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Parametric Study Of Integral Abutment Bridge

Patil Asha Amritrao[1], Dr. Jyoti Yadav[2], Mr. Vivek Shukla[3]
M. Tech. Scholar, Civil Department, SRK University, M.P. India[1]
HOD, Civil Department, SRK University, M.P .India[2]
Assistant Prof., Civil Department, SRK University, M.P. India[3]

Abstract: *Integral abutment bridges (IABs) have been designed and constructed since the 1930s around the world. In these bridges, the water leaking problems and maintenance issues of expansion joints are minimized. However, the behaviors of IABs under temperature effects have not been completely understood. In the state of Louisiana, the first full IAB, i.e., the Caminada Bay Bridge, was built on the soft soil conditions in 2011. This paper presents a numerical investigation on the thermal performance of this bridge using ANSYS software. Based on the analysis studies, the numerical modeling methodology for IABs, i.e., temperature loadings, backfill–abutment interactions, and soil–pile interactions, is validated by comparing the bridge response with the field measurements. In addition, a parametric study is performed and demonstrated that the behavior of IABs is affected by temperature loadings, boundary support types, backfills behind abutments, soils surrounding piles, and pile–bent connections. 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.*

Keywords: ANSYS, Boundary Condition, Analysis

1. Introduction

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 [1]. Generally, the foundation to be designed should be small and flexible to facilitate horizontal movement or rocking or the support. Piers for integral abutment bridges may be constructed either integrally with or independently of the superstructure. Abutments are small in order to limit the amount of passive resistance of backfill. Backfill is not compacted [2]. The problem with joints is not just because of their own failures and maintenance problems, but also because of the significance amount of corrosion damage in the girders and underlying substructures, caused by leaking run-off water containing corrosive deicing salts through the joints in the deck. Integral abutment bridges are usually economical due to the use of fewer piles, elimination of bearings and expansion joints and utilization of non-battered piles. Integral bridges eliminate the problems associated with movement joints and bearings and provide the following advantages:

Increased redundancy, enhanced load distribution at support & provide better overall structural system particularly under seismic loading Provide superior protection for girder ends Reduce maintenance costs and increase service life.

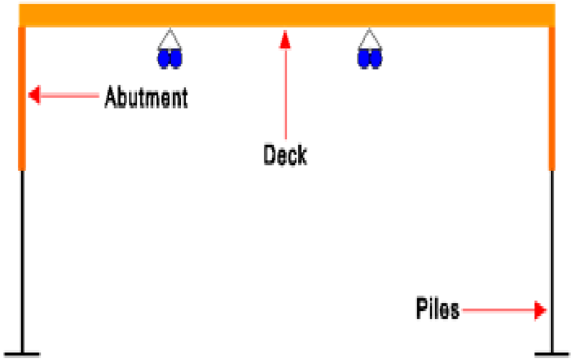

Figure 1 Typical Integral Abutment Bridge

1.1 Objective of the study

The intention of the current work is to study the behavior of the integral bridge under various loading such as self-weight, temperature loading, live load loading such as IRC class A loading, class 70R loading and combination of dead load and live loads. The main difference by which the analysis of integral abutment bridge differs from the conventional bridge is that the soil-structure interaction comes into picture. The greatest uncertainty in the analysis and design of integral abutment bridge is the reaction of the soil properties behind the abutment walls and beside the foundation piles. The current work involves the analysis of integral abutment bridge using nonlinear spoil-spring model. For the analysis of integral abutment bridge and simply supported bridge, STAAD.pro 2006 software is used.

1.2 Scope of present work includes

Comparative study of beam (Girder) moments, shear force and deflections due to dead load, IRC dead load and live load combination, temperature loads between integral abutment bridge and simply supported bridge. Parametric study will be conducted to investigate the effect of various structural properties and geometric of bridge components and geo-technical properties of the foundation soil on the performance of integral bridges subjected to temperature variations [22-24].

Comparative study of longitudinal girder moments and displacements due to dead load and thermal variations between integral abutment bridge and simply supported bridge.

Comparative study of the moments and displacements in Pile at End, s and Pile at Centre, for three different types of soils.

Comparative study of the moments and displacements in Pile at End, s and Pile at Centre, subjected to temperature variations.

