INTEGRAL ABUTMENT AND JOINTLESS BRIDGES

Vasant C. Mistry[1]

Abstract

There are many advantages to jointless bridges as many are performing well in service. There are long-term benefits to adopting integral bridge design concepts and therefore there should be greater use of integral bridge construction. Integral abutment and jointless bridges cost less to construct and require less maintenance then equivalent bridges with expansion joints. This paper explains why we should use Integral Abutment and Jointless Bridges, and discusses some of the recommended practices for Integral Abutment and Jointless Bridges.

Why Jointless Bridges?

One of the most important aspects of design, which can affect structure life and maintenance costs, is the reduction or elimination of roadway expansion joints and associated expansion bearings. Unfortunately, this is too often overlooked or avoided. Joints and bearings are expensive to buy, install, maintain and repair and more costly to replace. The most frequently encountered corrosion problem involves leaking expansion joints and seals that permit salt-laden run-off water from the roadway surface to attack the girder ends, bearings and supporting reinforced concrete substructures. Elastomeric glands get filled with dirt, rocks and trash, and ultimately fail to function. Many of our most costly maintenance problems originated with leaky joints.

Bridge deck joints are subjected to continual wear and heavy impact from repeated live loads as well as continual stages of movement from expansion and contraction caused by temperature changes, and or creep and shrinkage or long term movement effects such as settlement and soil pressure. Joints are sometimes subjected to impact loadings which can exceed their design capacity. Retaining hardware for joints are damaged and loosened by snowplows and the relentless pounding of heavy traffic. Broken hardware can become a hazard to motorists, and liability to owners.

1 Structural Engineer, Federal Highway Administration, Washington, DC

Deck joints are routinely one of the last items installed on a bridge and are sometimes not given the necessary attention it deserves to ensure the desired performance. While usually not a significant item based on cost, bridge deck joints can have a significant impact on a bridge performance. A wide variety of joints have been developed over the years to accommodate a wide range of movements, and promises of long lasting, durable, effective joints have led States to try many of them. Some joint types perform better than others, but all joints can cause maintenance problems.

Bearings also are expensive to buy and install and more costly to replace. Over time steel bearings tip over and seize up due to loss of lubrication or buildup of corrosion. Elastomeric bearings can split and rupture due to unanticipated movements or ratchet out of position.

Because of the underlying problems of installing, maintaining and repairing deck joints and bearings, many States have been eliminating joints and associated bearings where possible and are finding out that jointless bridges can perform well without the continual maintenance issues inherent in joints. When deck joints are not provided, the thermal movements induced in bridge superstructures by temperature changes, creep and shrinkage must be accommodated by other means. Typically, provisions are made for movement at the ends of the bridge by one of two methods: integral or semi-integral abutments, along with a joint in the pavement or at the end of a reinforced concrete approach slab. Specific guidelines for designing and detailing jointless bridges have not yet been developed by AASHTO so the States have been relying on established experience

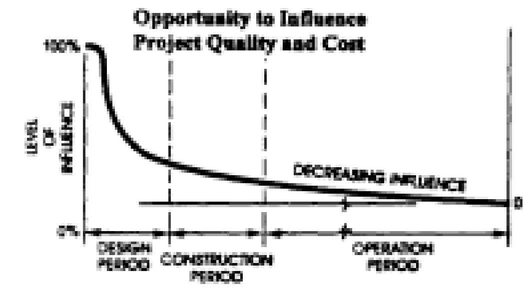
A 1985 FHWA report on tolerable movement of highway bridges examined 580 abutments in 314 bridges in the United States and Canada. Over 75 percent of these abutments experienced movement, contrary to their designer's intent, typically much greater movement vertically than horizontally. The following paragraph is from the report.

"The magnitude of the vertical movements tended to be substantially greater than the horizontal movements. This can be explained, in part, by the fact that in many instances the abutments moved inward until they became jammed against the beams or girders which acted as struts, thus preventing further horizontal movements. For those sill type abutments that had no backwalls, the horizontal movements were often substantially larger, with abutments moving inward until the beams were, in effect, extruded out behind the abutments."

The use of expansion joints and bearings to accommodate for thermal movements does not avoid maintenance problems; rather, the provision to these items can often facilitate such problems.

