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Comparative Analysis of Abutment Type Integral Bridge & Simply Supported Bridge by Providing Different Geometric Irregularity

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Abstract - The bridge construction methods are changing throughout the world. The new methods are only be accepted based upon the requirement of field & structural aspect. In this paper, we have introduced the concept of abutment integral bridge by providing a pier in between & comparing it, with conventional bridge. There are total 36 model is prepared for the research work.

The 24 model without soil structure interaction for abutment integral bridge & simply supported bridge (12 for each) is prepared based upon the length 20m, 25m & 30m with a skew angle of 15, 30, 45, 60. The result is displayed in form of graph which is dictated as deflection for moving load, self-weight, & temperature. The result in form of bending moment for moving load & self-weight are also shown in form of graph. The dynamic earth pressure is also taken into account and the graph showing bending moment on abutment for the earth pressure is also presented in this research paper. The seismic analysis on abutment for this 24 model is also viewed based upon IS-1893(part-3)-2014.

The 12 model of simply supported bridge which is mentioned in the above paragraph without pier spring was compared with 12 model of simply supported bridge with pier spring for soil structure interaction is prepared. The result for the bending moment at the bottom of pier for moving load is shown in form of chart.

Key Words: Geometric irregularity, Two Midway Pier, Gazetas's Spring Constants

1. INTRODUCTION

The traditional construction of simply supported bridge include the superstructure transferring the load on substructure through bearing. When there is a provision of expansion joints & bearing which ultimately allows the movement & rotation of bridge deck without transferring any of that force to abutment/pier & foundation due to thermal/creep/shrinkage induced movements, while the abutment integral bridge concept is a theory that is based upon the flexibility of structure & their thermal load due to temperature differences, is transferred to the substructure by the way of monolithic connection between superstructure & substructure. An integral bridge is a fully constructed bridge on a continuous moment connection between superstructure & substructure at the abutment & pier thereby eliminating the joint or bearing to accommodate the rotation & thermally induced displacement at the end of deck. The semi-integral type of bridge has no joint in the deck but there is a provision of bearing in its structures. This form is adopted when the ground on which this bridge rest is not suitable for fully integral bridge. The soil structure interaction on pier is also considered.

The main challenge for soil structure interaction is the incorporation is that the two field, that is, geotechnical and structural engineering meet simultaneously.

The modulus of elasticity of soil is used to measure soil stiffness. The modulus of elasticity is often used for estimation of settlement of soil and elastic deformation analysis. Generally, the modulus of elasticity of soil is determined using tri-axial test. But, for sand it is difficult to carry out tri-axial test because of its cohesionless, nature leading to limitation in preparation of sample mould for the testing. Therefore, in the present study an attempt made to carry out data from previous research paper & determination of modulus of elasticity of sand using plate load test analogy.

Researchers have developed various key set of models employing different techniques, tools & empherical formula to properly address the issues associated with the complexities while incorporating SSI The temperature, earth pressure is also mentioned based upon IRC:6-2017 Code.

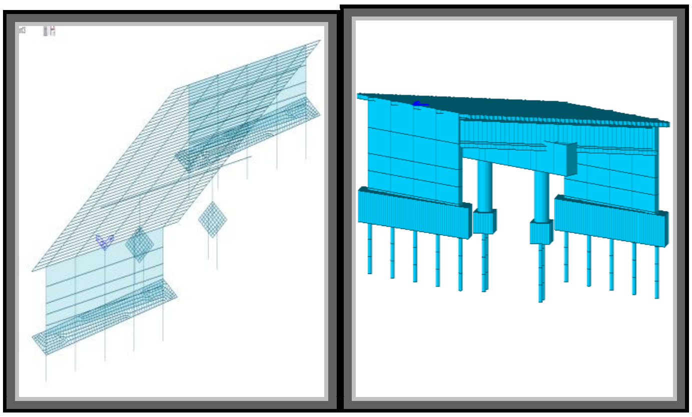

Fig -1: Bridge Perspective View

2. OBJECTIVE

The objective of this work is as follows:

1. To study the behavior of abutment integral bridge over simply supported bridge.
2. To predict the change in bending moment by changing skew angle
3. To compare the maximum bending moment due to self weight & live load.
4. To determine the displacement in terms of selfweight, moving load case 1 & case 2, Temperature Rise & Fall
5. To Compare the maximum bending moment due to earthfill on abutment & comparing it with simply supported bridge.
6. To introduce pier spring based upon soil condition at 1.5m from the bottom of pier & comparing it with same simply supported bridge without pier spring.\
7. To compare the result for self weight on pier with or without soil structure interaction.

