

DESIGN DETAILS OF INTEGRAL BRIDGES

By Eugenia Roman¹, Yasser Khodair², and Sophia Hassiotis³

¹ Res. Asst., Dept. of Civil, Environmental and Ocean Engineering, Stevens Institute of Technology, Hoboken, NJ;
Structural Engineer for Hardesty & Hanover, LLP, Hoboken, NJ

² Res. Asst., Dept. of Civil, Environmental and Ocean Engineering, Stevens Institute of Technology, Hoboken, NJ

³ Assoc. Prof., Dept. of Civil, Environmental and Ocean Engineering, Stevens Institute of Technology, Hoboken, NJ

ABSTRACT: Integral bridges have been found to outperform jointed bridges, decreasing maintenance costs, and enhancing the life expectancy of the superstructures. However, a standard design method for integral bridges does not exist. Several factors must still be investigated to gain a better understanding of the behavior of integral abutments, and the factors that influence their analysis, design, detailing, and construction. In this paper, we will be investigating the deck-stringer-abutment continuity details.

Most connections are designed as rigid by using adequate reinforcement detailing between the slab, girders and abutment. However, 1) cracking on the deck has been observed, 2) the detailing may vary as a function of structure geometry. In this work, we are evaluating design details that have been standardized for a variety of applications, and we are suggesting the next step in research that will result in final design specifications for integral abutments.

INTRODUCTION

The use of an integral abutment eliminates the need for deck joints and expansion bearings. The absence of joints and bearings significantly reduces costs during construction. More significantly, maintenance costs are also reduced since deck joints, which allow water to leak onto substructure elements and accelerate deterioration, are not needed. In addition, future widening or bridge replacement becomes easier, since the simple design of the integral abutment lends itself to simple structural modification.

The design of the replacement structure for the Scotch Road over Route I-95 structure, located in Ewing and Hopewell Townships in New Jersey, has implemented integral abutments. The existing Scotch Road Bridge is a 45m-span composite steel structure supported on conventional abutments. The proposed structure is a 2-span continuous composite steel structure with integral abutments skewed at approximately 15°. High Performance Steel (HPS) has been specified for the stringers. The Load and Resistance Factor Design (LRFD) method has been used to yield a more efficient structure.

The research herein pertains to the response of this structure to loading and seasonal temperature variations. Particularly, we will investigate the issues and concerns that are associated with integral abutment construction details, which include the deck slab, the approach slab the abutment, and the supporting pile foundation. Figure 1 depicts the integral abutment detail that will be used on Scotch Road.

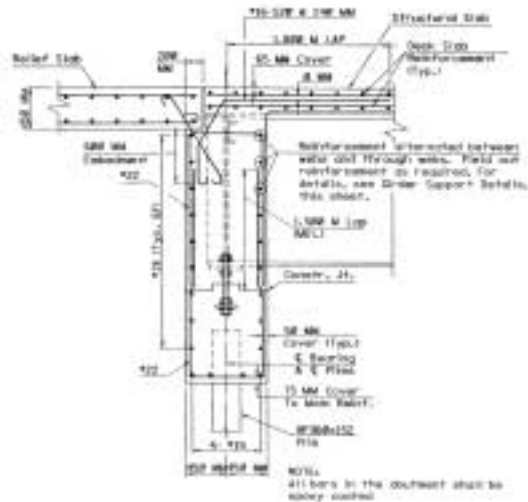


Figure 1. Integral Abutment Detail to be used on Scotch Road Bridge.

APPROACH SLAB INTERFACE JOINTS

Approach slabs are used to provide a smooth transition and span the problematic area between road pavements and bridge decks. There are two main types of approach slabs; one type is tied to the abutment as in integral abutment bridges (Fig. 2)⁴. The other type has an expansion joint between the bridge deck and the approach slab as in non-integral abutment bridges (Fig. 3)⁵. Figure 4 depicts the approach slab detail that will be used on Scotch Road.

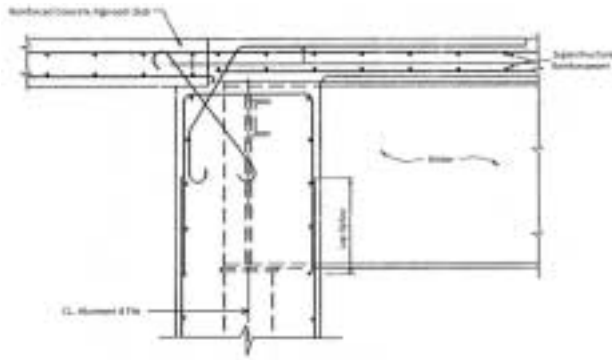


Figure 2. Integral Abutment Detail. Note formed rebar to establish connection between the abutment beam and the approach slab.