2. Literature Review

P. K. Basu & D. J. Knickerbocker

The report presents finite element models for a two-span joint-less HPC bridge built-in Dickson County, TN. The model accounts for pre-stress in the girders, reinforcing bars in girders, deck slab, and substructure, it also allows for material nonlinearities in concrete, abutment backfill materials, and the supporting piles. The results of a series of simulation are presented accounting far truck loading, as well as temperature, creep and shrinkage effects. A series of parametric studies are also undertaken to determine the effects of angle of skew on distribution factors. All computer simulation results are compared with actual test data accumulated over a period of four years from live load tests as well as continuous monitoring temperature, deflection, and strain variations resulting from environmental actions. Important conclusions are drawn at the end [7].

GW William, SN Shoukry, MY Riad

This paper demonstrates the use of field measurements to evaluate the performance of integral abutment bridges and to check the validity of the design assumptions. A newly constructed integral abutment bridge was heavily instrumented to monitor its long-term performance under the effects of environmental conditions and traffic loading. The collected data indicate that integral abutments resist the expansion of the bridge superstructure during summer time, leading to excessive axial compressive forces in the steel girders. Under such a condition, the 2002 AASHTO criteria for stability and yield of steel girders are barely satisfied under the effect of dead loads and temperature variations and are not satisfied when considering the effect of HS20-44 live load [8].

Arsoy, Sami

Bridges without expansion joints are called “integral bridges”. Eliminating joints from bridges crates concerns for the piles and the abutments of integral bridges because the abutments and the piles are subjected to temperature-induced cyclic lateral loads. As temperature change daily and seasonally, the lengths of integral bridges increase and decrease, pushing the abutment against the approach fill and pulling it away. As a result the bridge superstructure, the abutment, the approach fill, the foundation piles and the foundation soil are all subjected to cyclic loading, and understanding their interactions is important for effective design and satisfactory performance of integral bridges [14].

R. J. Lock

This report presents information collated on the earth pressures and settlements that developed behind model and full-scale integral bridge abutments. The objective is to facilitate the design of integral bridges; for which the current UK guidelines are arguably overly conservative. The report concludes that integral bridge design lengths should be incrementally increased. Modifications to BA 42/96 are suggested based on measured earth pressure increases due to cyclic loading. With adequate compaction and drainage, approach slabs are unnecessary [9].

Michael Paul, Jeffrey A. Laman, and Daniel G. Linzell

Forces and stresses that develop in the superstructure of prestressed concrete integral abutment bridges as a result of Temperature Load are investigated. Applied loading consists of uniform temperature changes in the superstructure. The influence of bridge length, number of spans, abutment height, and pile orientation on thermally induced superstructure forces is investigated. The largest thermally induced superstructure forces and stresses occurred near the abutment. It was determined that bridge length and abutment height most strongly influence on thermally induced superstructure stresses. Pile orientation influences thermally induced superstructure forces and stresses to a smaller degree. Results also indicate that thermally induced superstructure stresses and shear forces are comparable in magnitude to those caused by live load [5].

Eugenia Roman, Yasser Khodair, and Sophia Hassiotis
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 [10].

Yokoyama Koichi, Harada Takao, Tsuchiya Yoshinori
An integral-abutment bridge is a bridge without movement joints at the abutments or between supports while a traditional simply supported bridge needs shoes and expansion joints between the deck and abutments or supports. An integral-abutment bridge has several advantages i.e. low construction cost, easy maintenance, and reduced risk of damage through eliminating expansion joints and shoes. In an integral-abutment bridge design, consideration should be given to the interaction because the soil behind the abutment is not only part of the supporting structure but a load. The current Japanese bridge design code can not cover design of integral-abutment Bridge and few integral-abutment bridges have been constructed in Japan [13-15]. In this study, numerical analysis was conducted to assess temperature gradient in the deck and girder of concrete bridge and deformation of the girder and the abutment of the bridge taking account of meteorological conditions in order to evaluate the effects of temperature on integral-abutment Bridge. The results showed that the temperature and accompanied stress in the bridge deck becomes quite high in summer compared with the girder, but the curvature, expansion and stress of integral-abutment Bridge due to temperature difference are tolerable [12].