3. Model Data

Geometric Parameters	
Skew Angle	15,30,45,60
Length	20m, 25m, & 30m
Total Width	15m
Carriageway Width	14m
Landscape	1m
Cross Barrier Thickness	0.175m
Cross barrier Height	0.9m
Cross Barrier Load	3.94Kn/m
Other Load For Verge & Traffic Light	0.56Kn/m
Total no. of lane	4
Slab Thickness	0.2m
Wearing course	80mm
Joint For Simply supported Bridge	50mm
Pier Diameter	3m
Pier Height	4.5m
Pier Cap	3.2m X 1.5m
Abutment Thickness	1.2m
Abutment Height	4.5m
End Diaphragm	1.5m x 0.45m
Int Diaphragm	1m X 0.3m
Material Properties	
Grade of Concrete for Girder & Pier	M50
Grade Of Concrete For Abutment	M40
Grade of Steel	Fe 500
Loads Taken	
Cross Barrier	4.5Kn/m
Dead Load	25 Kn/m^3
Live Load	Case 1-(4Class A) Case 2-(70R + Class A)
Soil Parameters	
Soil	Dense Sand
Density Of Soil	18.5Kn/m^3
ϕ	33
K	0.36
K^*	1.15, 1.25, 1.34
Density Of Soil	18.5Kn/ m^3
Pile Spring	
E	22.75mpa
u	0.3
G	8.75mpa
K_H	61764.71Kn/m
K_R	112500
Temperature	
Location	Ahmedabad
Max Temp	47.5
Min Temp	0
Mean Temp	23.75
Temp Rise	33.75
Temp Fall	13.75
Initial Temperature	20
Humidity	
Maximum Humidity	67
Minimum Humidity	41
Mean Humidity	54

4. METHODOLOGY FOR ANALYSIS

1. The abutment integral bridge & simply supported bridge was analyzed by modelling a grillage model of span 20, 25 & 30m, with a skew angle of 15, 30, 45 & 60.

