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Effect of Modulus of Subgrade Reaction on Structural behaviour of Integral Bridge

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Abstract — Integral Abutment Bridges (IABs) are joint less and bearing less bridges whereby the deck is continuous and monolithic cast with abutment walls. The behaviour of Integral abutment bridge is interdependent between its structural components and soil medium, because complex behaviour of soil. IABs are complex structures due to the nonlinearity and uncertainties in bridge materials and soil boundaries. Modulus of subgrade reaction (Ks) of soil is the bearing capacity per unit settlement.

The present work includes the modelling of Integral abutment bridges with simple springs stiffness for the analysis. The bridge length is 50m, consists of two lanes and two spans of 25m each analyze as per IRC guidelines. Temperatures 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 super-structure, the abutment and foundation soil are all subjected to cyclic loading, and understanding their interactions is important for effective design and satisfactory performance of integral bridges. Applying the earth pressure loads is to assign appropriate spring stiffness to the abutment to represent the soil properties. The earth pressure on the abutments can be considered using appropriate pressure coefficient Ks with different soil types.

Depending on the soil conditions, the forces generated in the structure can vary significantly. Effect of loose, medium and dense sand soil stiffness is carried out for study of structural response of integral bridge. The final aim of this study is to propose modelling of integral abutment bridge system with influence of modulus of subgrade reaction which can allow predictions of dynamic response based on the results of static relative displacement studies coupled with simple soil stiffness subjected to the dynamic loading using standard software SAP series Csi bridge.

Keywords*- Integral abutment bridge, modulus of subgrade reaction, Csi bridge*

I. INTRODUCTION

The bridge is a structure designed to carry the users from point A to point B crossing an obstacle, thus making it very important to know about the loads acting on the bridge as well as the structural response to those loads. There are many different types of bridges which fulfil different requirements, e.g. suspension bridges, cable stayed bridges and arch stayed bridges. These bridges are in general used for long spans and long distances. For shorter spans, frame bridges or beam bridges are usually used. These bridges can be made either with or without joints transferring movements and forces that act on the bridge structure. One major problem regarding bridges with joints are the fact that the joints must not be exposed to water or dirt in order to function sufficiently. This will give high maintenance costs, something that will be avoided using joint less bridge, where instead moments are introduced to the rigid connections.

To categorise joint less bridges, the expressions integral bridges or integrated abutment bridges are often used. Some examples of integrated bridges are slab bridges, frame bridges, beam bridges or semi-integrated bridges. In the integral bridges, the abutments are used to lead both horizontal and vertical forces into the ground. A foundation of either spread foundations or piles are then used.

Bridges are generally designed as structures with bearings and roller connections at their supports. This is for several reasons, such as severity of the weather (temperature), movements of the earth, traffic loading condition, and the material which is used in construction, any of which could cause expansion and contraction to the bridge superstructure. For conventional bridges, expansion and contraction stresses are relieved by adding expansion joints in the structure. However, bearings and expansion joints are recognized as a reason for the high maintenance cost of bridges. The weak points in the bridges are also considered to occur at these bearings and joint connections, especially because they are vulnerable to environmental problems such as corrosion from humidity or ice and snow.

An alternative bridge construction is the integral bridge, which does not have expansion joints or bearings. Instead, integral bridges have a rigid structure and all of the loads, including stresses induced by expansion and contraction, are transferred directly to the abutments and sub-structures.

1.1 Concept of integral bridge

In traditional bridges, structural releases are provided in bridges to permit thermal expansion and contraction. These joints lead to water tightness problems. Water runoff into newly opened deck joints can cause extensive damage. Water corrodes the underlying steel elements (girders, supports, connection hardware, etc.), damages the concrete, and corrodes reinforcing steel. The cost of maintenance or replacement of expansion joints is a considerable portion of the total money spent for bridges every year. Joints and bearings in traditional bridges have emerged as major sources of bridge maintenance problems.

In an Integral abutment bridge (IAB), there are no girder bearings at the abutments. Instead, the girder ends are cast integrally with the abutment, hence the terminology integral abutment bridge. IABs have a lower construction cost and much lower life cycle costs because of minimal maintenance. Retrofitting traditional bridges with IAB features has also shown to be cost effective.

