**SECTION 15**

# INTEGRAL ABUTMENT BRIDGES

## 1.15.1 CHARACTERISTICS OF INTEGRAL BRIDGES

Integral abutment type bridge structures are simple or multiple span bridges that have their superstructure cast integrally with their substructure.

Integral abutment bridges accommodate superstructure movements without conventional expansion joints. With the superstructure rigidly connected to the substructure and with flexible substructure piling, the superstructure is permitted to expand and contract. Approach slabs, connected to the abutment and deck slab with reinforcement, move with the superstructure. At its junction to the approach pavement, the approach slab may be supported by a sleeper slab. If a sleeper slab is not utilized, the superstructure movement is accommodated using flexible pavement joints. Due to the elimination of the bridge deck expansion joints, construction and maintenance costs are reduced.

The integral abutment bridge concept is based on the theory that due to the flexibility of the piling, thermal stresses are transferred to the substructure by way of a rigid connection between the superstructure and substructure. The concrete abutment contains sufficient bulk to be considered a rigid mass. A positive connection with the ends of the beams or girders is provided by rigidly connecting the beams or girders and by encasing them in reinforced concrete. This provides for full transfer of temperature variation and live load rotational displacement to the abutment piling.

The connection between the abutments and the superstructure shall be assumed to be pinned for the superstructure's design and analysis. The superstructure design shall include a check for the adverse effects of fixity.

## 1.15.2 CRITERIA FOR INTEGRAL ABUTMENT BRIDGE DESIGN

The movement associated with integral abutment bridge design can be largely associated with thermal expansion and contraction of the superstructure. By definition, the length of an integral abutment structure shall be equal to the abutment center line of bearing to abutment center line of bearing dimension. This also applies to continuous span structure lengths with expansion bearings at the piers. This length of expansion mobilizes the horizontal passive soil pressure.

### A. Approach Slab.

1. Approach slabs will always be required for integral abutment bridge structures. Their lengths shall vary from a minimum of 3 m to a maximum that is based on the intercept of a 1 on 1.5 line from the bottom of the abutment excavation to the top of the highway pavement. This length is to be measured along the centerline of roadway.

2. The end of the approach slab shall be parallel to the skew. A width from face of rail to face of rail is recommended. Special provisions shall be made to allow free movement of the approach slabs if curbs or barriers are present. Approach

slabs shall always be a separate pour from the superstructure slab, but shall be joined together.

3. Where warranted, as per the Expansion Provisions stated below, to prevent the approach slab from moving excessively, it should rest on a keyed sleeper slab. The excavation for the sleeper slab shall be made after the compacted abutment backfill is placed. The sleeper slab shall be founded on undisturbed compacted material. No loose backfill may be used.

4. The approach slab shall be cast on two (2) layers of four (4) mil thick polyethylene sheets. It shall be designed as a structural slab that is supported at each end.

**B. Expansion Provisions.**

1. For bridge lengths 50 m or less, unless the highway pavement is rigid concrete, provision for expansion at the approach slab ends shall not be required.

2. For bridge lengths over 50 m and up to 100 m, provisions shall be made for expansion at the end of each approach slab by installation of a sleeper slab.

3. For bridge lengths over 100 m and up to 140 m, integral designs shall be approved by the Manager, Bureau of Structural Engineering, on an individual basis. Provision for expansion shall be made at the end of each approach slab by installation of a sleeper slab.

4. For bridge lengths over 140 m, integral abutments are not recommended at this time.

## 1.15.3 DESIGN PROCEDURE GUIDELINES

The following criteria shall be utilized in providing integral abutment bridge designs:

**A. Hydraulics.**

Integral abutment bridges provide fixity between the superstructure and substructure, and provide greater protection against translation and uplift than conventional bridges. The NJDOT Bridge Scour Evaluation Program and Structure Inventory and Appraisal Inventory records shall be studied to verify scour potential at a project site. To address potential impact of a scour effect on proposed Integral abutment bridge sites, the following areas should be reviewed and analyzed where scour potential exists:

1. Stream Velocity.

   Any history of erosion or scour at the bridge site should be reviewed and a determination made if the new structure will alleviate any problems (alignment, restricted opening etc.) that may contribute to scour. Where a scour history is determined, the potential positive affects of an Integral abutment bridge should be noted. Scour information may be obtained by researching the NJDOT Bridge

Scour Evaluation Program and Structural Inventory and Appraisal coding records.

2. Bank Protection.

Suitable slope protection construction, to provide protection against scour, should be provided. On all integral abutment bridges, geotextile bedding shall be used against the front face of the abutment, under the slope protection and down the slope a minimum of 2 m.

