INTEGRAL ABUTMENT BRIDGE- A Review and Comparison of the Integral Bridge and Conventional Bridge

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Abstract - *Nowadays the methods of bridge construction is changing all over the world. The new innovative methods are developed and adopted over the traditional construction method as per the requirement of the field and the structural requirement. In this paper introduced a brief understanding of the concept of Integral Abutment Bridge and it's working. We tried to give an idea about the procedure of construction of the Integral Abutment Bridge and explains its structural benefits. There are several advantages of the Integral Abutment Bridge over the conventional bridge system they also elaborate on this paper. The paper listed the different types of bridges and different types of the Integral Abutment Bridge. It tries to explain the need of Integral Abutment Bridge in specific areas where maintenance cost is way more And the damages due to leakage and corrosion of the bridge components is a major problem. The structural system has the potential to fulfill the requirements and demands of the structural requirement. The paper presents an elaborate comparison of the integral abutment system with the conventional bridge system.*

Key Words: Integral Abutment Bridge, jointless and bearing less structure, construction stage method, Midas civil, seismic loads, earth pressure, conventional bridge, maintenance cost, construction cost.

1. INTRODUCTION

The bridges are nothing but any structure which is constructed or used for the traveling or transportation over river, valley, uneven surface or any obstacle. A bridge should be designed such that it is safe, aesthetically pleasing, and economically beneficial. There are numerous bridges divided based on their different criteria like -construction method, the material used for construction, visual appearance, working concept, the connection of substructure and superstructure, span length and many more. Mainly the bridges are divided into six type as mention as Cantilever Bridges, Suspension Bridges, Cable-Stayed Bridge, Arch Bridge, Beam Bridge, Truss bridge. But with growing development the requirement of newly developed bridge construction technique and method increases to get maximum benefits from minimum cost and efforts with this to reduce the other impact of structure on surrounding environmental as well as social life. Integral Abutment Bridge is one of those innovative types of the bridge and a large number of countries in the world are accepted integral bridge over the conventional bridge because it's various benefits over Convention Bridge. Starting in the early 1960s, the use of jointless bridges for new bridge construction attracted lots of people's interest. The main basic concept of Integral Abutment Bridge is the bridge which totally eliminates the various types of joints from the deck which is provided in a conventional method and the bearings are also eliminated in the fully integral bridge but kept in a semi-integral type of bridges with the modification in bearing providing technique. Due to eliminating bearings and joints from the structure the corrosion damage and detrition and loss in strength of the structure is minimized which results in maximizing the lifespan of structure and minimizing the and the maintained cost of the structure. Due to its monolithic connection between deck and abutment, this bridge became very useful in an earthquake-prone area.

1.1 Characteristics of integral bridges:

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. An Integral bridge features a fully continuous moment connection between the superstructure and substructure at the abutments eliminating the need for joints or bearings to accommodate rotations and cyclical thermally-induced displacements at the ends of the deck, the Semi-integral bridge form has no deck joints but incorporates bearings at the supports. This form may be adopted when ground conditions are not suitable for a fully integral bridge in both cases, horizontal forces in the superstructure are transmitted to the abutment fill by a diaphragm that is continuous with the superstructure. The term Joint-less Bridge describes a bridge with a continuous deck over the intermediate piers but which has movement joints and bearings at the abutments. In multi-span integral bridges, the deck is made continuous between abutments and there are no joints in the deck at intermediate piers.

1.2 Type of integral abutment bridges

There are four basic ways that a bridge can be made integral, depending on the abutment detail. The four forms of abutment can be referred to as:

1.2.1 Frame abutments (fully integral bridges)

Integral bridge with frame abutments acts like the portal frame where moments, shear force and axial loads transfer directly to the supporting structure from a deck of the bridge. The frame abutments retain the backfill behind it like retaining walls.