In this 40-year national experience, many savings have been realized in initial construction costs by eliminating joints and bearings and in long-term maintenance expenses from the elimination of joint replacement and the repair of both super and substructures. Designers should always consider the possibilities of minimum or no joint construction to provide the most durable and cost-effective structure. Steel superstructure bridges up to 400 ft. long and concrete superstructure bridges up to 800 ft. long have been build with no joints, even at the abutments.

The impact on the total project cost and quality is best illustrated by the figure shown to the right. As is seen, the decisions made at the design stage account for over 80 percent of the influence on both cost (first and life cycle) and quality (service life performance) of the structure. Decisions made in the initial stages of design establish a program that is difficult and costly to change once detailed design or construction begins.



The following quote is very appropriate for bridge engineering:

"Quality is never an accident. It is always the result of high intention, sincere effort, intelligent direction, and skillful execution. It represents the wise choice of many alternatives."

This is especially true when the Engineer begins the task of planning, designing and detailing a bridge structure. The variables are many, each of which has a different, first and life cycle, cost factor. The question to be asked continuously through the entire process is what value is added if minimum cost is not selected? Another question to be asked is what futures should be incorporated in the structure to reduce the first and life cycle cost and enhance the quality? Most of the variables are controlled by the designer. These decisions influence the cost and quality of the project; for better or for worse!

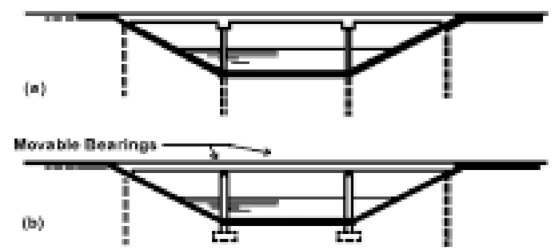
This paper presents some of the important features of Integral abutment and Jointless bridge design and some guidelines to achieve improved design. The intent of this paper is to enhance the awareness among the engineering community to use Integral Abutment and Jointless Bridges wherever possible.

What Is an Integral Abutment Bridge?

Integral abutment bridges are designed without any expansion joints in the bridge deck.

They are generally designed with the stiffness and flexibilities spread throughout the structure/soil system so that all supports accommodate the thermal and braking loads. They are single or multiple span bridges having their superstructure cast integrally with their substructure. Generally, these bridges include capped pile stub abutments. Piers for integral abutment bridges may be constructed either integrally with or independently of the superstructure. Semi-integral bridges are defined as single or multiple span continuous bridges with rigid, non-integral foundations and movement systems primarily composed of integral end diaphragms, compressible backfill, and movable bearings in a horizontal joint at the superstructure-abutment interface.

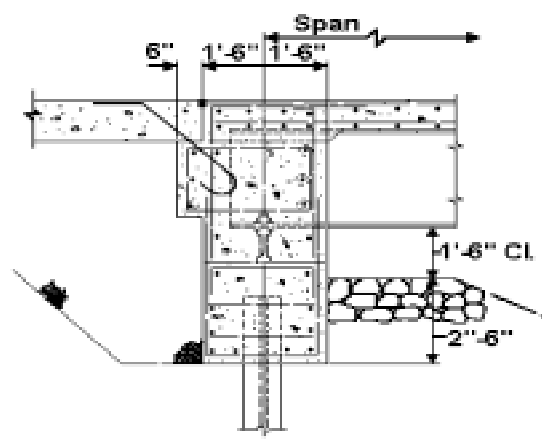
<u>Why Integral Abutments?</u>



Integral Bridges with capped-pile abutments and (a) flexible capped-pile piers; (b) semi-rigid piers with movable bearings.

As stated earlier, integral abutment and jointless bridges cost less to construct and require less maintenance then equivalent bridges with expansion joints. In addition to reducing first costs and future maintenance costs, integral abutments also provide for additional efficiencies in the overall structure design. Integral abutment bridges have numerous attributes and few limitations. Some of the more important attributes are summarized below.

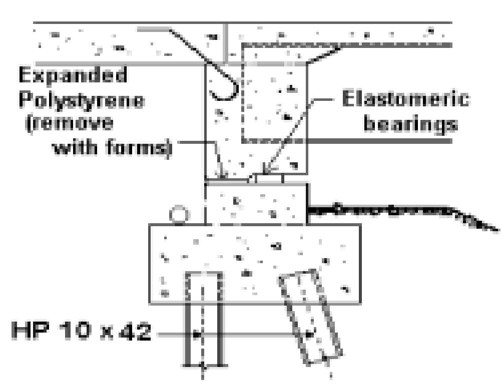
Simple Design - Where abutments and piers of a continuous bridges are each supported by a single row of piles attached to the superstructures, or where self-supporting piers are separated from the superstructure by movable bearings, an integral bridge may, for analysis and design purposes, be considered a continuous frame with a single horizontal member and two or more vertical members.



