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**Executive Summary Report**

**Identification and Evaluation of Pavement-Bridge Interface Ride Quality Improvement and Corrective Strategies**

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**Project Background**

Bridge owners have long recognized that the approach pavement at bridges is prone to exhibiting both settlement and cracking, which manifest as the “bump at the end of the bridge.” This deterioration requires considerable on-going maintenance expenditures, added risk to maintenance workers, increased distraction to drivers, reduced steering control, increased damage to vehicles, a negative public perception of the highway system, and a shortened useful bridge life. This problem has recently begun to receive significant national attention as bridge owners have increased the priority of dealing with the recurring problem.

No single factor, in and of itself (individually), leads to significant problems. Rather, it is an interaction between multiple factors that typically leads to problematic conditions. As such, solutions require interdisciplinary thinking and implementation. The bridge-abutment interface is a highly complex region and an effective “bump at the end of the bridge” solution must address the structural, geotechnical, hydraulic, and construction engineering disciplines. 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.

**Study Objectives**

The objective of this work is to assist the Ohio Department of Transportation (ODOT) in the development of pre-construction, construction, and post-construction strategies that will help eliminate or minimize the “bump at the end of the bridge.” Implementation of the details and procedures described herein will provide a tangible benefit to both ODOT and the traveling public in the form of smoother bridge transitions, reduced maintenance costs, and a safer driving environment.



## Description of Work

To achieve the project goals, the following general activities were performed:

- Review of the ODOT design and construction standards and specifications
- Literature review
- Review and summary of current, nationwide state-of-the-practice
- Field investigation of the behavior and condition of in-service bridges
- Laboratory and field testing of bridge embankment materials
- Compilation and comparison of collected information
- Development of recommendations

## Research Findings & Conclusions

The findings and conclusions are loosely grouped as either Structural or Geotechnical/Drainage. In some cases, the findings overlap between categories.

### *Structural*

- The ODOT definition of and details for integral and semi-integral abutments appear to differ from most other states. Of most importance are the ODOT integral abutment details, which do not allow for full connectivity/stiffness compatibility (rotational and translational) of the superstructure and substructure. The advantages of using integral abutments are well documented (including in this report) and ODOT may not be fully realizing all the known benefits. Again, the current ODOT semi-integral abutment detail is different from that used by most states. Specifically, the ODOT semi-integral detail does not provide for any connectivity between the superstructure and substructure—only between individual beams of the superstructure.
- ODOT approach slabs are detailed to have a partial positive connection to the bridge substructure. With this detail, the substructure and approach slab translate together. Any rotation of the substructure (which is designed to be zero) would similarly rotate the approach slab. However, because the superstructure and substructure do not rotate together, there is a rotational discontinuity between the superstructure and approach slab. This means, any rotation of one element (or both) will result in a rapid change in slope at the interface.
- ODOT approach slabs appear to be doubly reinforced. It is not clear, however, if the reinforcing details are sufficient (strength and/or stiffness) to allow the approach slab to bridge voids that may form below the slab.
- The ODOT Office of Pavement has standard details for the transition between the approach pavement and the mainline pavement. When asphalt pavement constitutes the mainline pavement, the asphalt is butted directly against the face of the approach slab. When concrete pavement is used, an asphalt pressure relief joint (4 ft of asphalt on a sleeper slab) is used. In either case, the only mechanism to accommodate temperature-induced expansion of the bridge and approach slab is compression of the asphalt. This compression generally results in upward bulging of the asphalt.



- Comparison of global geometric data and international roughness index (IRI) data indicate that some sources of poor ride quality are missed by one type of measurement. In other words, sometimes the global geometric data indicate ride quality issues, sometimes the IRI data indicate ride quality issues, and in some cases both indicate problematic conditions.
- Highly-variable falling weight deflectometer (FWD) test results were found. Of interest was the fact that, very near the bridge, FWD tests indicated a very stiff system (as expected), but moving away from the bridge, system stiffness decreases immediately and is thereafter highly variable. It was also found that there wasn't a reliable correlation between fill depth and FWD test results. This may indicate that the "quality" of material installation, rather than the amount of material installation, may be the greatest influence on vertical stiffness.
- Under live load, ODOT bridge abutments do not appear to be rotating under live loads. Given the standard integral and semi-integral abutment details, this is not surprising. Conversely, it was found that the abutments do translate under live loads. If the abutment backfill materials and their installation were not designed correctly, this could lead to the formation of voids behind the backwall.
- Differential settlement was observed at most bridge sites. However, the study found a lack of consistency in the location of the differential settlement, indicating there may be multiple sources of ride quality issues.