**B. Skew Angle.**

The maximum skew angle for integral abutment bridge designs shall be thirty (30) degrees. Skew angles greater than this shall preclude the use of integral abutment bridge construction.

**C. Foundation Types.**

1. The abutment and pile design shall assume that the girders transfer all moments and vertical and horizontal forces that are produced by the superimposed dead load, live load plus impact, earth pressure, temperature, shrinkage, creep and seismic loads. The transfer of these forces shall be considered to be achieved after the rigid connection to the abutments is made. The rigid connection shall be detailed to resist all applied loads.

2. All abutment substructure units shall be supported on a single row of piles. Cast-in-place (C.I.P.) or steel H piles may be used for structures with span lengths of 50 m or less. Only steel H piles should be used for structures with span lengths over 50 m. When steel H piles are used, the web of the piles shall be perpendicular to the centerline of the beams regardless of the skew. This will facilitate the bending about the weak axis of the pile.

3. To facilitate expansion, for bridge span lengths of 30 m or more, each pile at each substructure unit shall be inserted into a pre-bored hole that extends 2.5 m below the bottom of the footing. The cost of provision of pre-boring these holes, casings and cushion sand shall be included in the Unit Price Bid for the pile item. All details and notes required by the Foundation Design Report shall be placed on the plans. For bridge lengths under 30 m, pre-boring is not required.

4. The Designer must determine the practical point at which the embedded pile is determined to be fixed. The following steps may be followed to perform such an analysis.

   - Calculate the thermal movement demand. For a bridge structure with equal intermediate bent stiffness, the movement demand will be equal. The atmospheric temperature range, coefficient of expansion and the structure's length should be considered.

   - The plastic moment capacity of the embedded length of the pile (embedded in the concrete cap) must be calculated. As stated earlier, the pile shall be oriented for bending about the strong axis.

- The column capacity must then be calculated.

- The adequacy of the backwall to resist passive pressure due to expansion must be calculated.

5. When CIP piles are used, they must be pipe casings conforming to ASTM A252, Grade 2 with a minimum wall thickness of 6 mm. This shall be noted on the plans.

6. All piles shall be driven to provide proper penetration into a soil strata where the required pile action is achieved, or to a minimum penetration of 6 m. This is to avoid a stilt type effect, provide for scour protection and to provide sufficient lateral support to the pile.

7. A pile bent configuration should be used for the integral abutment substructure detailing. For steel superstructure bridges, a minimum of one pile per girder shall be used.

8. The piles shall be designed to be flexible under forces and moments acting on the abutment. They shall be designed for vertical and lateral loads and for bending induced by superstructure movement. The fixity between the superstructure and the pile top may be ignored.

9. The initial choice of pile selection shall be based upon the recommendations that are contained in the Geotechnical Report. The axial loads shall be based upon the reactions from the superstructure design. This shall include the superstructure dead load, live load plus impact and the substructure dead load.

10. Live load impact shall be included in the design of integral abutment piles. The total length for single span bridges and the end span length for multiple span length bridges should be considered.

## D. Superstructure.

1. Adjacent prestressed box beams, prestressed concrete girders and structural steel beams may be used for integral abutment designs. They shall be analyzed to determine the stresses in the beams that will result from thermal movements. In prestressed box beams, such stresses shall be judged to be critical when the beams act by pulling an abutment with an approach slab. Mild reinforcement shall be added to the ends of prestressed box beams to resist such stresses.

2. Standard Drawings 2.13-1 through 2.13-5 provide conceptional detailing for rigidly connecting the prestressed concrete box beams and structural steel type superstructures to the abutments. Steel superstructures may have their girders directly attached to the piles through the use of welded load plates as shown on

Standard Drawing number 2.13-1. Other type connections, such as bolting the girder to the abutment, may also be used. Prestressed girders may be connected by doweling them to the abutments.

3. Steel girders may be placed on plain elastomeric pads. The anchor bolts will pass through both the pad and the bottom flange of the girder. Another method is to use a longer bolt so that nuts may be placed above and below the bottom flange. The grade of the girder may be better controlled this way. Slotted holes should be used to allow better flexibility in aligning the girder.

   Slotted holes should also be used with the doweling of prestressed members to the abutments.

**G. Abutments.**

1. In integral abutment bridges, the ends of the superstructure girders are fixed to the integral abutments. Expansion joints are thus eliminated at these supports. When the expansion joints are eliminated, forces that are induced by resistance to thermal movements must be proportioned among all substructure units. This must be considered in the design of integral abutments.