Integral Abutment with attached approach slab

Jointless construction - Jointless construction is the primary attribute of the integral abutment bridges. The advantages of jointless construction are numerous as has been stated earlier.

Resistance to pressure - The jointless construction of integral bridges distributes longitudinal pavement pressures over a total superstructure area substantially greater than that of the approach pavement cross-section.



Rapid construction - Only one row of vertical piles is used, meaning fewer piles. The back wall can be cast simultaneously. Fewer parts are required. Expansion joints and bearings are not needed. The normal delays and the costs associated with bearings and joints installation, adjustment, and anchorages are eliminated.

Semi-Integral Abutment with attached approach slab

Ease in constructing embankments - Most of the embankment is done by large earth moving and compaction equipment requiring only little use of hand operated compaction equipment.

No cofferdams - Integral abutments are generally built with capped pile piers or drilled shafts piers that does not require cofferdams.

Vertical piles (no battered piles) - At abutment a single row of vertical piles is used.

Simple forms - Since pier and abutment pile caps are usually of a simple rectangle shape they require simple forms.

Few construction joints are required in the integral abutment bridges which results in rapid construction.

Reduced removal of existing elements - Integral abutment bridges can be built around the existing foundations without requiring the complete removal of existing substructures.

Simple beam seats - Preparation of load surface for beam seat can be simplified or eliminated in integral bridge construction.

Greater end span ratio ranges - Integral abutment bridges are more resistant to uplift. Integral abutment weight act as counterweights. Thus, a smaller end span to interior span ratio can be used without providing for expensive hold-downs to expansion bearings.

Simplified widening and replacement - Integral bridges with straight capped-pile substructures are convenient to widen and easy to replace. Their piling can be recapped and reused, or if necessary, they can be withdrawn or left in place. There are no expansion joints to match and no difficult temperature setting to make.

The integral abutment bridge act as a whole unit.

Lower construction costs and future maintenance costs.

Improved ride quality - Smooth jointless construction improves vehicular riding quality and diminishes vehicular impact stress levels.

Design efficiency - Design efficiencies are achieved in substructure design. Longitudinal and transverse loads acting upon the superstructure may be distributed over more number of supports.

For example, the longitudinal load distribution for the bent supporting a two span bridge is reduced 67 percent when abutments are made integral instead of expansion. Depending upon the type of bearings planned for an expansion abutment, transverse loadings on the same bent can be reduced by 67 percent as well.

Added redundancy and capacity for catastrophic events - Integral abutments provide added redundancy and capacity for catastrophic events. Joints introduce a potential collapse mechanism into the overall bridge structure. Integral abutments eliminate the most common cause of damage to bridges in seismic events, loss of girder support. Integral abutments have consistently performed well in actual seismic events and significantly reduced or avoided problems such as back wall and bearing damage, associated with seat type jointed abutments. Jointless design is preferable for highly seismic regions.

Improve Load distribution - Loads are given broader distribution through the continuous and full-depth end diaphragm.

Enhance protection for weathering steel girders

Tolerance problems are reduced or eliminated - The close tolerances required with expansion bearings and joints are eliminated or reduced with the use of integral abutments.

Recommended Best Practices

The following best practices are believed to contain the key elements to ensure quality improvements in designing and constructing Integral Abutment and Jointless Bridges.

- Develop design criteria or office practices for designing integral abutment and jointless bridges.

- In extending the remaining service lives of existing bridges, develop criteria for evaluating and retrofitting bridges with joints to integral or semi-integral structures.

- Establish an annual workshop between joint specialists of various States to exchange information in the areas of design, construction and maintenance of joints and jointless bridges since there is continuing innovation and changing technology. This will help leverage the expertise of limited manpower in all the States and allow more effective communication of "What works and what does not".

- The decision to install an approach slab should be made by the Bridges and Structures Office, with consultation from the Geotechnical group. The decision should be based upon long-term performance and life cycle costs, rather than just first costs to the project.