Y.A. Khodiar
Integral abutment bridges have gained increasing attention in the past few decades. They provide a cost-effective solution to the high maintenance expenses associated with the joints and bearings found in conventional bridges. This paper describes the observed behavior of granular soil backfill retained behind an integral abutment subjected to cyclic loading. Significant pressure build-up was observed in the soil behind the abutment in most locations. The pressure build-up is attributed to several mechanisms such as sand particle flow and densification due to cyclic loading, and the shearing of dense sand during bridge expansion. Therefore, the applicability of using u linear soil pressure distribution assumed by the classical theories in designing the integral abutment system is discussed.
Furthermore, the vertical and lateral distribution of the soil pressure behind the abutment has also been analyzed. Results from the data measured show that bridge skew resulted in bigger soil pressures at the obtuse side of the abutment compared to the acute. The conclusions of this paper highlight several new design aspects, which are usually overlooked by the common design methodologies of integral abutments that more accurately predict the vertical and lateral variation in the soil pressure behind abutments [17]. In the plan procedure, over the previous decade, auxiliary advancement has qualified as a significant device [8]. It very well may be accomplished through topology, size and shape improvement. The fundamental concentration in enhancement is to limit the weight, worries in material [22]. This can be using not exclusively to improve designing auxiliary execution and unwavering quality yet in addition to use for tailor microstructures. Presently the target of the advancement is to discover a plan that augments the firmness for a given measure of material [21].
Structural and basic specialists have dependably strived to utilize material as could reasonably be expected, for example by making structures as light as conceivable yet ready to convey the heaps exposed to them [17]. Before, the look for increasingly proficient structures was an experimentation procedure.

3. Analysis and Design Considerations of Integral Abutment Bridges

3.1 Design Load and Load Combination

In general, the primary loads that need to be considered for the design shall be as per IRC-6 -2000 and as applicable for any conventional bridge. The difference between the integral abutment bridges and conventional bridges mainly lies in the treatment of temperature loading, soil structure interaction behind abutment and adjacent to piles, effects of creep and shrinkage and seismic design considerations, which require elaborative study [11].

3.2 Temperature Loading

The integral bridges shall be designed for daily as well as seasonal variation in temperature and shrinkage strains, duly taking into account the effects due to creep of concrete. In case of concrete structure, when long term temperature movement is considered, the thermal modulus of elasticity may be taken half of that used for dynamic loads. Such benefits however shall not be available for short term movements caused due to daily variation in temperature. It is desirable that the effective bridge temperature during construction at the time of integral connection is within +10o C and -10o C of the mean between extreme minimum and extreme maximum shade air temperature. This will ensure minimum variation in temperature for design purpose. In case it is found difficult to keep the temperature within the stipulated range, suitable external measures (such as using chilled water/ hot water or heating/ shading the aggregates) shall be taken for controlling the concrete temperature while casting the integral connection [11]. Effects of Temperature.

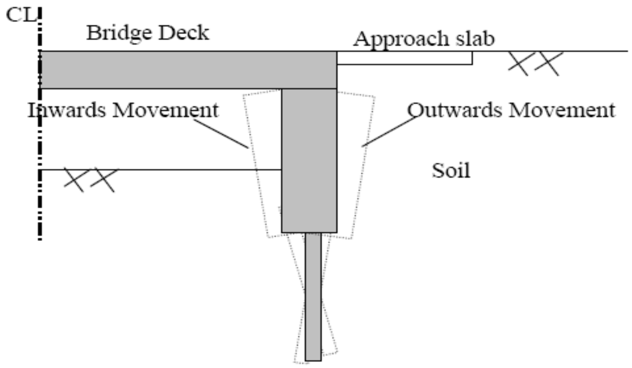

Figure 2 Movement of abutment and piles.

Bridge deck movements are caused primarily by changes in the environmental temperature and solar radiation. If these movements are restrained, it will cause additional stresses in the bridge deck. However, these movements are changing continuously due to variation in the thermal properties of the bridge materials. In addition, the temperatures are not uniform throughout the bridge deck. The stresses caused by the temperature differential can be assumed to be arising from; A uniform temperature rise over the entire section. Differential temperature on the outer and inner faces, of each of bridge components. As the integral bridge exhibit changes in its length due to the temperature variation, it causes the structurally connected abutments to move outwards and inwards during expansion and contraction of the bridge. The mode of abutment movement is primarily rotation about their bottom although there is a component of horizontal translation displacement as well [5].

Conventional Analysis and Design.
Integral abutment bridges are joint-less bridges structures where the deck is continued and casted or connected monolithically with the wall abutment with a moment resisting connection. A line of vertical piles beneath the abutment wall is used to carry the vertical bridge loads. The IAB concept has become increasingly popular in recent years due to reduced maintenance costs associated with the expansion joints and the abutment bearings, reduced corrosion and better overall structural performance particularly under seismic loading.