2. The integral bridge concept is based on the theory that, due to the flexibility of piles, thermal stresses are transferred to the substructure by way of a rigid connection. The concrete abutment contains sufficient bulk to be considered a rigid mass. To facilitate the stress transfer, abutments shall be placed parallel to each other and ideally be of equal height.

3. The positive moment connection between the girder ends and the abutment provides for full transfer of temperature variation and live load rotational displacement to the abutment piling.

4. To support the integral abutment, it is customary to use a single row of piles. The piles are driven vertically and none are battered. This arrangement of piles permits the abutment to move in a longitudinal direction under temperature effects.

5. The most desirable type abutment is the stub type. It will provide greater flexibility and will offer the least resistance to cyclic thermal movements.

**H. Piers.**

1. Piers for integral bridges have similar design requirements and share common design procedures with the piers of a more traditional bridge. The primary distinguishing features of the piers for an integral abutment bridge involve their ability to accommodate potentially large superstructure movements and the sharing of lateral and longitudinal forces among the substructure units.

2. As with integral abutments, the piers must also be designed to accommodate the movements of the superstructure. Thermal movements are usually the major concern, although superstructure movements, due to concrete creep and drying shrinkage, will also be present to some degree. Creep and shrinkage

movements may be ignored for prestressed concrete girders; however, for longer bridges, these effects must also be considered in the design of the piers.

3. As part of the overall structural system, integral abutment bridge piers will typically be required to carry a portion of the externally applied longitudinal and transverse loads on the bridge. In addition, thermal movements of the superstructure will induce forces as the piers attempt to restrain those movements.

4. As the superstructure expands and contracts with seasonal temperature changes, and to a lesser extent, creep and shrinkage, the tops of the piers will be forced to undergo displacements relative to their bases. These displacements will produce curvatures in the columns that can be closely estimated based on the magnitude of the movements, the fixity conditions at the top and bottom of the columns and the height of the columns.

5. Once curvatures are estimated, an effective column stiffness must be considered to compute internal moments and shears. A set of equivalent external forces, in equilibrium with the computed internal moments and shears, must be computed. This set of equivalent forces is used in subsequent analysis to represent the effects of superstructure movements on the piers.

6. Forces induced by the distribution of the superstructure movements must be computed. Also, the distribution of externally applied loads to the substructure units must be estimated.

7. Similar to the design of a traditional pier, piers of integral abutment bridges are designed for load combinations. Often, load combinations involving temperature, creep and shrinkage control the design of integral abutment bridges, as opposed to combinations containing external loads only. A pier must be capable of undergoing the imposed superstructure movements while simultaneously resisting external forces.

8. A bearing at a pier of an integral abutment bridge structure should only be fixed when the amount of expected expansion from the bearing to both abutments or adjoining pier is equal. All other cases should use expansion bearings.

9. The following guidance shall be followed in determining the type of pier selection in integral abutment bridge designs:

   a. Continuity at Piers.

      1.) The concrete deck slab must be physically continuous, with joints limited to sawcut control joints or construction joints. Distinction must be made between slab continuity and girder continuity at the piers.

      2.) If, in accommodating the load transfer, girder continuity is deemed appropriate by the design, the superstructure shall be assumed continuous for live loads and superimposed dead loads only. Girders shall be erected as simple spans and made continuous by the addition of mild steel in the deck slab.

3.) Longer span integral bridges; i.e., those with spans over 30 meters shall be detailed to provide a deck slab placement sequence if girder continuity is to be provided. Where applicable, casting of concrete diaphragms over the piers should be done concurrently with placement of the slab.

4.) When slab-only continuity is provided over the piers, girders are to be designed as simply supported for all loads.

b. Types of Piers.

To design piers to accommodate potentially large superstructure movements, the following options are available:

1.) Flexible piers, rigidly connected to the superstructure;

2.) Isolated rigid piers, connected to the superstructure by means of flexible bearings;

3.) Semi-rigid piers, connected to the superstructure with dowels and neoprene bearing pads;

4.) Hinged-base piers, connected to the superstructure with dowels and neoprene bearing pads.

c. Flexible Piers.

1.) A single row of piles, with a concrete cap that may be rigidly attached to the superstructure, provides a typical example of a flexible pier. This type of pier is assumed to provide vertical support only. The moments induced in the piles due to superstructure rotation or translation are small and may be ignored.

2.) A bridge constructed with flexible piers relies entirely on the integral abutments for lateral stability and for resisting lateral forces. Passive pressures behind the backwalls, friction, and passive pressures on the abutment piles should be mobilized to resist lateral and longitudinal forces.