- Standardize practice of using sleeper slabs at the end of all approach slabs. An irregular crack and pavement settlement typically develops at the interface of the approach slab and the approach pavement. Develop a method to control and seal this cracking, and if not already provided, develop a method to channel the water coming through this crack away from the pavement without allowing material to be washed away.

Recommended Design Details for Integral Abutments

- Use embankment and stub-type abutments.
- Use single row of flexible piles and orient piles for weak axis bending.
- Use steel piles for maximum ductility and durability.
- Embed piles at least two pile sizes into the pile cap to achieve pile fixedly to abutment.
- Provide abutment stem wide enough to allow for some misalignment of piles.
- Provide an earth bench near superstructure to minimize abutment depth and wingwall lengths.
- Provide minimum penetration of abutment into embankment.
- Make wingwalls as small as practicable to minimize the amount of structure and earth that have to move with the abutment during thermal expansion of the deck.
- For shallow superstructures, use cantilevered turn-back wingwalls (parallel to center line of roadway) instead of transverse wingwalls.
- Provide loose backfill beneath cantilevered wingwalls.
- Provide well-drained granular backfill to accommodate the imposed expansion and contraction.
- Provide under-drains under and around abutment and around wingwalls.
- Encase stringers completely by end-diaphragm concrete.
- Paint ends of girders.
- Caulk interface between beam and backwall.
- Provide holes in steel beam ends to thread through longitudinal abutment reinforcement.
- Provide temporary support bolts anchored into the pile cap to support beams in lieu of cast bridge seats.
- Tie approach slabs to abutments with hinge type reinforcing.
- Use generous shrinkage reinforcement in the deck slab above the abutment.
- Pile length should not be less than 10 ft. to provide sufficient flexibility.
- Provide pre bored holes to a depth of 10 feet for piles if necessary for dense and/or cohesive soils to allow for flexing as the superstructure translates.
- Provide pavement joints to allow bridge cyclic movements and pavement growth.
- Focus on entire bridge and not just its abutments.
- Provide symmetry on integral bridges to minimize potential longitudinal forces on piers and to equalize longitudinal pressure on abutments.
- Provide two layers of polyethylene sheets or a fabric under the approach slab to minimize friction against horizontal movement.
- Limit use of integral abutment to bridges with skew less than 30 degree to minimize the magnitude and lateral eccentricity of potential longitudinal forces.

Summary

There are many advantages to jointless bridges as many are performing well in service. There are long-term benefits to adopting integral bridge design concepts and therefore there should be greater use of integral bridge construction. Due to limited funding sources for bridge maintenance, it is desirable to establish strategies for eliminating joints as much as possible and converting/retrofitting bridges with troublesome joints to jointless design.

The National Bridge Inventory database notes that eighty percent of the bridges in the United States have a total length of 180-ft. or less. These bridges are well within the limit of total length for integral abutment and jointless bridges. Where jointless bridges are not feasible, installation of bridge deck joints should be done with greater care and closer tolerances than normal bridge construction to achieve good performance.

Since 1987, numerous States have adopted integral abutment bridges as structures of choice when conditions allow. At least 40 States are now building integral and/or semi-integral abutment type of bridges. Preference range from Washington State and Nebraska, where 80-90 percent of structures are semi-integral; to California and Ohio, which prefer integral, but use mix, depending upon the application; to Tennessee, which builds a mix of both integral and semi-integral, but builds integral wherever possible.

While superstructures with deck-end joints still predominate, the trend appears to be moving toward integral. Although no general agreement, regarding a maximum safe-length for integral abutment and jointless bridges, exists among the state DOTs, the study has shown that design practices followed by the most DOTs are conservative and longer jointless bridges could be constructed.

There are several activities underway that will affect the way States are designing jointless bridges in the future. These include a joint AASHTO/NCHRP task force responsible for initiating and drafting AASHTO design guide specifications and synthesis report on current practices for integral and semi-integral abutment bridges, FHWA-sponsored research study on Jointless Bridges, update of LRFD specs to address jointless bridge design issues, and future workshops. An excellent reference document on current issues regarding jointless bridges is the FHWA Region 3 Workshop manual on Integral Abutment Bridges, November, 1996.

Continuity and elimination of joints, besides providing a more maintenance free durable structure, can lead the way to more innovative and aesthetically pleasing solutions to bridge design. As bridge designers we should never take the easy way out, but consider the needs of our customer, the motoring public first. Providing a joint free and maintenance free bridge should be our ultimate goal. The best joint is no joint.

References

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