4. STAAD MODELS AND RESULTS

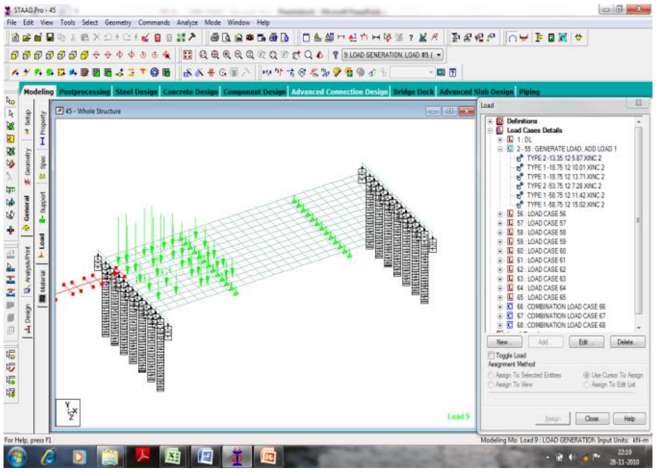

Figure 3 Integral Abutment Bridge with Pile

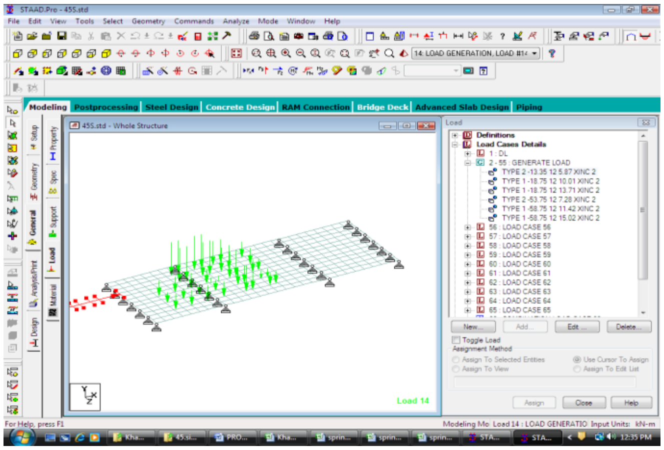

Figure 4 Simple Supported T- Beam Bridge

4.1 Pile Bending Moment

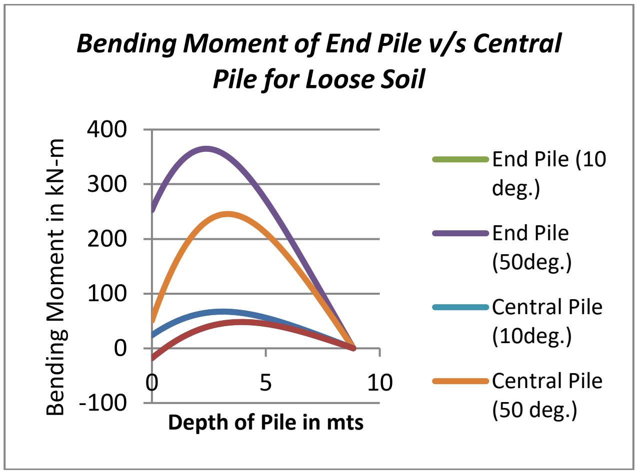

Figure 5 Bending Moment Comparison of Pile at End, V/S Pile at Centre, for Loose Soil

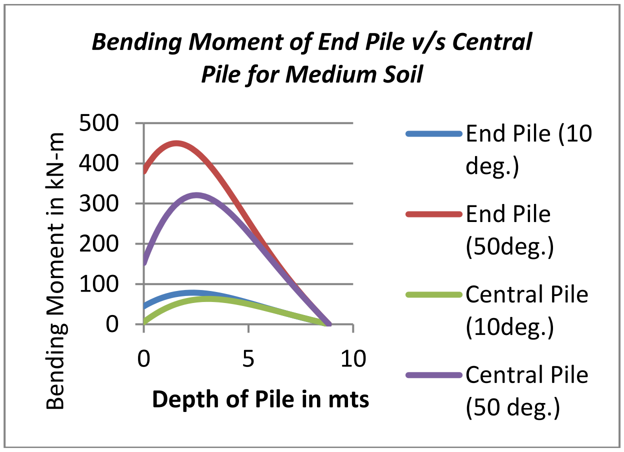

Figure 6 Bending Moment Comparison of Pile at End, V/S Pile at Centre, for Medium Soil