3.) With this type of pier use, temporary lateral bracing may be required to provide stability during construction. Designers must consider a means to account for passive soil pressures in the vicinity of the backwalls.

d. Isolated Rigid Piers.

1.) Rigid piers are defined as piers whose base is considered fixed against rotation and translation, either by large footings bearing on soil or rock, or by pile groups designed to resist moment. The connection to the superstructure is usually detailed in a way that allows free longitudinal movement of the superstructure, but restrains transverse movements. This type of detailing permits the superstructure to undergo thermal movements freely, yet allows the pier to participate in carrying transverse forces.

2.) With this class of pier, the superstructure is supported on relatively tall shimmed neoprene bearing pads. A shear block, isolated from the pier diaphragm with a compressible material such as cork, is cast on the top of the pier cap to guide the movement longitudinally, while restraining transverse movements.

3.) This type pier represents the traditional solution taken with steel girder bridges at so called expansion piers. It offers the advantage of eliminating the stresses associated with superstructure thermal movements. It also provides piers that require no temporary shoring for stability during construction.

4.) In utilizing this system, additional consideration must be given to the detailing associated with the taller bearing pads and the detailing associated with the shear key. In addition, because the pier and the superstructure are isolated longitudinally, the designer must ensure that the bearing seats are wide enough to accommodate seismic movements.

e. Semi-Rigid Piers.

1.) These piers are similar to rigid piers. Their bases are considered fixed by either large spread footings or pile groups; however, the connection of the piers to the superstructure differs significantly.

2.) In utilizing prestressed concrete girders that bear on elastomeric pads, a diaphragm is placed between the ends of the girders. Dowels, perhaps combined with a shear key between girders, connect the diaphragm to the pier cap. Compressible materials are frequently introduced along the edges of the diaphragm, and, along with the elastomeric bearing pads, allow the girders to rotate freely under live load.

3.) The dowels force the pier to move with the superstructure as it undergoes thermal expansion and contraction and, to a lesser extent, creep and shrinkage. Accommodation of these movements requires careful analysis during the design of the piers. Normally, the stiffness of the piers is assumed to be reduced due to cracking and creep.

4.) There are several advantages to this type of pier: detailing is simplified, use of thin elastomeric pads are relatively inexpensive, temporary shoring is not required during construction, all piers participate in resisting seismic forces and the girders are positively attached to the piers. In addition, with many piers active in resisting longitudinal and transverse forces, the designer need not rely on passive soil pressures at the integral abutments to resist lateral forces.

5.) Design of semi-rigid piers is slightly more complicated because careful assessment of foundation conditions, pier stiffnesses and estimated movements is required. In some situations semi-rigid piers are inappropriate. For example, short piers bearing on solid rock may not have adequate flexibility to accommodate movements without distress.

f. Hinged-Base Piers.

1.) This type of pier may be used to avoid the need for an expansion pier in a situation where semi-rigid piers have inadequate flexibility. A "hinge" is cast into the top of the footing to permit flexibility of the column.

2.) Temporary construction shoring may be required, and additional detailing requirements at the top of the footing may increase cost; however, the designer should keep this alternate in mind under special circumstances where the other pier types are not feasible.

**D. Wingwall Configuration.**

1. In-Line wingwalls cantilevered off the abutments are the preferred arrangement for integral abutment construction. Wingwalls in excess of 4 meters should be supported on their own foundation independent of the integral abutment system. In this case, a flexible joint must be provided between the wingwall stem and the abutment backwall.

2. Flared walls cantilevered off of the abutments may be considered by the Designer on a case by case basis. The use of flared wingwalls should generally only be considered at stream crossings where the alignment and velocity of the stream would make in-line walls vulnerable to scour. Piles shall not be placed under any flared walls that are integral with the abutment stem.

3. U-walls cantilevered off the abutment stem shall be allowed only if in-line or flared walls cannot be used because of right-of-way or wetlands encroachment. The U-walls shall preferably not measure more than 3 meters from the rear face of the abutment stem.

   If U-walls greater than 3 meters in length are required, the wingwall foundation should be separated from the abutment foundation. A flexible joint between the abutment backwall and wingwall stem should be provided. This type arrangement will maintain the abutment/pile flexibility so that the thermal movement of the superstructure is permitted.

4. The distance between the approach slab and the rear face of the U-wall should preferably be a minimum of 1.2 m. If the approach slab must extend to the U-

wall, they shall be separated by a 50 mm joint filled with Resilient Joint Filler.

**E. Horizontal Alignment.**

Only straight beams will be allowed. Provided that the beams are straight, structures on curved alignments will be permitted.