1.2.2 Bank pad abutments

Integral bridge with bank pad abutments is another type in which stiff portal frame type arrangement can be constructed. In this type, the end supports are fully integrated with the deck beams but these supports are not fixed in the ground. They are allowed to slide and rotate.

- ❖ The subtype of bank pad abutment are;
- ➢ Bank pad abutment on a piled foundation.
- ➢ Bank pad abutment on a sleeved piled foundation.
- ➢ Flexible support abutment in front of RC earth retaining wall piled.
- ➢ Bank pad abutment in reinforced earth.

1.2.3 Flexible support abutments

In Flexible support abutments, Post holes are created around the piles up to the depth of piles. The posthole should provide enough space for the pile to move horizontally during thermal expansion or contraction. This will eliminate the soil and foundation interaction.

1.2.4 Semi-integral end screen abutments

In this case, also end screen wall and deck beams are integral with each other but end screen wall does not give support to the deck beams. Structure with Bearings which can accommodate horizontal displacement is provided as support to the deck beams. Since the support is separate the soil- substructure interaction is negligible in this case.

2. LITERATURE REVIEW

2.1 Review of Selected Literature

1) B. Kong et.al 2016-In this paper they explain about the water leaking problems, maintenance issues of expansion joints, temperature loadings, backfill–abutment interactions, and soil–pile interactions, is validated by comparing the bridge response with the field measurements. It needs to balance all these parameters in designs so that the thermal deformation of slabs is appropriately accommodated without compromising the integrity of the superstructure and substructure.

2) Dunja Peric et.al 2015- In this paper explain the effect of thermally induced soil-structure interaction in an integral bridge. In research, it was found that the type of abutment motion is significantly affected by the compaction level of the soil adjacent to the abutment and the magnitude of the temperature increase. As much as the temperature increases and the sand will be looser, it is because integral bridges act as a single structural unit that the type of abutment motion is directly relevant for the maximum bending moments in piles.

3) Jin-Hee Ahn et.al 2011- In this paper tells us that the Integral abutment bridges can reduce the amount and cost of construction and maintenance work since they do not have expansion joints and shoes in order to increase stability and durability of the bridges system. In order to transfer member forces between abutment and H-pile, the abutment–pile connection in the integral abutment bridge should have rigid behaviour. Three types of new abutment–pile connections are proposed in this study. They feature transverse reinforcing bars perforated in H-pile, stud connectors and perfobond rib connectors on the flange of H-pile.

4) Robert E. Abendroth et.al. 2007- This paper gives the idea about problems if we used prestress member in Integral Abutment Bridge. Prestressed concrete piles in integral abutment bridges have still in limitation because of concerns over pile flexibility and the potential for concrete cracking and deterioration of the prestressing strands due to long-term exposure to moisture.

5) Suhail M. Albhaisi et.al 2003- They have recommended that the maximum lengths for concrete integral bridges be limited to 190 m in cold climates and 240 m in moderate climates while that of the steel integral bridges are limited to 100 m in cold climates and 160 m in moderate climates. When the foundation soil becomes stiffer the displacement capacity of integral bridges decreases considerably. In case of Concrete bridges, they are more suited for integral bridge construction as they are less sensitive to temperature variations and are recommended especially in cold climates.

3. DISCERPTION OF EXISTING IAB

1) Panchcheel Club Flyover, New Delhi-

Location- Durgapur Expressway,
Span 15m + 2×22.0 m + 15m, Continuous over the support. The deck is RC solid slab type integral with the twin piers. The bridge is a jointless bridge without any expansion joint over intermediate piers without any bearings the seven-span continuous Integral Flyover, with a 190m long stilted portion. The superstructure is reinforced concrete voided slab type deck which is made integral (monolithic) with the piers. The flyovers were designed for seismic (zone IV) and duly account for the superstructure.

Fig -1: Panchcheel Club Flyover, New Delhi.

