Integral Bridges
An Exploratory Study on Integral Bridges

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Abstract- *In this thesis, an exploratory study on Integral Bridges is discussed. Integral bridges are bridges without expansion joints between the abutment and the superstructure. Integral bridges have instead their continuous decks and girders integrated into the abutments. They are the most cost-effective system in terms of construction, maintenance, and longevity. The overall life cycle cost of the Integral Bridge system is comparatively lesser than Conventional Bridge System. The purpose of constructing an Integral Abutment Bridge is to prevent the corrosion of structure due to water seepage through joints. The simple and rapid construction provides a smooth, uninterrupted deck that is aesthetically pleasing and safer for riding. They also provide greater load distribution at bridge ends which facilitates in reducing damage to the abutments, especially from overweight vehicles.*

Keywords- Integral Bridges, Continuous bridge, Life-cycle cost, etc

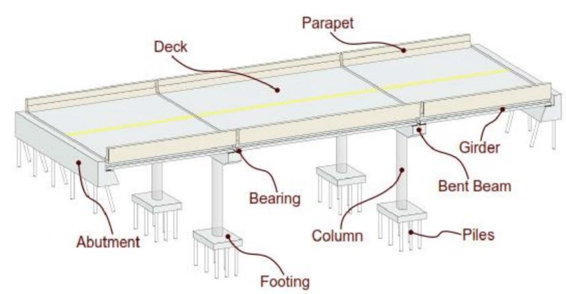
I. INTRODUCTION

1. Bridges: A structure built to span a physical obstacle (such as a body of water, valley, road, or rail) without blocking the way underneath. It is constructed to provide passage over the obstacle, which is usually, otherwise difficult or impossible to cross. There are many different designs of bridges, each serving a particular purpose and applicable to different situations. Designs of bridges vary depending on factors such as the function of the bridge, the nature of the terrain where the bridge is constructed and anchored, the material used to make it, and the funds available to build it. Bridges can be categorized in several different ways. Common categories include the type of structural elements used, what they carry, whether they are fixed or movable, and the materials used.

1.1 Components of bridge structure:

There are different types of bridges. Following are the main parts of a bridge:

a. Deck
b. Abutment
c. Pile
d. Pier
e. Girder
f. Carriageway



To give a preliminary idea of these bridge parts a brief description of each part is given below.

<u>a. Deck</u>

A deck is a fundamental part of any bridge to pass vehicles, goods, people, etc. from one side to another.

<u>b. Abutment</u>

The support provided at the two ends of a bridge is known as an abutment.

<u>c. Piles</u>

For the bridge with a pier, the pile is a fundamental component. Pile type foundation is generally needed when the upper soil layer is loose. Pile depth depends on the soil layer. To find the hard soil layer which will make the structure stable, the pile is usually extended to some depth into the hard soil layer.

<u>d. Pier</u>

Pier is the compression member which stays above the pile and makes the structure stable. Pier generally provides for span at intermediate points.

Piers perform two main functions:

- Transferring superstructure vertical loads to the foundation.
- Resisting the horizontal forces acting on the bridges.

For bridge pier to pier, distance is the span. Water pressure is the extra pressure that acts onto the pier laterally.

e. Girder (Box or I-joist)

Just like the beam, a girder is used in the bridge can be of two types I-joist and Box. This name has been given because of its shape. The I-joist girder type is commonly used in bridges. Box girder can be precast or cast in place and it is generally existing in pre-stressed condition.

1.2. Types of Bridges

Bridges can be categorized by materials used, type of superstructure, types of span, function, and inter-span relation. Followings are the main types of bridges.

· Beam Bridges.
· Integral Beam Bridges.
· Cantilever Bridges.
· Arch Bridges.
· Cable-stayed Bridges.

II. LITERATURE REVIEW

One of the most commonly discussed problems concerning bridges built without expansion joints is the accommodation of longitudinal elongation and contraction due to temperature variations (Keshavamurthy et al., 2014). A bridge built with integral abutments is supported by steel or concrete piles. The longitudinal elongation and contraction of the superstructure induce a displacement and a moment in these piles, which in time may cause a fatigue failure (Karalar and Dicleli, 2016). Therefore, The amplitude of the strains is important.

There are a couple of different names for this type of bridge in literature. Integral bridges, jointless bridges, continuous bridges, and rigid frame bridges are sometimes used instead of Integral abutment bridges (Yen et al., 2017). Two types of Integral bridges are Semi-Integral Abutment Bridge and Full Integral Abutment Bridge (Cai and Kong, 2015).

