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Abstract- The comparative study on the effect of pile head connection with abutment on integral abutment bridges is presented in this paper. The influence on the design parameters such as bending moment, shear force and longitudinal stresses in deck slab has been considered. The study demonstrates that the design parameters are affected by the pile head to abutment connection. In addition, the results of DL (Dead Load) + temperature and DL + LL (Live Load) + temperature combination with varying span numbers have been compared with single span and with DL. Similarly the effect on interior and exterior girder has also been studied. In case of only DL, the negative maximum end Bending Moment (BM) reduced by 10.5% in the case of single span, 28.5% in two spans integral abutment bridge, while no change is observed in three spans of the integral abutment bridge. The positive BM, however, showed an increasing trend. An interesting outcome of the study is an inversely proportional relation between the number of spans and the design parameters. The increase in temperature tends to enhances negative BM and decreases positive BM. Furthermore, the SF in deck slab increased by 5.9% in two spans integral abutment bridge having pile head with pinned connection, however no change is observed in SF in single and three span configurations.

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I. Introduction

The Integral Abutment Bridges are bridges generally built with their superstructures integral with the abutments in the absence of expansion or contraction joints over the entire length of the superstructure. These are designed as single span or multi span and typically have stub-type abutments supported on piles and a continuous bridge deck from one embankment to the other. Although the small and flexible foundations facilitate horizontal movement or rocking of the support, the bridge structures react to the temperature changes and deform when subjected to the internally developed thermal stresses. The thermal effect is therefore an essential feature in the design of integral bridges and constitutes the biggest challenge in the analysis and design of the abutment.

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The rigid connection facilitates the integral bridges to act as a single unit in resisting thermal and brake loads. The integral design and construction eliminates joints in the bridge resulting in avoiding common issues related to bridges such as corrosion of reinforcements due to leakage of water and the use of de-icing chemicals through joints. Failure to proper response to unanticipated movements results in overstress and subsequent structural damage to the bridge elements via split and rupture of abutment bearings, abutment-rotation and abutment overturning. With an edge over many issues related to conventional bridge design and operation, the integral bridges are trending towards a definite change in the design of highway bridges. (Arsoy*et al.*, 1999; Manjunath and Bastwadkar, 2012; and Khodair and Hassiotis, 2013). David et al. (2010, 2014) found an increase in the performance of the integral bridge with short H-Piles and they reported that sufficient design is required in order to accommodate the effects due to thermal loading.

Khodair and Hassiotis (2013) studied the effect of temperature on integral bridges in conjunction with skew effect. According to them, the effect of temperature changes on daily and seasonal scales as well as the varying coefficient of thermal expansion between the various components of bridge superstructure in the horizontal and vertical directions results in cyclic expansion and contractions. Shreedhar et al. (2012) studied the behavior of integral bridge with and without soil interaction using STAAD Beava. Dunker and Liu (2007) extensively studied the behavior of integral bridges under various conditions such as the connections at abutments (fixed and pinned pile head), foundations and others. They used commercially available finite element software packages. The present study describes the effect of pile head connection with abutment on the various design parameters of deck slab of integral abutment bridge and behavior under temperature load. The commercially available finite element software SAP 2000 has been employed for the purpose. The bridge models are prepared for pile head with fixed connection and pinned connection and analyzed for load combinations like Dead Load (DL), Live Load (LL) and temperature. The effect of pile head connections on deck slab is studied by observing variations in Bending Moment (BM), shear force (SF), axial force and longitudinal stresses.

II. Model Description

Three cases of bridge models were developed by varying the length and number of spans. Single span with length of 60 m, two spans of 30 m each and three spans of 20 m each were considered with pile head having fixed connection and pinned connection. The 12 m width of the bridge was adopted with thickness of the deck slab as 0.25 m. The main girders are of 0.35 m ×1.5 m placed at a distance of 2.4 m c/c. The height of the integral abutment from the bottom of the abutment to bottom of girder is 3 m. Cast-in-situ piles of 1.1 m diameter and pier of 1.2 m diameter were considered in the present study. The models of integral abutment bridge developed using SAP 2000 are presented in Figure 1, Figure 2 and Figure 3 of single, two and three spans bridges, respectively.