2) Mukerba Chowk Traffic Interchange, Delhi-

Location- outskirts of Delhi.
Built by Public- Works Department, NCT of Delhi, The mixed traffic had made it the most heavily trafficked junction in the country. The 8-lane main flyover consists of a continuous steel box girder with a composite concrete slab. The aesthetically designed slip road and loop structures are of integral concrete bridge construction, allowing for the

elimination of bearings and expansion joints. The structures designed features for earthquake resistance. Use of fly ash, blast furnace slag cement, segregation of motorized vehicles from cyclists and pedestrians, integrating the existing features at site and creation of innovative and aesthetic structural designs were some of the highlights of the project.

Fig -2: Mukerba Chowk Traffic Interchange, Delhi.

Awards for this bridge:-

1) Construction Industry Development Council Vishwakarma Award 2012.
2) Association of Consulting Civil Engineers Award 2010 for Innovative Design.3) CPWD Director-General Award of Excellence (2009-10) First Prize.

3) Bridge Over River Yamuna, Wazirabad, Delhi-

Location- western and eastern bank of Yamuna River, Delhi. Which involves nearly 50000 sqm of an open portion of the elevated flyover, 25000 sqm of a closed portion of a viaduct, 90000 sqm of an embankment. It is proposed to adopt precast segmentally constructed, 4 spans continuous curved box girder of 164.5m length as a standard continuous unit. Wide precast superstructure deck will be further split into a spine box girders & side frame cantilevers. Cantilever construction or span by span construction method using launching girder will be employed.

Fig -3: Bridge Over River Yamuna, Wazirabad, Delhi.

4) Kalkaji Flyover-

Location- vital T-junction on Ring Road near Kalkaji Temple. Span- 150m integral flyover. The typical five-span continuous deck (25m + 30m + 40m + 30m + 25m), has voided slab reinforced concrete deck with a depth of 1.70m, which was increased to 2.20m at the piers supporting the 40.0m obligatory main span.

Fig -4: Kalkaji Flyover.

5) A11, Bruges-

Location-Bruges, Belgium. Total length –approx. 770m+300m (K032+K031), approx. 220m (K034), approx. 150m (K112), Regular span - 35 m, max. Span - 55 m, width-35.20 m, Total bridge areas - 39,000 m^2 (K032 + K031). 7,900 m^2 (K034). 5,900 m^2 (K112).

Fig -4: A11, Bruges.

5) Happy Hollow Creek-

Location-Tennessee.
Span-358m, it is a super-long curved integral abutment bridge at just over 1175 feet (358 m) in length. The bridge has 9 spans of precast, prestressed concrete bulb-T girders with no expansion bearings. The spans are ranging from 127 to 138 feet (38.8 to 42.2 m). The two-column pier bents vary in height from 51 to 91 feet (15.5 to 27.7 m).

Fig -5: Happy Hollow Creek.

6) Isola Della Scala Italy-

Integral Abutment Bridge that located at Isola Della Scala in the province of Verona. The total length of the structure is approximately 400 m with 13 spans, which is the longest integral abutment bridge in the world up to now (Zordan & Briseghella, 2007). Therefore, it would be of necessity to have specialty grid-lines for existing and future construction of integral abutment bridges.

Fig -6: Isola Della Scala Italy

4. CONSTRUCTION OF INTEGRAL ABUTMENT BRIDGE

The integral abutment bridge is not so complicated structure like other bridge structure.

We can understand the normal procedure of casting and construction of integral abutment bridge step by step. In the following figure, the steps or we can say the procedure of casting and construction of parts of the structure at per order is shown. Firstly collected the all necessary data of subsoil, ground condition, various types of loads which are going to act on structure, the available resources, a budget of project and time for construction all are studied well and make a suitable construction plan for a project. As we talk about the steps or procedure of parts of structure construction then the sequence is;

1) The pile should be cast, then some required duration is given to set the pile.