1.2 Structural arrangement

Integral bridges are specific when compared with traditional girder bridges, because they do not contain expansion joints and bearings. The elimination of these structural elements separating the superstructure from the substructure leads to many differences between integral bridges and traditional girder bridges.

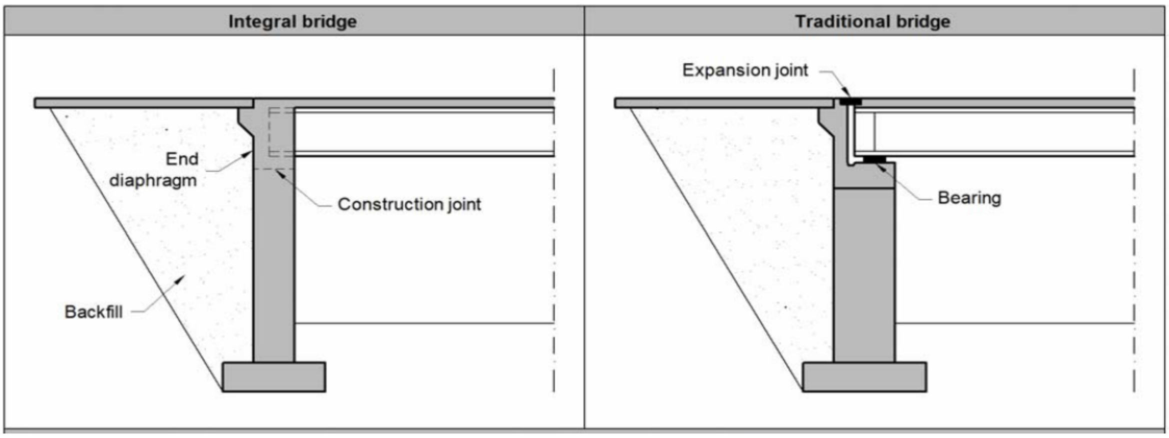


Figure:1 Structural arrangement of integral bridge and conventional bridge

1.3 Statical action

Differences in structural arrangements of integral bridges and traditional girder bridges lead to differences of their statical action. The most important differences are following:

1) Rigid frame joint between a super-structure and a sub-structure,
2) Interaction between the super-structure, the sub-structure and the surrounding soil,
3) Restraint of free expansion of the superstructure.

The super-structure of integral bridge is fixed to the sub-structure, all displacements and rotations of the Super-structure is transmitted to the sub-structure. During the thermal expansion, the abutments are pushed into the soil of backfill, which brings about passive earth pressures acting on the abutments. The movements of the superstructure are restrained by the stiffness of the abutments and by the earth pressure acting on the abutments. This causes an interaction of the super-structure, the sub-structure and the surrounding soil.

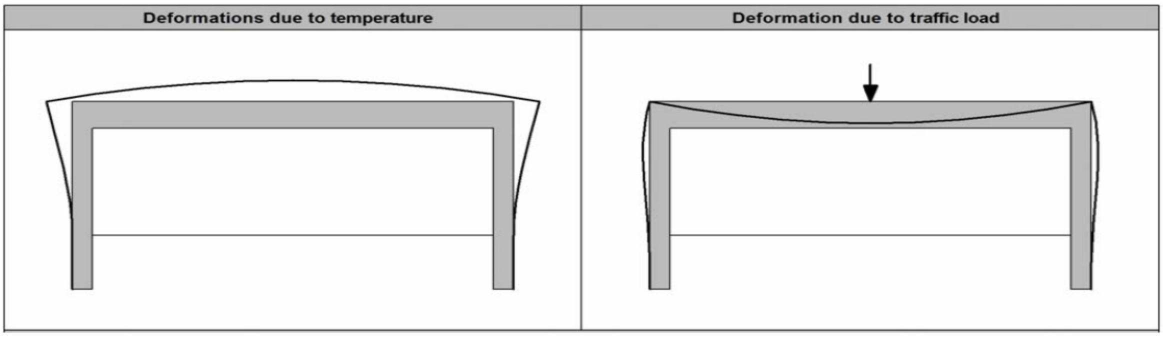


Figure:2 Deformations of integral bridge

1.4 General loads on integral bridge

1. Temperature load

Temperature loads affect bridges due to stress changes, for example when the concrete is heated up, it expands, and when it cools down it contracts again. The movement mainly happens in the horizontal direction. Concrete is a material with a relatively low heat conduction capacity, meaning that the heat transfer inside the material is low, making it more sensitive for thermal variations because large differences in temperature will arise within the structure.