The bridge models were developed using rigid links between deck slab and girder. The deck slab was modeled by quadrilateral shell element, which couples bending with membrane action and the longitudinal girders as well as diaphragm and piles were modeled as frame elements. The deck and girders were placed at their vertical locations of the centroid respectively. The composite action between the deck and girders were affected by the rigid links.

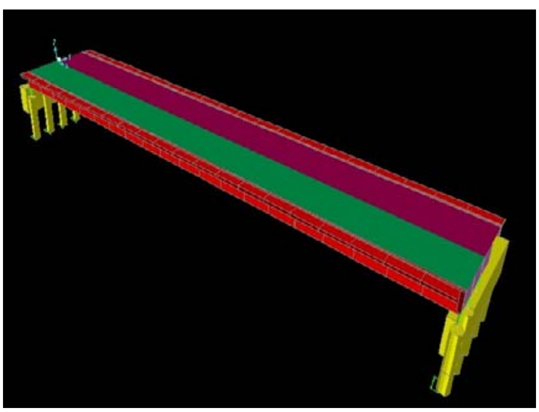

Fig. 1 : 3-D view of the single span integral abutment bridge

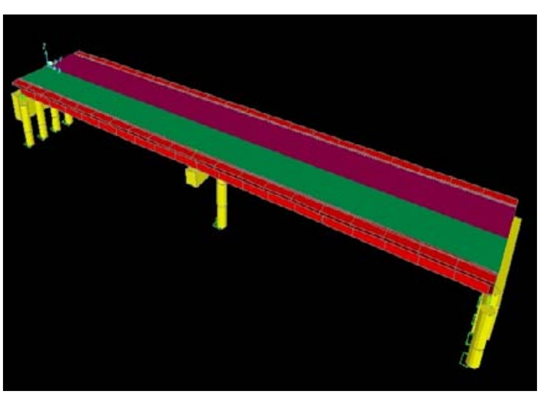

Fig. 2 : 3-D view of the two spans integral abutment bridge

The analysis was carried out by applying LL as per IRC: 6-2000 and by considering a change in temperature of +10°C. The standard characteristics of M30 concrete and Fe-415 steel were adopted as prescribed in IRC: 21 -2000. The single span bridge model post-analysis under LL and temperature stresses is shown in the Figure 4 and 5.

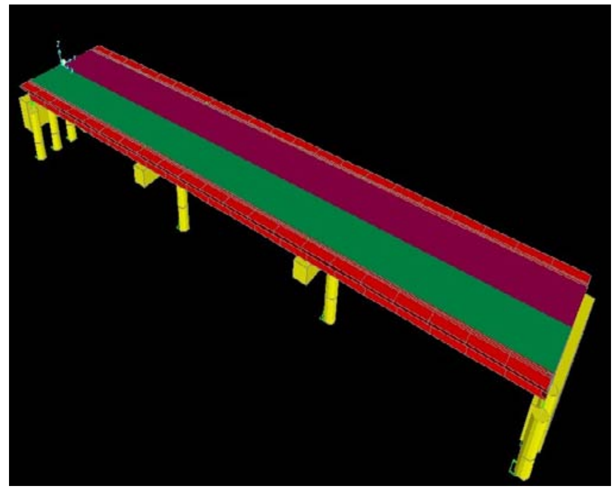

Fig. 3 : 3-D view of the three spans integral abutment bridge

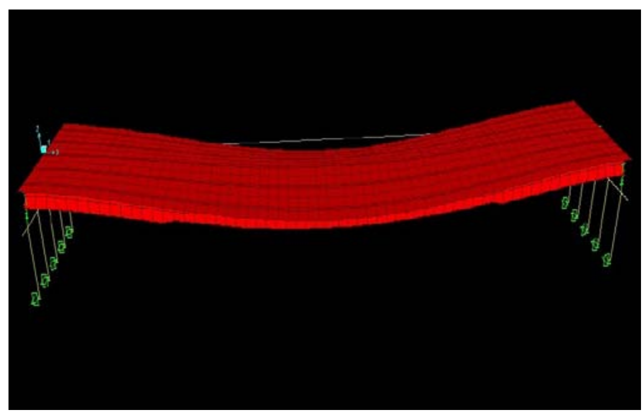

Fig. 4 : Deformed shape of the single span integral abutment bridge model for live load