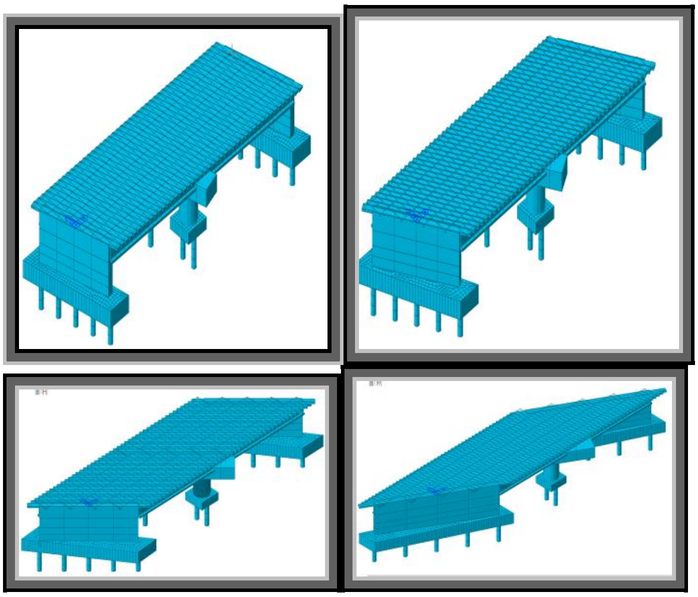

Fig -2: Bridge Skew Angle

2. The Two span model was taken into consideration with following precast RCC composite girder.

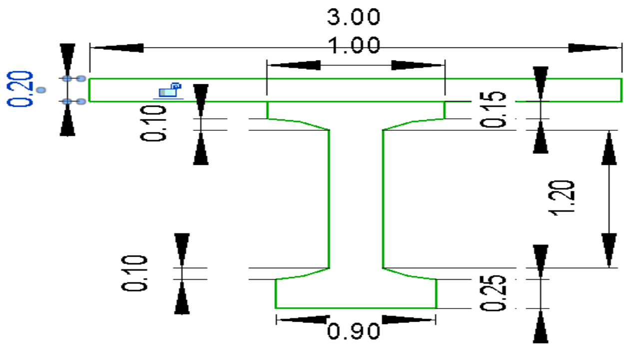

Fig -3: Girder Cross section

3. Section Properties & Their Material were assigned as per the dimension consideration.
4. Loads were applied on bridge as per IRC 6(2017)

Sr. no	Loads	Type/Direction
1	Gravity Load	Self weight, Load due to Crash Barrier & Bearing surface coat
2	Lateral Load	Earth pressure, Live Surcharge Load
3	Temperature Loads	Temperature Rise & Fall
4	Live Loads	Case:1- 4@ Class A & Case:2- 70R + 2@ Class A

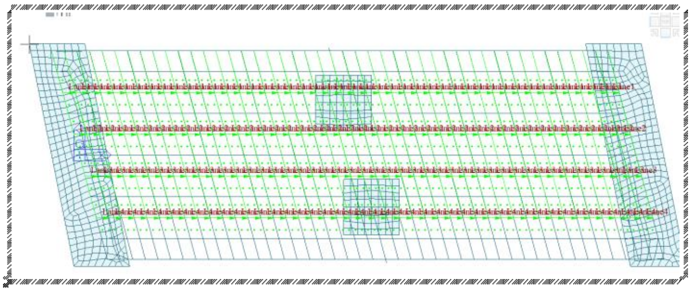

Fig -4: Traffic Lane

5. The consideration of soil structure interaction for the pier is also taken into the account.
6. The pier height above the ground is taken as 3m, while below the ground is taken as 1.5m, only for simply supported bridge.
7. the spring is provided from the bottom, towards the total distance of 1.5m, at an interval of 0.5m.
8. for simply supported bridge, the bending moment of pier at the bottom edge is compare with or without soil structure interaction.
9. After Considering the forces that is acting on the structure, the magnitude of bending moment of various components were summarized from the model.
10. the result of 12 model for abutment integral bridge (without soil structure interaction), compared with 12 model of Simply supported bridge (without soil structure interaction), are dictated in form of graph which is mentioned below.
11. The 12 model of simply supported bridge without pier spring is compared with 12 model of simply supported bridge with pier spring which is also explained below in a result format.

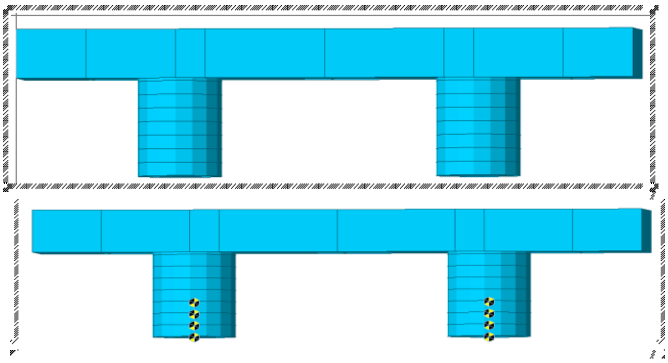

Fig -5: With or Without Soil Structure Interaction on Pier

5. VARIOUS EXPRESSION BASED UPON IRC CODE & EMPHORICAL FORMULA

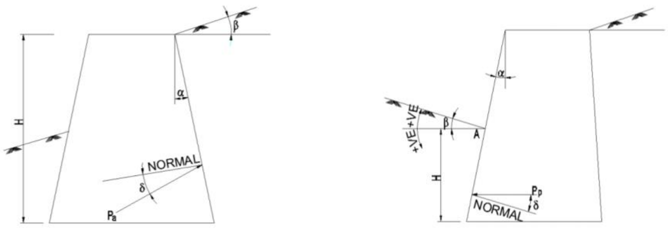

Fig -6: Diagram For Active & Passive Earth Pressure

1. EARTH PRESSURE

(a). Active earth pressure due to earth fill

The total dynamic force in Kn/m length wall due to dynamic active earth pressure shall be