#### *Geotechnical/Drainage*

- Gradation results indicate that the granular backfill materials being placed below the approach slab and around the abutment back walls have bulking moisture content of about 6%. Sandy granular backfill materials placed at the bulking moisture content can experience collapse under load. The collapse potential for the granular backfill materials tested in this study ranged from almost zero to more than 10%. Without exception, bulking moisture content should be avoided during construction. Field-controlling the moisture content to avoid the bulking range can mitigate the potential for collapse and therefore eliminate one behavior known to impact bridge ride quality. Incremental wetting of the material in situ during construction can be effective at reducing post-construction collapse.
- According to the light weight deflectometer (LWD) test results and dynamic cone penetrometer (DCP) California Bearing Ratio (CBR) profiles from all investigated bridges, the backfill materials placed within about 5 ft of the abutment back wall are poorly compacted. This is due to limiting the compaction effort in this zone next to the abutment wall. Specific observations for some of the bridge sites are as follows:
  - Based on field moisture and dry unit weight measurements for Bridge #1, the backfill material was placed at the bulking moisture content and the dry unit weight was close to the minimum dry unit weight obtained from laboratory testing.
  - The moisture content and dry unit weight measurement for Bridge #5 show that the backfill material had the moisture content within the optimum moisture content, but the dry unit weight was lower than the maximum dry unit weight.
  - Field collapse potential tests indicate minimal in-situ collapse of the backfill material for Bridge #6.



## Implementation Recommendations

The recommendations represent a holistic group of changes that, collectively, will improve the ride quality or rideability of bridges in Ohio. The recommendations include suggestions on modifications to specifications, details, and policy. Select recommendations include:

- A specification that ensures an acceptable ride quality at the time of construction should be created and adopted by ODOT. Once created, we suggest that an annual review of the specification be completed for a minimum of five years to ensure that ODOT is achieving the desired results (acceptable ride quality at a reasonable cost). The specification should contain two parts:
  - Maximum global roughness
  - Maximum local roughness
- On structures where unusual/unproven construction practices are required (or requested by the contractor), the bridge deck should be constructed with a minimum of 1/2 in. of additional sacrificial thickness, such that planned blanket grinding can, without question, occur (unless deemed unnecessary). This sacrificial thickness will give ODOT the flexibility to correct structures that unexpectedly have poor ride characteristics.
- Improve the stiffness compatibility between the bridge superstructure, substructure, approach slab, and supporting materials as follows:
  - Use integral abutments whenever possible and revise the integral abutment details such that the superstructure and piles are rigidly connected (so they rotate and translate as a unit).
  - Although published literature does not provide enough data to indicate if the use of sleeper slabs improve rideability, the researchers recommend that, regardless of the mainline approach type, support the approach slab on a sleeper slab.
- Replace the current ODOT approach slab to mainline pavement joint detail with an expansion joint that is sized to accommodate the expected bridge and approach slab expansion and contraction.
- Actively maintain the recommended expansion joint to prevent the development of high stresses in the approach slab and bridge. Such maintenance activities will ensure that the bridge is free to expand and contract with temperature variations.
- Develop a lab test protocol to determine the bulking moisture content for granular backfill materials and establish a practice to field control the moisture content to avoid bulking moisture contents. Compaction curves for cohesionless sands readily show bulking in the range of 3 to 5% moisture content.
- Consider use of alternative backfill materials, such as geosynthetic-reinforced soil, geofoam, or flowable fill, as an alternative to collapsible backfill.
- Water drainage needs to be an integral part of the bridge and embankment design. The bridge and embankment need to be detailed to drain water away from the bridge deck, joints, and embankment without causing erosion or changes in the soil properties.
- Use the developed methodology to determine the timing of and type of corrective action required.