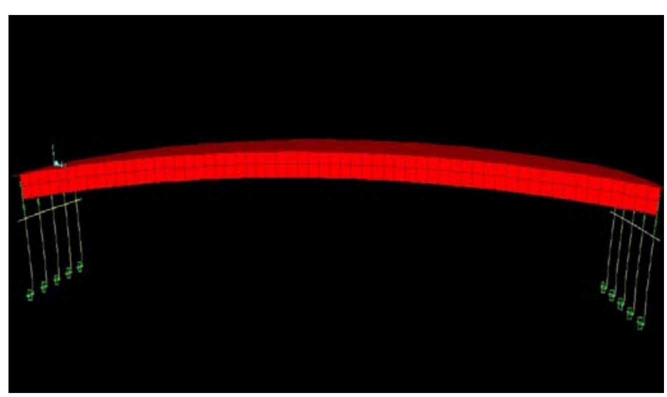

Fig. 5 : Deformed shape of the single span integral abutment bridge model for temperature load

III. Results and Discussion

The results of finite element analysis were compared for the bending moments (BM), shear forces (SF), longitudinal stresses in the deck slab, bending moments (BM) and shear forces (SF) in exterior and interior girders of integral abutment bridge having pile head with fixed and pinned connections have been discussed as follows.

Figure 6 and Figure 7 shows the comparison of BM in deck slab of integral abutment bridge, central girder and exterior girder of single span integral abutment bridge having pile head with fixed and pinned connection under only DL. It may be observed that the positive maximum BM increased by 17.69%, while negative maximum BM reduced by 10.5% in deck slab of pinned pile head connection as compared to fixed pile head connection. Similarly in the central girder, the positive maximum BM is increased by 17.79% and negative maximum BM is reduced by 10.62%. An increase of 17.62% in positive maximum BM and decrease of 10.31% of negative maximum BM was observed in the exterior girder.

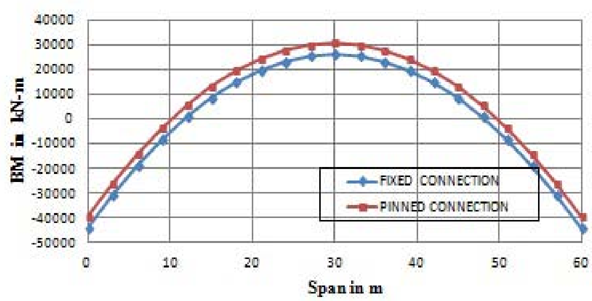

Fig. 6 : Comparison of BM variation in deck slab due to DL for pile head with fixed and pinned connection

No change in SF values were observed in the deck slab of single span integral abutment bridge having pile head fixed as compared with pile head pinned connection as shown in Figure 8. The central girder was subjected to lesser SF by 0.19% and increased in exterior girder by 0.74%in case of pinned pile head connection than that in fixed pile head connection. Figure 9 shows the variation in BM, SF and axial force.