This is because of the material heat tardiness, and the differences in temperature within the material. The stresses and strains caused by the thermal actions are initiated by the restraining of the structure.

2. Earth pressure

Soil can be divided into two main groups, cohesion soil and friction soil sand. The friction soil is characterized by the internal friction angle ϕ which describes the angle of the line for the shear stress in the Mohr-Coulomb's circle and also describes the limit angle of the surface of the material. The stress history of the soil is described by the consolidation, i.e. how much it is compacted. The passive and active earth pressure will give rise to different failures modes not only in the backwall, but also in the soil. The failure mode is partly characterised by the internal friction angle, by comparing the earth pressure coefficients, the passive earth pressure is approximately 25 times larger than the active earth pressure.

Changes in earth pressure behind a backwall occur due to horizontal loading of the bridge superstructure, which are transferred to the backwalls. For example, temperature changes of the bridge can induce a passive earth pressure if the bridge expands, and an active earth pressure if the bridge contracts.

3. Lateral earth pressure

The vertical loads, both external loads and the weight of the soil, spreads down in the ground. The self-weight of the soil magnifies with increasing depth and the stresses are calculated by multiplying the weight of the soil with the depth. To transform the vertical loads, denoted $\sigma 1$, into horizontal components, i.e. $\sigma 2$ and $\sigma 3$, the stress is multiplied with the earth pressure coefficient K. The coefficient K_0 represent the earth pressure coefficient at rest, K_a the earth pressure coefficient for active earth pressure and K_p is the coefficient for the passive earth pressure.

$$K_0 = 1-\sin(\phi') \quad ..... (1)$$
$$Ka = \tan2\ (45° - \phi'/ 2) \quad .....(2)$$
$$Kp = \tan2(45°+ \phi'/ 2) \quad .....(3)$$

where:

ϕ = internal friction angle

4 Traffic loads

The traffic load is defined as a variable load, and thus many different load models exist to compensate for the many different outcomes of traffic. The only traffic load contributing to the horizontal displacement of the backwall is the braking force.

5 Surcharge loads

If a vehicle is standing on the road, beside the bridge, the load is taken up by the soil. The horizontal component of this load, decided by the earth pressure coefficient, will induce an active earth pressure on the bridge backwall, which in turn will cause a passive pressure in the other side. This type of load is called surcharge load.

II. GUIDELINES AND METHEDOLOGY

The bridge models analyze as per IRC guidelines.

2.1 Soil constitutive model for conducting soil stiffness

1. Winkler Model

The Winkler model is easy to implement in a structural system. The stiffness of a discrete spring ki can be estimated with different approaches but is always defined as a relation between the settlement δi and reaction force Ri in a point. For one specific point the relation can be written as:

$$Ki=Ri/\delta i \qquad \text{....(4)}$$

Where:

Ki=stiffness of discrete spring
Ri=reaction force at point
δi=settlement

In a simple model, the spring stiffness can be assumed to be uniformly distributed. A normal approximation for calculation of settlements is to assume a 2:1 stress distribution in the soil. The stiffness for discrete springs is calculated by dividing the vertical load affecting one spring q*s by the settlement δ, where s is the spacing between the springs. With uniform spring stiffness, constant E modulus Es through the depth in the soil and assuming 2:1 stress distribution, the stiffness of discrete springs is determined with equation, where L is the length of the superstructure and H height of the subgrade.

$$Ki=qs/\delta \qquad \text{.....(5)}$$

Winkler model is the simplest structural model. The primary deficiency of the model is that the shear capacity of the soil is neglected. As a result of omitting the shear stresses, displacement has no spread in transverse direction. Therefore, displacement discontinuity appears between loaded and unloaded surfaces.

