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## Tech Brief



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### EVALUATION OF INTEGRAL ABUTMENTS

FHWA-NJ-2005-025

September 2006

**SUMMARY** An integral bridge is a single or multiple-span structure that is cast monolithically to its abutments. Stub abutments supported on a single row of vertical piles create a flexible connection that can accommodate the longitudinal displacements of the superstructure. The primary purpose of using integral abutments is the elimination of deck-movement joints and bearings that have been found expensive to maintain.

This research project is centered on the evaluation of integral abutments as a design alternative to the use of bearings in medium-length highway bridges. It includes: 1) an extensive literature search; 2) the instrumentation of Scotch-Road Bridge in Trenton, N.J. to obtain strain data on the piles, displacement and rotation data on the abutment, soil-pressure data on the abutments and the MSE wall, and strain data on deck connection; and 3) a finite element model of the system. The end result is the recommended design procedure for integral abutments of highway bridges. Integral abutments have been found to be a safe alternative design. A step-by-step design procedure for piles to withstand the horizontal thermal loading is included.

**INTRODUCTION/BACKGROUND** Integral abutment bridges have no expansion joints between the deck and the abutments. They have been in use since masonry arches were introduced thousands of years ago. Modern highway bridges have also been built with integral construction. However, an increasingly analytical approach to bridge design in recent years has resulted in the erection of many new highway bridges that use complicated movement joints and sliding bearings to accommodate calculated thermal effects and horizontal displacements. Unfortunately, many of these jointed bridges are exhibiting deterioration of beam ends, pedestals, and piers predominately caused by the flow, through the bridge joints, of deck drainage waters contaminated with deicing chemicals. Nationwide, rehabilitation costs for damaged bridge joints and substructures figure into millions of dollars annually. As a result, integral bridges are seen as a cost-effective alternative, and are becoming increasingly popular.

**RESEARCH APPROACH** The New Jersey Department of Transportation (NJDOT) initiated a research project to:

1. Summarize and evaluate the present state of knowledge in the field of integral abutments.
2. Evaluate the design, details, and construction of a bridge with integral abutments.
3. Instrument the bridge and gather sufficient data to assess present design and construction practices.
4. Use measured data to evaluate and update numerical models, and further use these models to understand the behavior.
5. Use all knowledge gathered to modify the design codes and design assumptions.

To achieve the objectives, a comprehensive research plan has been accomplished. This includes instrumentation and monitoring of the Scotch Road Integral Abutment Bridge, (located in Mercer County, New Jersey, over I-95), literature search, numerical calculations, and ultimately, the presentation of design detailing and construction methods

**FINDINGS/CONCLUSIONS** This report summarizes the collective knowledge on the issues surrounding the design and construction of integral abutment bridges. Information from the New Jersey Department of Transportation was combined with the experience of other departments of transportation around the country, recent research and testing from several research teams around the country, and evidence gathered from the measurements of the Scotch Road Bridge, over I-95 in Trenton, New Jersey. The result is the accumulation of several observations and recommendations for a successful integral abutment design.

Based on this research project on integral abutments, our recommendations are:

1. Integral abutments constitute a preferable design for new bridge construction.
2. The major factors that limit integral abutment construction are the skew, curvature, and length of the bridge.
3. Another factor that should be considered in choosing an integral abutment is the available depth to the bedrock. The piles must be long to develop their curvature.
4. The limiting factors can be overcome with careful design.
5. Either steel or concrete superstructures can be candidates for integral-abutment construction.
6. Pile-supported, stub-type abutments are preferable.
7. A single row of long, slender, vertical steel H piles oriented for weak-axis bending is the best pile type for integral abutments.
8. Battered piles cause damage to the slab seat and should be avoided.
9. Pre-drilling oversized holes in stiff soils and surrounding the piles with loose sand is a common and advantageous method in reducing the stresses in the piles.
10. Calculations by this research team show that the larger the pre-drilled hole (in strong soils) the smaller the stresses on the piles.
11. Piles under the wing-walls can experience tension under vertical loading.
12. Calculations and measurements by this research team show that the p-y method (found in L-PILE, COM624P, etc) was an adequate method to analyze the piles for bending due to maximum horizontal movement of the bridge.

13. Calculations by this research team verified that piles in a group carry unequal amount of lateral loads due to “shadowing”. One can use p-multipliers to account for the difference.
14. Measurements taken herein show that piles directly under a girder experience higher displacements and rotations that are imparted to the pile from the girder.
15. Measurements taken herein verify that passive soil pressures develop behind the abutment due to densification and “soil ratcheting” during cyclic loading. The pressures were found to be much higher than usual design values.
16. Research completed after the present project shows that for longer bridges, the maximum passive pressure (after cyclic loading) can be assumed to be a Rankine pressure calculated with a maximum density of the soil and a  $K_p$  for a maximum angle of internal friction<sup>i</sup>. A conservative  $K_p$  can be found in NCHRP (1991) and can be used with a Rankine pressure distribution.
17. Measurements herein showed that the obtuse corner of the bridge experienced higher passive pressures. This was explained by the unequal movement of the bridge into the backfill soil due to the skew.
18. Porous, granular, well-compacted backfill should be used behind the abutment.
19. Measurements of stress taken around the pile sleeves and at the MSE wall, as well as calculations performed in this research effort show that the stresses that the piles impart to the surrounding soil due to their lateral movement dissipate quickly. As such, the MSE wall (or other retaining structure) is not loaded due to the movement of the bridge.
20. At the Scotch Road Bridge, temperatures at the deck reached up to 20° F higher than ambient during the summer months. Temperature at the steel girder reached up to 10° F higher than ambient. Both reached about ambient during the winter months.
21. The Scotch-Road Bridge experienced higher rotation during the summer months due to a higher variation of temperature along the depth of the girder. Such rotations can be transmitted to the piles during the summer months.
22. Calculations performed as part of this project show that the abutment is not rigid. It acts as a flexible member and does not transmit all of the top displacement/rotation to the pile top. This leads to a conservative design for the piles.

The wing walls and other construction peripheral to the bridge were not addressed herein. Anecdotal evidence and testimonials on such members have been summarized in the literature search.

**RECOMMENDATIONS** Since the conclusion of this research, the LRFD method for the design of the foundations has been in effect. This should not compromise the overall design directive and method that has been given herein. However, 1) load factors, 2) resistance factors and 3) limit analysis have not been addressed for the piles in the presence of strong sand. These should be the subjects of further research.

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A final report is available online at <http://www.state.nj.us/transportation/research/research.html>

If you would like a copy of the full report, please FAX the NJDOT, Division of Research and Technology, Technology Transfer Group at (609) 530-3722 or send an e-mail to [Research.Division@dot.state.nj.us](mailto:Research.Division@dot.state.nj.us) and ask for:

Evaluation of Integral Abutments

NJDOT Research Report No: FHWA-NJ-2005-025