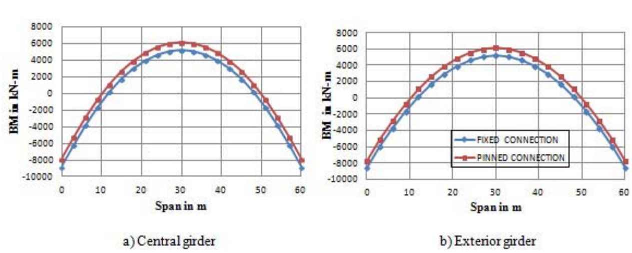

Fig. 7 : Comparison of BM variation in (a) central girder and (b) exterior girder due to DL for single span pile head with fixed and pinned connection

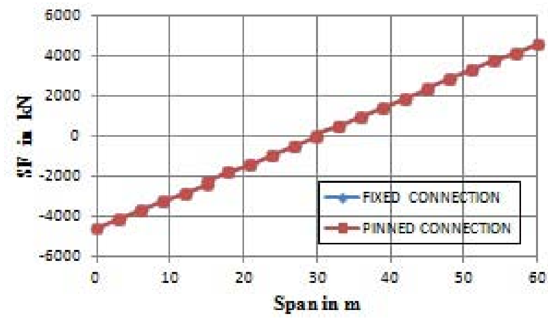

Fig. 8 : Comparison of SF variation in deck slab of single span integral abutment bridge due to DL for pile head with fixed and pinned connection

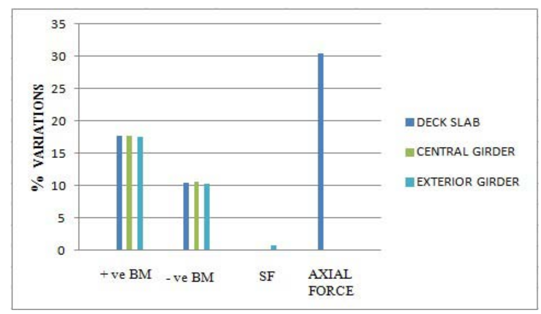

Fig. 9 : Comparison of percentage changes in all the parameters considered in deck slab, central girder and exterior girder in single span integral abutment bridge having pile head with pinned connection under DL with respect to single span bridge with fixed pile head

In the case of bridge deck slab with two spans, it was found that the positive and negative maximum BM increased by 10.93% and 11.4%, respectively in pinned pile head connection as compared with the fixed pile head connection as shown in the Figure 10. The negative BM at the end of deck slab reduced by 28.5% in case of pinned pile head connection as compared to the fixed pile head connection. It was also observed that in the central girder, the positive maximum BM increased by 10.5% and negative maximum BM increased by 10.9%, an increase of 11.4% in positive maximum BM and 11.5% in negative BM in case of exterior girder with pinned pile head connection as compared with the fixed pile head connection.

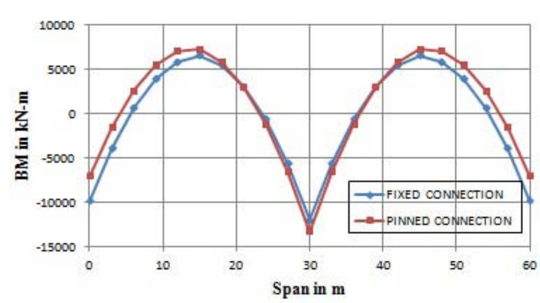

Fig. 10 : Comparison of BM variation in deck slab of two spans integral abutment bridge due to DL for pile head with fixed and pinned connection

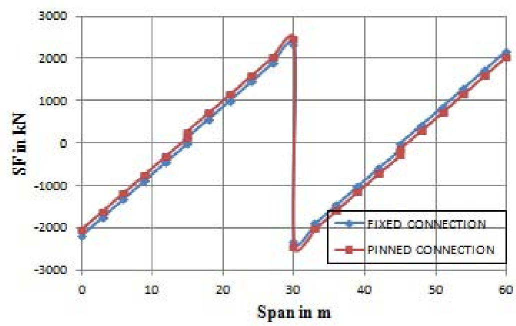

Fig. 11 : Comparison of SF variation in super structure of two spans integral abutment bridge due to DL for pile head fixed and pile head pinned connection

The Figure 11 presents the comparison of SF variations, which shows 5.9% increase of SF values in pinned pile head connection as compared with the fixed pile head connection. In the central girder, the SF reduced by 5.8% and in exterior girder SF increased by 6% with pile head having pinned connection than in fixed connection.