Integral Abutment Bridge can be easily used in place of small bridges and culverts because of its strength, the faster rate of construction, lower maintenance cost, improve driving and aesthetic conditions, and resistance to seismic forces (Roy and Pendharkar, 2017). It can also be used for the rehabilitation of existing bridges (Choine et al., 2016). It can be constructed as Structural steel, RCC, or Composite bridge. Some examples of Integral abutment bridges in India are Dankuni-Palsit flyover and Kalkaji flyover. Dankuni-Palsit flyover is situated at the durgapur Expressway. The span arrangement for the overpass is 15m + 2×22.0 m + 15m, continuous over the support. The deck is RC solid slab type integral with twin piers. The bridge is a jointless bridge without any expansion joint over intermediate piers without any bearings. Kalkaji flyover is a 150m integral flyover that has been provided at the vital T-junction on Ring Road near Kalkaji Temple. The typical five-span continuous deck (25m + 30m + 40m + 30m + 25m), has avoided slab-reinforced concrete deck with a depth of 1.70m, which was hunched and increased to 2.20m at the piers supporting the 40.0m obligatory main span (Tandon, 2005).

The first integral bridge in the United States was named the Teens Run Bridge. It was built in 1938. It consists of five continuous reinforced concrete slab spans. Since that time construction of integral bridges has spread throughout the United States and abroad. The United Kingdom recently adopted them for routine applications. Japan completed the first two in 1996 (Yauyov et al., 2015).

A study made in the USA, shows that 29 of 52 states design agencies permits the design and construction of integral bridges. But there were only two states that calculated the pile stresses due to the lateral thermal movements. Most of the states neglected these stresses, while a few states demanded some construction details that should reduce these stresses. One example of how pile stresses could be reduced is to drive the piles into pre-drilled oversized holes, which are backfilled with loose sand (Samyak et al., 2017).

According to Noorzaei et al. (2011), there are now at least 40 states that are constructing some form of jointless bridge. The trend seems to be moving towards integral abutment bridges, but most of the bridges are still constructed with expansion joints. In 2004, The Federal Highway Administration surveyed integral abutment and jointless bridges.

III. INTEGRAL BRIDGES

3.1 What is Integral Bridge?

An integral bridge refers to a bridge in which the superstructure and the pier/abutment are integrated together out of necessity. The integration between the superstructure and substructure implies that there is no bearing that transmits force or displacement between the two structures.

Bridges in which the pier and the superstructure are integrated together are often used when the construction method is determined by the required span length. For example, they are structural systems used for long-span bridges constructed with the balanced cantilever method (or free cantilever method, FCM). Since the pier and the superstructure are rigidly connected (rigid frame), it is difficult to accurately consider problems arising from external and internal factors in the design stage of integral bridges, but they are still steadily being used because of the advantages of FCM.

Fig. Integral Pier Bridge (Brisbane Gateway Bridge)

Expansion joints and bearings play an important role in bridge maintenance as they need periodic monitoring and replacement becomes tedious task. Therefore, to avoid problems that may occur during bridge maintenance as well as increasing structural efficiency, bridges in which abutments and superstructures are integrated are used. These types of bridges are referred as integral bridges (integral abutment bridges).

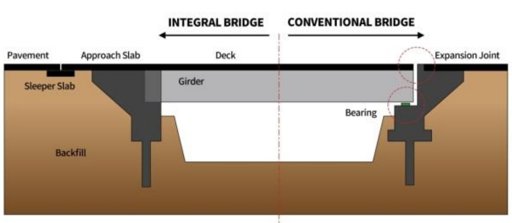


Fig. Integral bridge and conventional bridge

Integral bridges have the advantage over conventional bridges due to their easy maintenance and reduced cost. This is possible only because some bearings and expansion joints are removed. Furthermore, the elimination of expansion joints improves ride comfort and durability because rain, snow, and chloride cannot penetrate the substructure.

Fig. Expansion joint

Some features of integral bridges include:

- Applicable to both concrete and steel bridges.
- Displacement caused by thermal expansion and contraction is directly transmitted to the abutments and pile foundations, so displacement limitation is required.
- Accurate evaluation of the Integral bridge is difficult because interaction between the abutment and the soil surrounding the structure is complex.
- Effects of creep and shrinkage should be considered in concrete girders.
- Material and construction method of the backfill on the back of the abutment are important.
- Precast girders can be used, but the reinforcement detail for moment connection as well as the beam-end rotation due to creep and shrinkage must be considered.

Additionally, geometric design standards (the span length, skew, and height of abutment, regional design conditions for temperature gradient, seismic, and moving loads) must be considered.

Fig. Integral bridge

3.2 Advantages and Disadvantages of using Integral Bridges

Some of the advantages of adopting integral bridge concept as against the conventional bridge concept are summarized below:

i. Added redundancy with improved seismic performance
ii. Improved structural reliability and redundancy
iii. Improved ride-quality and noise reduction
iv. Improved durability due to absence of expansion joints, which is the source of moisture ingress
v. Potential for reduced initial cost
vi. Reduced maintenance requirement
vii. Reduced traffic disruption
viii. Lower whole-of-life cost and
ix. Improvement of bridge appearance
x. Simplified Widening & Replacement detail
xi. Useful concept for strengthening of existing bridges

Some of the disadvantages of adopting integral bridge concept are summarized below:

i. Limited span range due to restraints to movements caused by thermal, creep and shrinkage.
ii. Differential settlement between foundations resting on varying strata or varying scour conditions in case of river bridges.
iii. Climatic conditions with large variation in maximum and minimum ambient temperatures.
iv. As soil-structure analysis in involved, structure analysis becomes complex.