2) Then we will construct the abutment, some duration is provided for the abutment to create monolithic connection and become rigid.
3) Then the girder is seated on the abutment temporarily. After that, the connection between deck and abutment is fixed and the final connection is done to abutment girder joint.
4) After the deck and abutment, a joint is done the soil backfill is started.in this process special care should be taken. The filling should be done in such manner both end of the bridge the soil filling level should be same or maximum 1m difference is allowed in a level of soil filling.
5) Once the connection fixing and soil filling are done then all other superstructure activities like approach slab pavement railing crash barrier and all other required structural components are constructed.

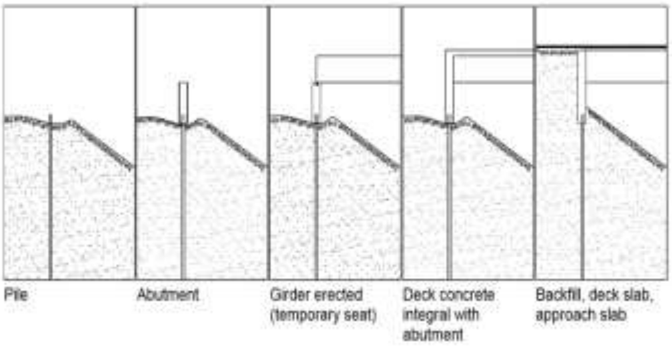

Fig -7: Construction phases for Integral Abutment Bridge

5. CONVENTIONAL VS. INTEGRAL ABUTMENT BRIDGE.

5.1 Advantages of integral bridges over conventional bridges:

Generally, conventional bridges are low-cost construction but it requires high maintenance cost hence integral bridges reduced life-cycle cost and long-term maintenance.

- The integral bridge gives improved design efficiency and improved riding quality more than the conventional type of bridges.
- Added redundancy with improved seismic performance ease in constructing embankments.
- Integral bridges give us benefit like the elimination of water leakage on critical structural elements.
- Integral bridges give us lesser tolerance restriction due to the elimination of bearings and expansion joints.
- The construction speed is increased due to the simplifying process.
- Simplified widening and replacement detail useful for the strengthening of existing bridges.
- When earthquake forces are predominant or when considerations like increased resistance to blasts the integral bridge concept is an excellent option.
- The construction cost is more but if we consider overall it is less expensive.

Table -1: Conventional VS. Integral Abutment Bridge components.

Structural type	Bearing support	Expansion Joints	Girder adjustment of expansion from thermal changes
Conventional bridge	Install	Install	Deform by the foundation
Integral abutment	Uninstall (rigid frame)	Uninstall	Deform by the flexible pile foundation
Portal frame	Uninstall (rigid frame)	Uninstall	Resist by the rigidity of back wall and foundation

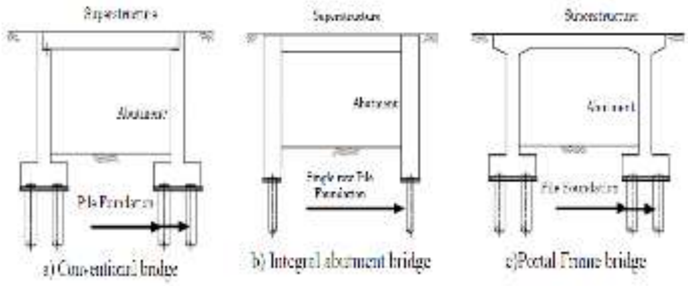

Fig -7: Structural details of different bridge system.

5.2 Survey report about IAB system

Survey on integral abutment bridges conducted by the University Of Maryland in 2009.

1) Total no of states under the survey is 50 and the output is as follow;

41 states use integral abutment bridges.
9 states do not use integral abutment bridges in which,
3 States never used integral abutment bridges.
3 States discontinued because of problems.
3 States discontinued for other reasons.

2) On basis of problems with integral abutment bridges, the output is as follow;

25 States have no problems.
3 States didn't respond to the survey
3 States discontinued although they had no problems.
3 States had serious problems and discontinued.
3 States never used integral abutment bridges.
1 State responded too early to report any problems.
12 States report minor to moderate problems.