III. BRIDGE CONFIGURATION AND MODELS

3.1 Model Data:

- **Bridge layout line data**
- Length of bridge=50m
- Spans of bridge for 50m bridge=Two equal span of 25m
- Horizontal and vertical layout=straight
- Centreline offset=1.825m
- Lane width=3.65m
- Abutment: Depth=3 to 6m
- Width=2.5m
- Cap bent: Depth=2 to 3m
- Width=1.6m
- Pile: 1m dia.

- **3.2 Material Properties**

The material properties used in the models are as follows:

- Steel girders=Fe345
- Concrete section=M30
- Rebar materials=HYSD 415
- Poisson's Ratio= 0.3
- Slab material: M30

3.3 Loading Data

The loads which are considered for this analysis are Dead loads, Live loads.
1)Dead load

- Asphalt load: 2 KN/m
- Railing load: 1 KN/m
-

2) Live load (Moving loads)

- As per IRC design guidelines.
- Vehicle classes: IRC 70R 7x2x2
- IRC AA Tracked
- IRC AA Wheeled
- Load combination: (DL+LL)
- Load cases: Static linear and Moving live load

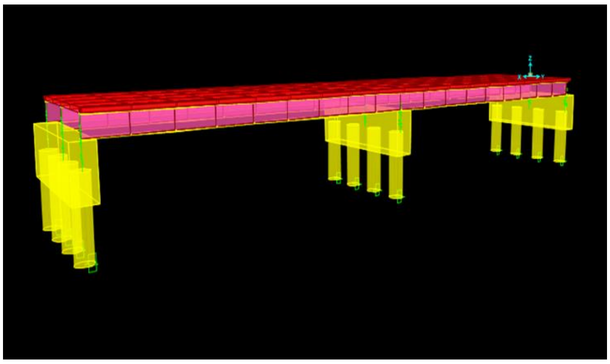
3) Bridge temperature considered as per IRC guideline

3.4 Parameters for Modulus of subgrade reaction values

Soil type	Density δ (Kg/m^3)	Modulus of elasticity Es (N/mm^2)	Poisson's ratio (μ)	Allowable bearing pressure (KN/m^2)	Angle of internal friction (ϕ)	Modulus of subgrade reaction (Ks) $KN/m^2/m$
Loose sand	17	20	0.20	150	29	4800
Medium dense sand	19	40	0.30	250	35	9600
Dense sand	21	60	0.40	450	40	64000

Bridge type	Minimum Temperature	Maximum temperature
Concrete super-structure	3 C	50 C
Concrete deck on steel girders or beams	-2 C	60 C

3.5 Bridge Model:



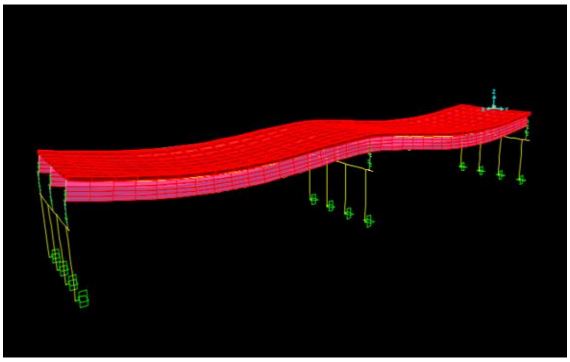


Figure -3.5.1: 3D models of 1)50m length bridge consists of two equal spans of 25m 2) Deformed shape of 50m bridge after analysis

