill around subdrain	82
Porous backfill only and subdrain	92
Tenax Ultra-Vera geocomposite drain at abutment face with granular backfill	222
STIPDRAIN 75 geocomposite drain at abutment face with granular backfill	383
Tire chip drainage system at abutment face	552

Recommended Design Alternatives

The following design changes are recommended for implementing on a pilot test basis:

1. Use a combination of porous backfill and geocomposite drainage systems behind the abutment to improve drainage capacity and reduce erosion around the abutment. Several alternative design details are provided for these recommendations and can be implemented on new construction or rehabilitation of existing bridges.
2. For bridges with soft foundation or embankment soils, implement practices of improved embankment compaction with moisture control, foundation preloading, ground improvement, soil removal and replacement, or soil reinforcement that reduce time-dependent post construction settlements and possibly lateral squeeze.
3. Connect the approach slab to the abutment or the deck of the bridge and eliminate the expansion joint at the bridge end of the approach slab. Support the far end of the approach slab on a sleeper beam with a construction joint of two inches and provide an improved joint sealing system at the CF joint. A rubber V-shaped gland joint sealing system is recommended on a pilot test basis. Replace the #5 vertical reinforcing bars in the abutment wall with #7 reinforcing bars in future non-integral bridges.