The percentage change in variation of all the parameters considered for two span integral abutment bridge having pile head with pinned connection in comparison with pile head fixed connection is shown in Figure 12.

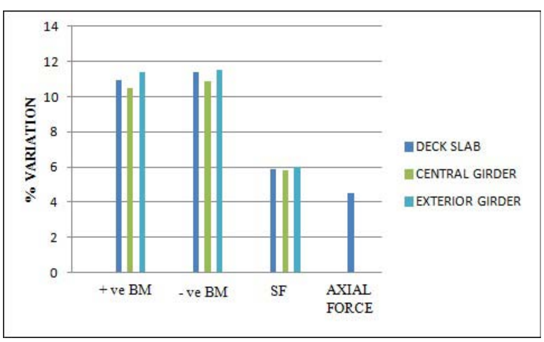

Fig. 12 : Comparison of percentage changes in all the parameters considered in deck slab, central girder and exterior girder in two spans integral abutment bridge having pile head with pinned connection under DL with respect to single span bridge with fixed pile head

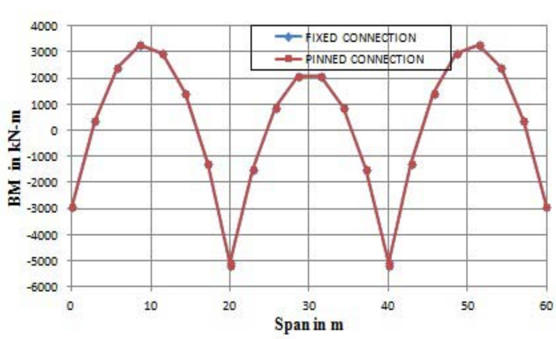

Fig. 13 : Comparison of BM variation in deck slab of three spans integral abutment bridge due to DL for pile head with fixed and pinned connection

An interesting outcome of the study was the negligible variation of BM and SF in deck slab of three spans integral abutment bridge having shaving pile head with fixed connection when compared with pinned connection as shown in Figures 13 and 14.

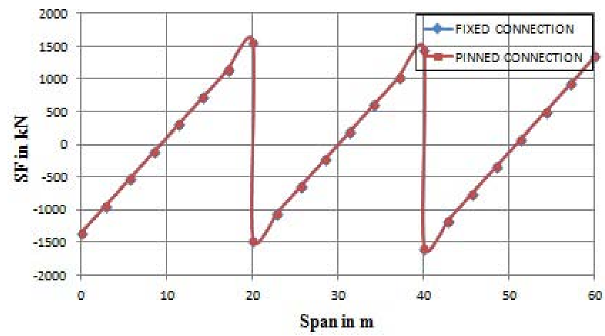

Fig. 14 : Comparison of SF variation in deck slab of three spans integral abutment bridge due to DL for pile head with fixed and pinned connection

Similarly, no change in the variation of BM and SF was observed in central and exterior girder of three spans integral abutment bridge having pile head with fixed connection as compared with pile head pinned connection bridge.

The variations of BM and SF in the deck slab, central girder and exterior girder under DL+ Temperature (10°C positive increase in temperature), DL + LL+ Temperature loading condition were similar as under only DL case when compared with pile head having fixed connection with pinned connection.

The changes in percentage of BM, SF and longitudinal stress in deck slab under only DL case with pile head having fixed and pinned connection for two spans and three spans with respect to single span is shown in Figures 15 and 16. In case of DL, the BM observed was maximum for single span (60 m). However, for two spans (30 m each) integral abutment bridge BM reduced upto 75% and for three spans (20 m each), it has reduced to 88% as compared with single span. This reduction in BM may be attributed to the increase in number of spans and the decrease in span length. SF also has maximum value for single span (60 m) integral abutment bridge. For two spanned bridge, the SF reduces to 50% and for three spans (20 m each) SF further reduced to 66% as compared with single span. Axial force was maximum for single span integral abutment bridge (60 m), while in case of two spans (30 m each) and three spans (20 m each) integral abutment bridge, the axial force reduced respectively by 77.5% and 90% as compared with single span bridge.