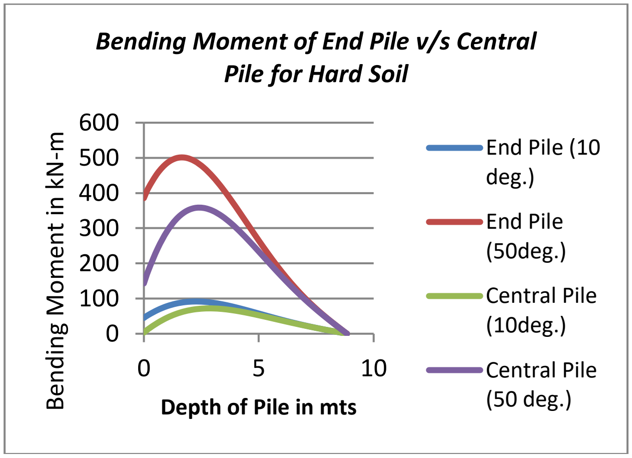

Figure 7 Bending Moment Comparison of Pile at End, V/S Pile at Centre, for Loose Soil

The difference in behavior of the Pile at Centre, and Pile at End, are shown. While the Displacement curves and Bending Moment diagram show the same Tendency, it is interesting to observe the Pile at End, deflected slightly more than the Pile at Centre, when loose soil was behind the abutment. Conversely, when soil behind the abutment got denser, the Pile at Centre, deflected relatively more than the Pile at End,. The Tendency in bending moment is traceable to the deflection observed.

definitive moment limit was expanded relying upon the width of this strip. Utilizing such methods is repetitive and conflicting in a parametric report. Third and fourth preliminaries are clearly over-obliged. The versatile buckling and non-straight examination results are a lot higher than those anticipated by AS 4100. Third preliminary limit conditions are regularly utilized in tests. Notwithstanding the numerical model shows that pillar testing with this arrangement won't accomplish the admired essentially upheld shaft conditions.

The versatile buckling examination result from the fifth preliminary shows that this kind of limit condition would be the most appropriate model. A right glorified pin bolster limit condition must have the option to conquer the limitation issues found in Trials 1, 3, and 4. Besides, the twisting moment and hub power applied must not cause neighborhood stress focuses which may prompt untimely failure during inelastic non-direct examinations.

The concluded limit conditions are the improved rendition from Trial 5, and are appeared in Figure 7. The principle improvement is by permitting the inflexible shafts connected to the spines and the web to move freely. These heap and limit

5. Conclusion

The results of the analysis presented clearly show that the overall behavior of Integral Abutment Bridges is significantly affected by the type of soil adjacent to the abutment and pile. The following are the conclusion derived:

The mid-span sagging moments in main girder is reduced in integral bridges as compared to simply supported bridges due to support hogging moments developed in integral bridges. The deflection in the girder is also considerably reduced in each span of integral bridges as compared to simply supported bridge. The Variation of Bending Moments and Deflections in Main Girder increases with the increase in temperature for integral Abutment Bridges. Hence the temperature effects are more significant in case of Integral Abutment Bridge.

Similarly, study done for Integral Abutment Bridges with three type of soil for temperature variation and it was observed that there is significant variation of Bending Moments and Deflections with Variation in temperature. Hence it can be concluded that combined effect of temperature variation and compaction levels of soil are the factors to be considered in design of Integral Abutment Bridges. Analysis show linear response due to selected temperature change ranges. The properties of soil adjacent to the abutment and pile are major factors governing the response of Integral Abutment Bridges to Temperature Loads.

There is reduction in pile top displacement as there is increase in relative compaction of the soil behind the abutment. Maximum Bending Moment Variation is for Pile at End, with Hard Soil behind the abutment and pile for 50°C. The largest difference in Max. Bending Moment between Pile at Centre, and Pile at End, occurs for Hard Soil case and temp. 50°C

6. Further Studies

Comparison of bending moments, deflection and shear force for longitudinal and transverse direction of the deck of integral abutment bridge and simple support T – beam bridge for different types of soils behind the abutment and round the piles for various temperature variations. Comparison of bending moments and displacements between integral abutments with various support conditions such as different type pier with pile foundation Incorporation of soil stiffness springs near abutments and round pile foundations with thermal variation in soil from top of the abutment to bottom of the pile. Effect of pile size and pile orientation can be considered for further study. Effect of abutment height can be considered.

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