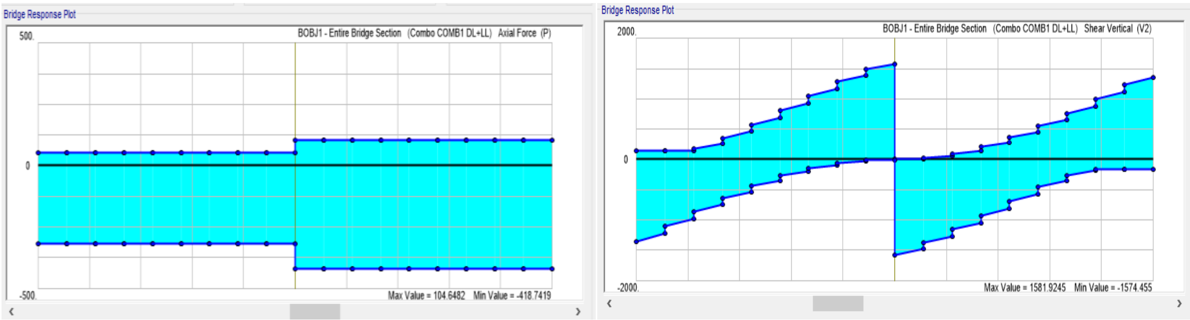


Figure-3.5.2: Bridge response plot for axial force(P) KN and shear force (V) KN due to load combination (DL+LL)

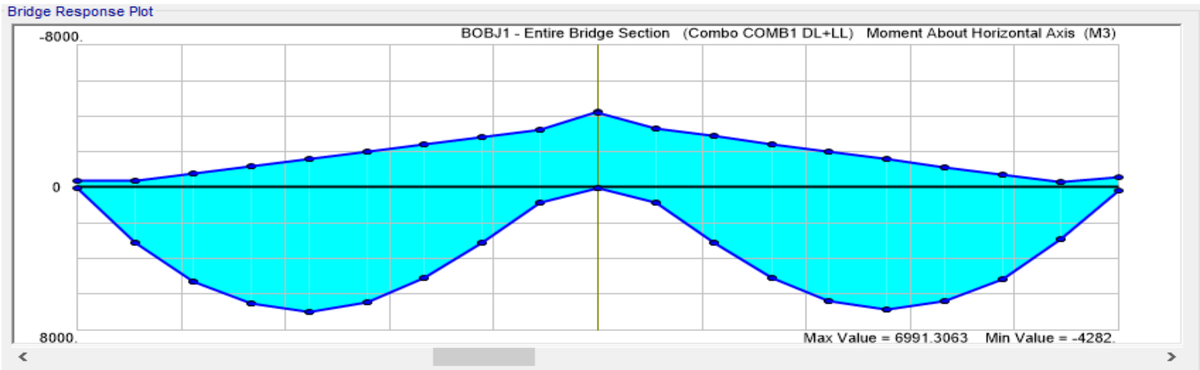


Figure-3.5.3: Bridge response plot for Bending moment (KN.m) for load combination (DL+LL)

Table 3.1: Results for entire bridge (DL+LL) combination

Layout distance	Axial force	Shear force	Torsion	Moment
(m)	**(P) KN**	**(V) KN**	**(T) KN.m**	**(M) KN.m**
0	**-219.70**	**-783.21**	**1.294**	**-242.99**
2.77	**-219.70**	**-558.63**	**1.294**	**1620.67**
5.55	**-219.70**	**-334.06**	**1.294**	**2860.54**
8.33	**-219.70**	**-109.49**	**1.294**	**3476.59**
11.11	**-219.70**	**115.08**	**1.294**	**3468.82**
16.66	**-219.70**	**564.22**	**1.294**	**1581.85**
19.44	**-219.70**	**788.80**	**1.294**	**-297.34**
22.22	**-219.70**	**1013.37**	**1.294**	**-2800.36**
25	**-219.70**	**1237.94**	**1.294**	**-5927.19**
27.77	**-245.21**	**-1010.73**	**-1.294**	**-2843.55**
30.55	**-245.21**	**-786.16**	**-1.294**	**-347.85**
33.33	**-245.21**	**-561.16**	**-1.294**	**1524.02**

36.11	**-245.21**	**-337.01**	**-1.294**	**2772.08**
38.88	**-245.21**	**-112.44**	**-1.294**	**3396.34**
41.66	**-245.21**	**112.12**	**-1.294**	**3396.78**
44.44	**-245.21**	**336.70**	**-1.294**	**2773.40**
47.22	**-245.21**	**561.27**	**-1.294**	**1526.22**
50	**-245.21**	**785.84**	**-1.294**	**-344.77**

IV. RESULTS AND DISCUSSION

The linear static analysis is carried out for the model including temperature load and analyzed as per IRC guidelines.