$$P_a = \frac{wh^2 Ca}{2}$$

Where,

C_a = Coefficient of dynamic active earth pressure

$$C_a = \frac{(1 \pm Av)\cos^2(\phi-\lambda-\alpha)}{\cos\lambda \cos^2\alpha \cos(\delta+\alpha+\lambda)} X \left(\frac{1}{1+\sqrt{\frac{\sin(\phi+\delta)\sin(\phi-\beta-\lambda)}{\cos(\alpha-\beta)\cos(\delta+\alpha+\lambda)}}} \right)^2$$

(b). Active earth pressure due to earth fill

The total dynamic force in Kn/m length wall due to dynamic Passive earth pressure shall be

$$P_p = \frac{wh^2 Cp}{2}$$

Where,

C_p = Coefficient of dynamic passive earth pressure

$$C_p = \frac{(1 \pm Av)\cos^2(\phi-\lambda+\alpha)}{\cos\lambda \cos^2\alpha \cos(\delta-\alpha+\lambda)} X \left(\frac{1}{1-\sqrt{\frac{\sin(\phi+\delta)\sin(\phi+\beta-\lambda)}{\cos(\alpha-\beta)\cos(\delta-\alpha+\lambda)}}} \right)^2$$

(C). earth pressure on Integral bridge due to earth fill

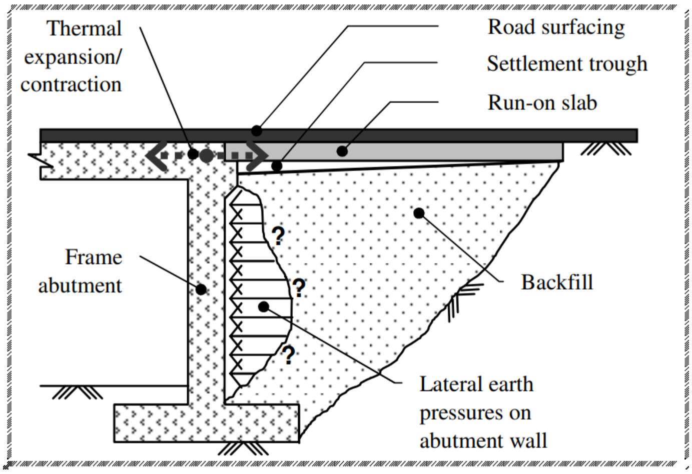

Fig -7: Abutment Feature For An Integral Bridge

The total dynamic force in Kn/m length wall due to dynamic Passive earth pressure shall be

$$P_I = \frac{wh^2 K*}{2}$$

Where,

K* = Coefficient of dynamic earth pressure

$$K^* = K_o + \left(\frac{d}{0.03H}\right)^{0.6} K_p$$

Where A_v = Vertical Seismic coefficient

ϕ = Angle of internal friction of soil

$$\lambda = tan^{-1} \frac{Ah}{1 \pm Av}$$

α = Angle which earth face of the wall makes with the vertical

Ko = Earth Pressure at rest(1-sin ϕ)

β = Slope of earth fill

δ = Angle of friction between the wall and earth fill and

A_h = Horizontal seismic coefficient, shall be taken as (Z/2), for zone factor Z, refer Table 16 of IRC-6

For design purpose, the greater value of C_a & C_p shall be taken, out of its two values corresponding to ± A_v.

2. Temperature

Since the load due to temperature vary from region to region , the temperature range of the Ahmedabad city was taken into consideration . following were the calculation for the thermal load that was taken into account.