3.2 DESIGN GUIDELINES

To use the simplified design methods as per this guideline, the structure should satisfy the following requirements:

1) The characteristic thermal movement at the end of the deck does not exceed ±20 mm under normal case from the position at the time of restraints during construction;
2) shall have a skew angle less than or equal to 30 degrees;
3) shall be a straight bridge or a curved bridge with the radius of curvature exceeding 100 m;
4) shall not have a connected splayed wing wall.

Loads and Load combinations:

Bridge structures and abutments in particular of integral Bridges must be designed for the movements due to thermal strains, both increasing and decreasing, and the decreasing strains due to shrinkage of the superstructure if it is concrete and in addition the decreasing strains due to creep in case of pre-stressed concrete decks. The forces developed in the structural system are a function of the relative stiffness of the elements, their foundations, their interaction with the surrounding soils, and the sequence of construction.

The forces due to applied loads must also be accommodated, and these are the dead loads, the vehicular live loads plus impact, the horizontal force due to wind, vehicle braking and centrifugal force, and seismic force as applicable.

The connection between the superstructure and the substructure must also be designed for a Minimum Lateral Restraint Capacity to ensure that the superstructure has sufficient lateral restraint to resist unaccounted lateral forces notwithstanding that has been catered for in the design. Integral Bridges therefore should also be designed for a force of 500kN or 5% of the superstructure dead load, whichever is the greater acting at the junction of superstructure and substructure in addition to the actual forces.

Integral bridges should be designed to resist all the vertical and lateral loads acting on them individually and in combination. The combined load effects on the structure at various stages of construction and stage-by-stage development of stresses in structural members should be considered in the design. The stages at which the structure is simply supported, then made integral with abutments, and backfilling are of primary importance. Design should be carried out according to the limit state provisions of current IRC codes, using the same limit state principles as any other bridge type, taking appropriate partial safety factors.

All types of structural forms can be adopted with Integral abutments. The possible types commonly used are :

a) Precast RCC/PSC Girder with in-situ RCC deck slab for composite action.
b) Steel Girder with RCC in-situ RCC deck slab for composite action.
c) Cast-in-place Solid Slab/Voided Slab deck
d) RCC/Pre-stressed Box Girder deck

The selection is governed by the project economics and functional requirements, in the same manner as for the traditional bridges.

Integral abutment forms such as piled abutments, spread footings, full-height abutments, and RS walls are mainly dictated by geotechnical considerations. Detailing of connection between Superstructure and Substructure requires special considerations when the pre-cast concrete superstructure is adopted. Particular attention is required for the following:

1) Embedment of precast concrete beams into the abutment;
2) The reinforcement detail for the moment connection between the abutment and the precast beams;
3) Detailed construction staging consideration of beams and abutments for prediction of beam end rotations due to creep and shrinkage.

3.3 ANALYSIS

The Integral Bridges are complicated structural systems for design. Additional to the primary loads (i,e. dead, live, wind …etc.), secondary loads (such as creep, shrinkage, settlement, temperature effects ..etc.) also needs to be considered under the serviceability limit state as well as the ultimate limit state.

Methods of analysis, and methods of modeling of structure for analysis, as given in existing code IRC:112 (For reinforced/pre-stressed concrete structures), IRC:22 (For composite structures) and IRC:24 (For steel structures) will be applicable for integral bridges as well. Linear Elastic analysis may be used for both the serviceability and ultimate limit states.

IV. CONCLUSION

An integral Bridge is a jointless bridge in which the deck is continuous and monolithic with abutment walls. Their principal advantages are derived from the absence of expansion joints and sliding bearings in the deck, making it the most cost-effective system in terms of construction, maintenance, and longevity. The main purpose of constructing an Integral Bridge is to improve the riding quality, increase the life of the structure and minimize the maintenance cost. The simple and rapid construction provides a smooth, uninterrupted deck that is aesthetically pleasing and safer for riding. Integral abutment bridges perform well with fewer maintenance problems than conventional bridges. Without joints in the bridge deck, the usual damage to the girders and piers caused by water and contaminants from the roadway is avoided. There is no significant effect of stresses on the abutment due to vertical load. This form of bridge construction has been used for steel, concrete, and pre-stressed concrete bridge. It provides a smooth ride, thereby reducing impact loads to the bridge. They also provide greater load distribution at bridge ends which aid in reducing damage to the abutments, especially from overweight vehicles. Finally, Integral bridges can be a better option for conventional bridge systems with lesser Life-cycle cost.

V. ACKNOWLEDGMENT

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