Table 4.2: Backfill stiffness and structural response for 50m bridge length (DL+LL combination)

Soil backfill type	Axial force (P) KN max.(-ve)	Shear force (V) KN max. (+ve)	Moment (M) KN.m max. (+ve)
Loose sand	-512.36	2154.02	2241.66
Medium dense sand	-455.02	1756.66	2858.78
Dense sand	-379.58	1237.94	3396.34

IV. CONCLUSION

Based on this study bridge model response loose backfill materials seen greater axial force, shear force and bending moment as compared to medium dense sand and dense sand. The soil stiffness is found to have no effect on the shape of influence lines for live load analysis. Loose backfill soil stiffness gives the maximum negative axial force and lesser bending moment compare to medium and dense sand backfill material.

REFERENCES

[1]. IS: 456-2000, Indian Standard Code of Practice for Plain and Reinforced Concrete
[2] IRC: 78-2014, Standard Specifications and Code of Practice for Road Bridges-SECTION: VII.
[3] IRC 6.2014, Standard specification and code of practice for Road and Bridges Section Load and stress
[4] IRC 5.2015, Standard specification and code of practice for Road and Bridges section I Load and stress
[5] Design of Bridge Structures by T.R. Jagadeesh and M.A. Jayaram [1]
[6] Scott A. Civjan, Emre Kalayci, Brooke H. Quinn, Sergio F. Bren, Chad A. Allen "Observed integral abutment bridge substructure response" ISSN: 0141-0296 Engineering structures. @2013 Elsevier Ltd. All rights reserved.
[7] Aslam Amirahmada and A. Rahman Al-Sinaidia "Analysis of Integral Bridges by Finite Element Method" ISSN: 1877-7058 Procedia Engineering @ 2013 the Authors Published by Elsevier Ltd.
[8] WooSeok Kima, Jeffrey A. Lamanb "Integral abutment bridge response under thermal loading" ISSN: 0141-0296 Engineering structures @2010 Elsevier Ltd. All rights reserved.
[9] Jamshid Sadrekarimi, Maryam Akbarzad Ghamari University of Tabriz, Tabriz, Iran "The Coefficient of Subgrade Reaction and Its Accuracy on Design of Foundations". International Conference on Case Histories in Geotechnical Engineering, Arlington, VA, August 11-16,2008.
[10] M. GadElRab Hussein, "Experimental Evaluation of the Subgrade Reaction and Soil Modulus Profiles for Granular Backfills" Al-Azhar University, Nasr City, Cairo, Egypt Current Visiting Research at McGill University, Montreal, Quebec, Canada Conference paper 2009 GeoHalifax.
[11] Emre Kalayci, Scott A. Civjan, Sergio F. Breña "Parametric study on the thermal response of curved integral abutment bridges" ISSN: 0141-0296 Engineering Structures. 2012 Elsevier Ltd. All rights reserved.
[12] Murat Dicleli, Suhail M. Albhaisi "Performance of abutment–backfill system under thermal variations in integral bridges built on clay" ISSN: 0141-0296 Engineering Structures, 2004 Elsevier Ltd. All rights reserved.

[13] Murat Dicleli, Semih Erhan "Effect of soil bridge interaction on the magnitude of internal forces in integral abutment bridge components due to live load effects" ISSN: 0141-0296 Engineering structures.2009 Elsevier Ltd. All rights reserved.
[14] R. Ziaie-moayed and M. janbaz "Effective parameters on Modulus of Subgrade Reaction in clayey soils" ISSN: 1812-5654 Journal of applied science 9, 2009 Iran.
[15] Constantine Spyrakosa, George Loannidis "Seismic behaviour of a post- tensioned integral bridge including soil–structure interaction (SSI)" ISSN: 0267-7261 Soil Dynamics and Earthquake Engineering @2002 Published by Elsevier Science Ltd.