3) On the basis of comparative construction costs of the integral abutment and conventional bridges the output is as follow;

27 States Construction cost is lower.
3 States Construction cost is the same.
3 States didn't respond to the question.
3 States didn't respond to the survey.
9 states don't use integral abutment bridges.
5 states Construction cost is higher.

4) On the basis of comparative maintenance costs of the integral abutment and conventional bridges, the output is as follow;

32 states Maintenance cost is lower.
9 states don't use integral abutment bridges.
3 states didn’t respond to the survey.
3 states didn't respond to the question.
3 states Maintenance cost is the same.

No state reports higher maintenance cost for integral abutment bridges.

6. CONSTRUCTION STAGE ANALYSIS FOR INTEGRAL BRIDGES

General analysis is performed under the assumption that all loads are simultaneously applied to complete structure. This assumption is not valid in the real construction sequences because most bridges are constructed by segment and dead loads act sequentially and hence we required construction stage analysis to get correct results.

- Consider before and after composite properties of the deck.
- Changes in boundary conditions can be done. (i.e. simply supported to the integral condition.)
- Allows us to consider deck pouring sequence for better optimization of sections.
- Interlocked stresses in members.
- Each construction stage is identified with activated or deactivated element boundary and load groups.
- Each stage retains a unique element group, a boundary group, and a load group, farming an Interim Independent Structure.

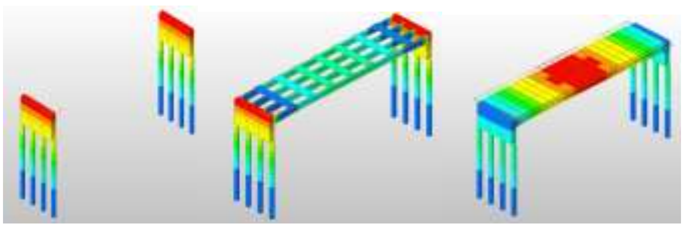

Fig 4.1: Construction Stage 1, 2 and 3 (respectively).

Construction Stage 1-Only abutment and pile.
Construction Stage 2-Abutment pile and steel structure.
Construction Stage 3-All bridge member.

7. CONCLUSIONS

The integral bridge concept is nothing but an excellent option for the replacement of conventional bridge method. The integral bridge is the best method when the maintenance cost of the bridge is high and the frequent maintenance is required and damage to the structure due to leakage and corrosion. The integral bridge gives lots of advantages over other methods of bridge construction like the seismic response of the integral bridge is very good and suitable for earthquake-prone areas. And helps to improve load distribution and durability of the structure. The construction speed is also increased in case of the integral bridge due to its simple structural system. The integral bridge can be used to the strengthening of existing conventional bridges and better option to replace or videoing conventional bridge. The all around the world majority of the country are accepted the integral bridge and India is also moving forward in integral bridge system.

The construction stage method for analysis of structure is used then it will give us exact results which we cannot achieve in the conventional analysis method. The Midas civil is a best and suitable tool (software) to do an analysis of the bridge structure as per construction stage method.

7. FUTURE SCOPE

As per I studied and understand the concept the integral bridge There is some scope for further work in the area of the integral bridge, some are as below.

1) The maximum span limit for the integral bridge is not exactly clear so study in that field is also required.

2) The important problem in the integral bridge is cyclic loading of temperature to avoid its large effect the suitable solution should find out.

3) Nonlinear material models of concrete need to be implemented to study the long-term effects of cyclic loading during the lifespan of the integral bridge. This will help in understanding cracking of concrete deck, girders, and piles.

4) The integral bridge could be analyzed for a longer span with more number of traffic lanes and considering skew of the substructure.

5) The integral bridge can be analyzed for bridges with horizontal curves because many times it is not possible to have straight bridges, especially in urban areas.

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