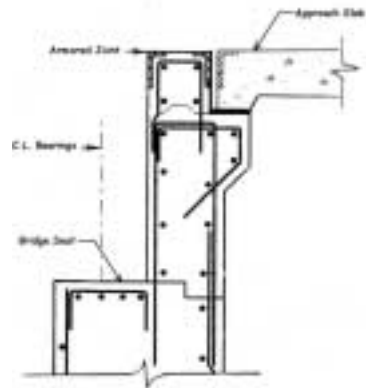


Figure 3. Convention Abutment Detail. Note the gap between the edge of the approach slab and the edge of the header.

⁴ New Jersey Department of Transportation, "Bridges and Structures Design Manual", Third Edition 1998, Plate No. 2.13-1 (modified for clarity)

⁵ New Jersey Department of Transportation, "Bridges and Structures Design Manual", Third Edition 1998, Plate No. 3.3-1 (modified for clarity)

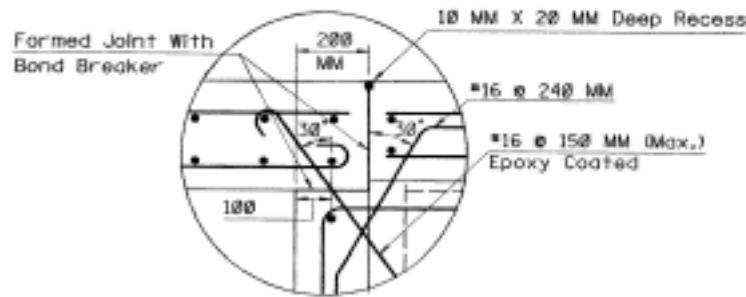


Figure 4. Approach slab detail to be used on the Scotch Road bridge.

The detailing of the joints at the ends of approach slabs in integral abutment bridges plays an essential role in the determination of its ductility and rotational capacity. The primary task of the joints is to transfer vehicular live loads and thermal loads to the approach slab. Inadequate design of joints may result in crack development in approach slabs. Both longitudinal and transverse cracking take place in approach slabs.

Transverse cracking usually occurs due to one or more of three major factors: 1) heavy vehicular live loads; 2) settlement of the backfill soil and 3) void development under the approach slab. Transverse cracking due to vehicular live load usually occur solely in the right or middle lanes as a result of extensive traffic flow, (Khodair, 2001). Moreover, transverse cracking has been observed in all lanes at the end of the dowel bars extending from the bridge abutment. This cracking has developed due to void development and loss of support under approach slabs.

Longitudinal cracking also develops on approaches with voids under the approach slab (Schaefer et al., 1992). Furthermore, most backfill materials are not perfectly elastic, which permits cyclic abutment movements to create voids between the backfill and the abutment. As a result, some states resorted to using special details in order to accommodate the cyclic movement of the abutment. For example, North Dakota adopted the design illustrated in Figure 5 to provide a pressure relief mechanism between the backfill and the abutment. This mechanism relies on providing a void space of 4" between the abutment and its backfill. Moreover, the piles were drilled in oversized holes. The holes were backfilled with sand to accommodate the movement of the abutment and the piles. Wahls (1990) suggests that the performance of integral abutments could be improved by the development of new compressible elastic materials to be installed between the abutment and the surrounding backfill.

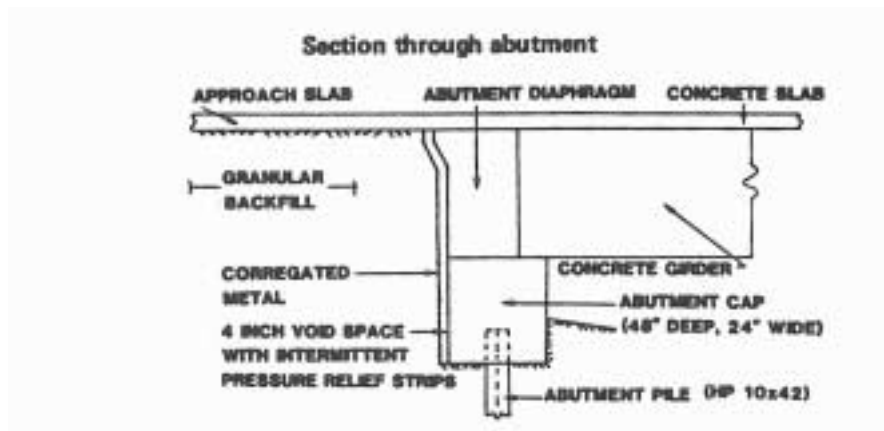


Figure 5. Special Integral Abutment Design, North Dakota (Wahls, 1990).