Longitudinal extreme top and bottom fibre stresses were maximum for single span (60 m), and they reduced to 75% for two spans (30 m each) integral abutment bridge and 89% for three spans (20 m each) integral abutment bridge as compared to single span.

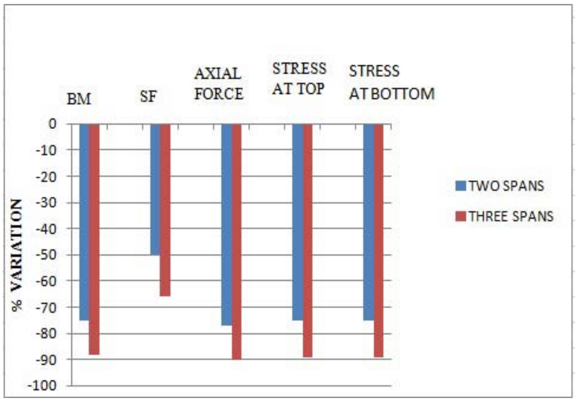

Fig. 15 : Comparison of percentage changes in all the parameters considered in deck slab of integral abutment bridge having pile head with fixed connection for two and three spans with respect to single span due to dead load

The variation of BM, SF, axial force and longitudinal stresses in the deck slab, central girder and exterior girder due to DL, DL + temperature (10°C change in temperature) and DL + LL (IRC 70R wheeled vehicle) + temperature load (10°C change in temperature) were compared for different spans with fixed pile head connection. Following charts from Figure 17 to 22 shows percentage changes in variation of all the parameters of integral abutment bridges having pile head with fixed connection for single, two and three spans bridges due to DL+ temperature and DL + LL + temperature cases in reference to only dead load for deck slab, central girder and exterior girders.

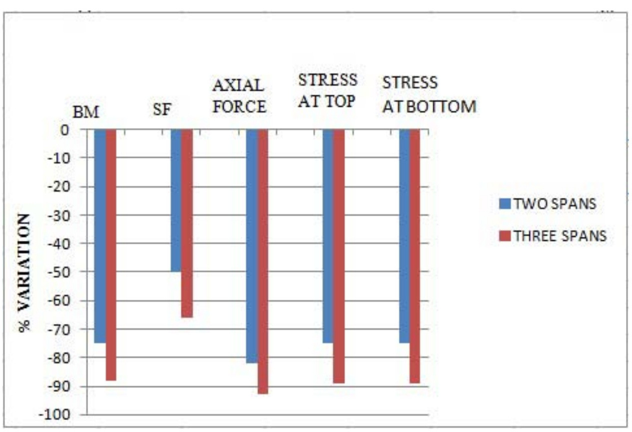

Fig. 16 : Comparison of percentage changes in all the parameters considered in deck slab of integral abutment bridge having pile head with pinned connection for two and three spans with respect to single span due to dead load

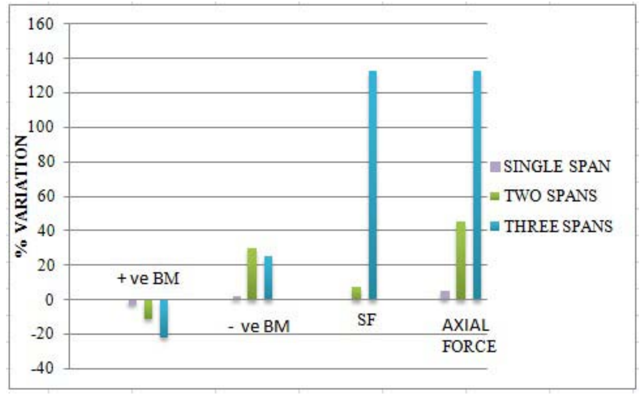

Fig. 17 : Comparison of percentage changes in all the parameters considered in deck slab of single, two and three spans integral abutment bridge due to DL+ temperature with respect to DL