**F. Grade.**

The maximum grade between abutments shall be 5%.

**G. Stage Construction.**

Stage Construction is permitted. Special consideration shall be given to the superstructure's rigid connection to the substructure during concrete placement when staging construction. The superstructure should be secured, free from rotation, until all concrete, up to the deck slab, is placed.

**H. Seismic Modeling.**

1. The general concept behind modeling the seismic response of a bridge structure is to determine a force-displacement relationship for the total structure which is consistent with the ability of the structure to resist the predicted forces and displacements.

2. Integral abutments shall be modeled to move under seismic loading in both the longitudinal and the transverse directions, thus distributing more transverse forces to the piers.

3. The bridge structure shall be modeled in three dimensions for a stiffness analysis. A single or multi-mode analysis may be used.

## 1.15.4 CONSTRUCTION PROCEDURES

The following sequence is recommended when constructing integral bridges. This will reduce the effects of thermal movements on fresh concrete and control moments induced into the supporting pile system.

A. Drive piling and pour the concrete to the required bridge seat elevation and install the rigid connection systems. Pour concrete for wingwalls concurrently.

B. Set the beams/girders and anchor to the abutment. Standard Drawing 2.13-1 provides details for a welded plate rigid connection, for steel superstructures, to the substructure. As an alternate, slotted bolt holes in the bottom flanges may be used. The slotted holes will aid the girder placement. Anchor nuts should not be fully tightened at this time. Free play for further dead load rotations should be accounted for.

C. Pour the bridge deck in the sequence desired excluding the abutment backwall/diaphragm and the last portion of the bridge deck equal to the backwall/diaphragm width. In this manner, all dead load slab rotations will occur prior to lock-up, and no dead load moments will be transferred to the supporting piles.

D. If utilizing anchor bolts, tighten anchor nuts and pour the backwall/diaphragm full height. Since no backfilling has occurred to this point, the abutment is free to move without overcoming passive pressures against the backwall/diaphragm. The wingwalls may also be poured concurrently.

E. Place back of wall drain system and backfill in 150 mm lifts until the desired subgrade elevation is reached. Place bond breaker on abutment surfaces in contact with approach pavement.

F. Pour the approach slab concrete starting at the end away from the abutment, progressing toward the backwall. If it can be so controlled, approach pavements should be poured in early morning so that the superstructure is expanding, and therefore not placing the slab in tension.

G. A construction joint should be located at a distance of 150 mm from the back of the backwall between the approach slab and bridge slab. This will provide a controlled crack location rather than allowing a random crack pattern to develop. Corrosion coated dowels shall pass through the joint and shall be located near the bottom of the slab. This will keep the joint tight but still allow the approach slab to settle without causing tension cracking in the top of the slab.

H. The excavation for the approach slabs shall be carefully made after compacted abutment embankment material is in place. The slabs shall be founded on undisturbed compacted material. No loose backfill will be allowed.

I. To permit unhindered longitudinal movement of the approach slab, the surface of the subbase course must be accurately controlled to follow and be parallel to the roadway grade and cross slope.

J. A filter fabric or some type of bond breaker such as polyethylene sheets shall be placed on the finished subbase course the full width of the roadway prior to placement of approach slab reinforcement.

K. A lateral drainage system should be provided at the end of the approach slab adjacent to the sleeper slab.

Suitable notes should be provided on the plans to incorporate these construction procedures.

### 1.15.5 SEMI-INTEGRAL ABUTMENT DESIGN

A. A semi-integral abutment design structure is one whose superstructure is not rigidly connected to its substructure. It may be a single or multiple span continuous structure whose integral characteristics include a jointless deck, integral end diaphragms, compressible backfill and movable bearings. In this concept, the transfer of displacement due to the piles is minimized. The rotation is generally accomplished by use of a flexible bearing surface at a horizontal interface in the abutment. Horizontal displacements not eliminated in a semi-integral concept must still be considered in the design.

In lieu of conventional deck joint bridges, or where a full integral bridge is not desirable, semi-integral bridges may be considered. The foundations for this type structure shall be stable and fixed. A single row of piles should not be utilized. The foundation piles should be stiffened by inclusion of battered piles, or the foundation may be founded on bed rock.

B. The expansion and contraction movement of the superstructure should be accommodated at the roadway side of an approach slab. This type design shall only be used for symmetrical, straight beam structures. The geometry of the approach slab, design of the wingwalls and transition parapet, if any, must be compatible with the freedom required for the integral configuration (beams, deck, backwall and approach) to move longitudinally.

Refer to Standard Drawing Plate 2.13-4 for detailing of a Semi-Integral Abutment configuration.