DECK SLAB CONCERNS

Secondary stresses in the bridge deck caused by thermal changes and settlement of the substructure can be significantly greater than those permitted by current design specifications. However, a study performed by Mourad and Tabsh (1999) has found that the maximum transverse stresses in the deck slab can be 25-50% lower using an integral abutment configuration rather than the simply supported configuration.

Alampalli and Yannotti (1998) inspected and rated 30 steel superstructure bridges with integral abutments at varying skews. Their research assigned a numerical rating to the condition of the bridge deck, the approach slab and the abutment stem. Analysis of the condition ratings of the sample bridges indicated that the greater the skew of the bridge deck, the lower the condition and performance ratings were for the deck, approach slab and abutment stem.

Burke (1999) has noted typical patterns of early-age cracking in the decks of integral bridges. Both diagonal and straight cracks occasionally develop at the acute corners and over (previously) placed concrete end diaphragms, respectively. In addition, transverse cracks at relatively uniform spacing have also been a major concern for bridge designers and contractors. He concludes that such cracking has occurred as a result of insufficient continuous temperature and shrinkage reinforcement in the deck slabs over the end-diaphragms. Connections between the static abutments and the moving deck/superstructure can be stressed and crack if a significant temperature change was to occur during the initial concrete setting or if proper construction inspection methods were not adhered to during the setting. To prevent the occurrence of stressing/cracking, the following procedures have evolved:

1. Place continuity connection at sunrise
2. Place deck slabs and continuity connections at night
3. Place continuity connections after deck slab placement
4. Use crack sealers

Realizing the observations that other researchers have made, our research is concentrating on the integral connection detailed by the designer, the concrete placement sequence adopted by the contractor, and the stresses resulting from the cyclical loading of the deck, approach slab, the abutment, and supporting piles. A main part of our research includes the instrumentation of the

principal components of the integral connection in an effort to quantify the movements and loads realized at this connection. We are in the process of installing instrumentation at the Scotch Road Bridge during the construction phase. Strain gages are placed at the girders, piles, and on sister bars inside the abutment/superstructure connection. These will give the stresses present at the connection. Tiltmeters placed on the girders will measure the rotation of the abutment. Load cells on the abutment wall will measure soil pressures developed behind the abutment. Load cells in front of the piles will measure possible loads imposed by the integral connection on the retaining wall at the foot of the bridge. Data will be collected at regular intervals to account for variation in loading and in thermal conditions. This information, along with the construction details and implemented construction procedures, will be analyzed for continuity and efficiency. If necessary, modifications to the implemented integral connection detail and the construction sequence will be suggested for use on future projects.

CONCLUSIONS

Through an extensive literature search on the subject of integral abutments and their connection details to the deck slab and approach slab, it is apparent that there is still a great deal of research to be performed on these structures. In an attempt to investigate this problem further, the Scotch Road Bridge will be instrumented during construction. Data will be collected and analyzed for a three-year period. The results of this study will add to the base knowledge of integral bridges.

REFERENCES

1. Alampalli, Sreenivas and Yannotti, Arthur P. (1998), "In-Service Performance of Integral Bridges and Jointless Decks", Transportation Research Record 1624, Paper No. 98-0540.
2. Briaud, Jean-Louis, James, Ray W and Hoffman, Stacey B. TRB(1997), NCHRP Synthesis of Highway Practice 234: Settlement of Bridge Approaches "Bump at the End of the Bridge". National Academy Press, Washington, D.C. 1997.
3. Burke, Martin P., Jr., (1999), "Cracking of Concrete Decks and Other Problems with Integral-Type Bridges", Transportation Research Record 1688, Paper No. 99-0104.
4. Khodair, Yasser A (2001). Master of Science Thesis, "Finite Element Modeling of Approach and Transition Slabs". Department of Civil and Environmental Engineering, Rutgers University, 2001.
5. Mourad, Shehab and Tabsh, Sami W. (1999), "Deck Slab Stresses In Integral Abutment Bridges", Journal of Bridge Engineering, May 1999.
6. NCHRP (1990), Synthesis of Highway Practice 159, "Design and Construction of Bridge Approaches". Transportation Research Board, National Research Council, Washington, D.C, 1990.
7. Schaefer, Vernon R and Koch, Jay C (1992), "Void Development under Bridge Approaches". Final Report No SD90-03. South Dakota Department of Transportation, November 1992.