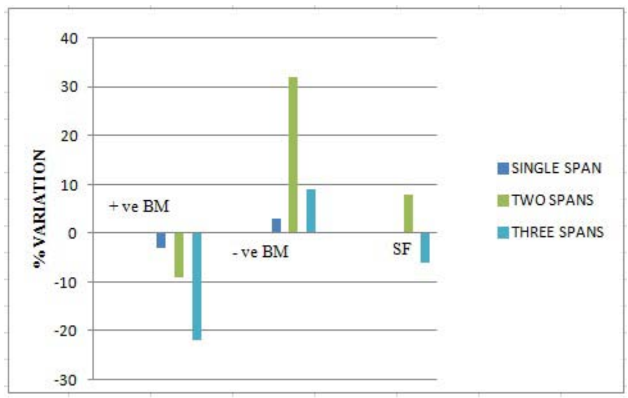

Fig. 18 : Comparison of percentage changes in all the parameters considered in central girder of single, two and three spans integral abutment bridge due to DL+ temperature with respect to DL

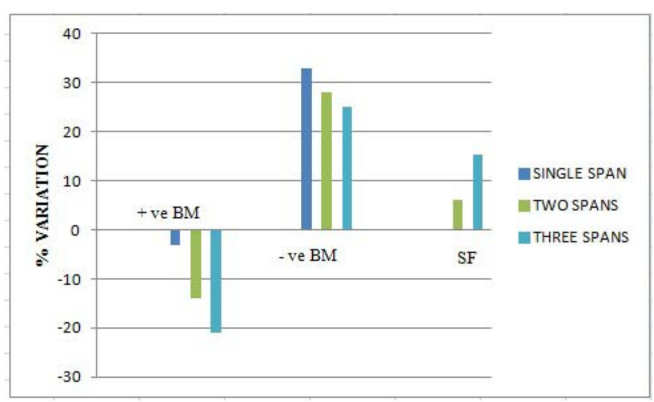

Fig. 19 : Comparison of percentage changes in all the parameters considered in exterior girder of single, two and three spans integral abutment bridge due to DL+ temperature with respect to DL

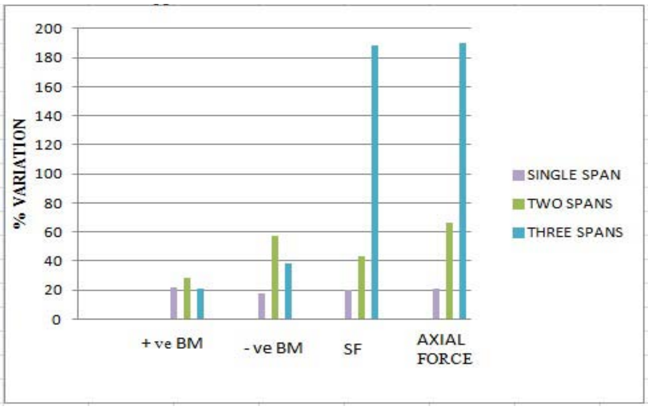

Fig. 20 : Comparison of percentage changes in all the parameters considered in deck slab of single, two and three spans integral abutment bridge due to DL+ LL + temperature with respect to DL

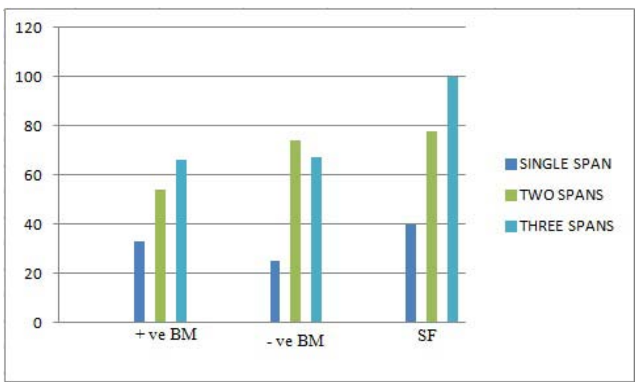

Fig. 21 : Comparison of percentage changes in all the parameters considered in exterior girder of single, two and three spans integral abutment bridge due to DL+ LL + temperature with respect to DL

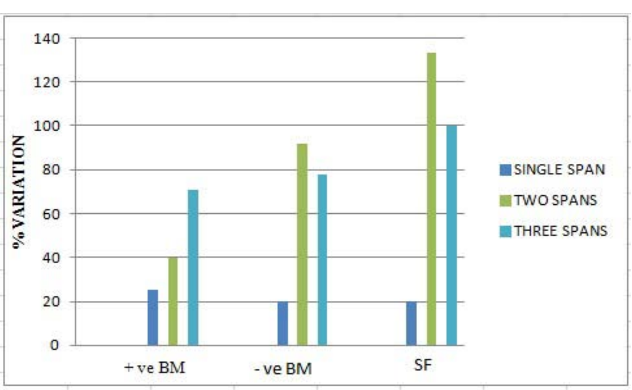

Fig. 22 : Comparison of percentage changes in all the parameters considered in central girder of single, two and three spans integral abutment bridge due to DL+ LL + temperature with respect to DL

IV. Conclusions

The following conclusions are drawn from the present analysis:

- The design parameters are affected by the pile head to abutment connection in integral abutment bridges.
- The negative BM at the end of deck slab and girders tend to reduce by 10.5% in single span and 28.5% in two spans, while there is no change in three spanned integral abutment bridge. Correspondingly, reduction of stresses at the end of deck slab is observed for the bridges having pinned pile head connection as compared with fixed pile head connection.
- An increase in SF at the deck slab was observed with a magnitude of 5.9% in two spans integral abutment bridge having pile head with pinned connection, whereas there was no change in SF in single and three spans. In the central girder, a decrease in SF and in external girder increase in SF is however observed in single and two spans bridge and there is no change in three spanned bridge girders.
- Abutment and deck connection can be designed for less BM in integral abutment bridge having pile head pinned connection as compared with fixed connection.
- The relation between the number of spans and all the design parameters was found to be inversely proportional. As the number of span increased, the design parameters such as BM and SF drastically decreased. The percentage reduction was observed to be the same for integral abutment bridges having pile head with fixed and pinned connection.
- 6. An inversely proportional relation was also observed between the number of spans and the top and bottom fibre stresses in deck slab. The stresses tend to decrease with increase in number of spans.
- The increase in temperature increases the negative moment when compared only with DL because of its hogging effect decreases in the positive BM. This trend is opposite to that of only DL which shows increase in positive BM and decrease in negative BM.
- With DL + temperature combination, the positive BM is increased by a magnitude of 17.69% and negative BM reduced by 10.5% in deck slab and girders with single span. In two span integral abutment bridge, the both positive and negative BM increased by nearly 10.93% and 11.4% respectively. However, there is no change in three spans bridge with pinned pile head as compared with fixed condition. Similar trend is also observed with DL + LL + temperature case.
- No change in shear force was observed in deck slab of one and three spanned bridges, but in case of two spans, there is 5.9% increase for the bridge

with pinned pile head connection as compared with fixed connection. Further, SF decreased in central girder and increased in exterior girder for one and two span bridges and there is no change in three spans bridge. Similar change in percentage is found in DL + LL + temperature case.

- The positive maximum BM in deck slab of integral abutment for different spans reduced in case of DL and temperature combination as compared only with DL. On the other hand negative maximum BM shows increasing trend in case of both DL and temperature and DL, LL, and temperature cases. Similar trend is also observed in interior and exterior girders.
- The SF in deck slab of integral abutment bridge for different spans increased both in case of DL + temperature combination and DL + LL + temperature combination as compared with DL, but it is zero for single span bridge with DL+ temperature combination.

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