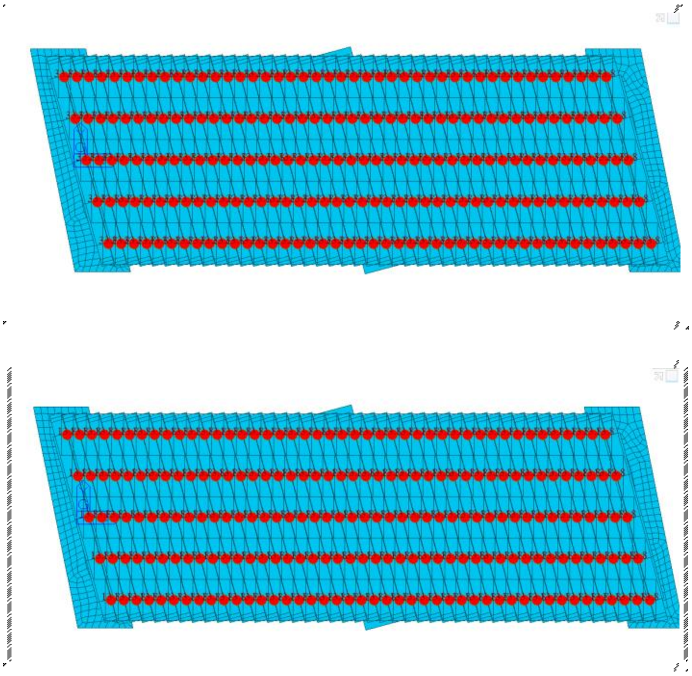

Fig -8: Temperature Rise & Fall

3. Pile Spring

A. Based upon Newmark's distribution Method, the spring stiffness is given as follows

$$K_{s1} = \frac{DL}{24} X((7K_h{}^{n}) + (6K_h{}^{n+1}) - (K_h{}^{n+2}))$$

$$K_{s2} = \frac{DL}{12} X((K_h{}^{n-1}) + (6K_h{}^{n}) + (K_h{}^{n+1}))$$

$$K_{s1} = \frac{DL}{24} X\left((7K_h{}^{n}) + (6K_h{}^{n-1}) - (K_h{}^{n-2})\right)$$

Where

D= diameter Of Pile

l= Spacing Between Two adjacent Springs

$K_h{}^n$= Modulus of Subgrade of n^th spring

It is determined by Vesic 1961 Equation based upon numbers of spring

$$K_h = \frac{0.65}{D} X 12 \sqrt{\frac{E_s D^4}{E_p I_p}} X \frac{E_s}{1-u_s{}^2}$$

B. Based upon Gazetas (1983) Spring constant

Horizontal $K_h = \frac{8GR}{2-u}$

Rotational $K_o = \frac{8GR^3}{3(1-u)}$

Where

G= The Shear Modulus Of soil

$$G = \frac{E}{2(1+u)}$$

u=Poisson ratio

E=Soil Modulus of Elasticity

R= Radius of Circular Element

The modulus of elasticity of soil is taken from the research paper "Estimation of Modulus of Elasticity of Sand Using Plate Load Test"

6. RESULT

[**Note:** SW=Self Weight, SSB= Simply Supported Bridge, IAB= Integral Abutment Bridge, SSI=Soil Structure Interaction Rsx=Seismic Force in X Direction, Rsy= Seismic Force In y Direction]

<table>
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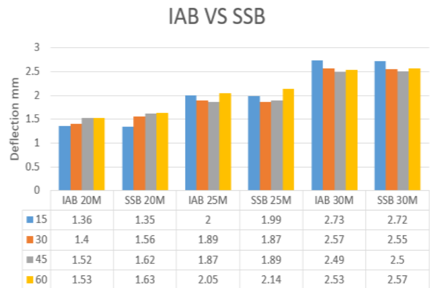
Case 1</td><td>
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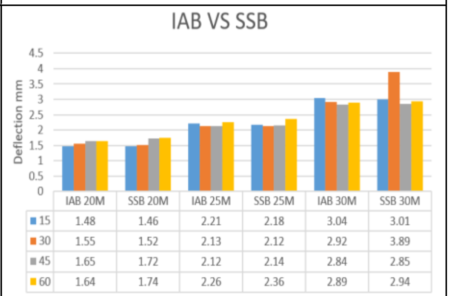
Case 2</td><td>
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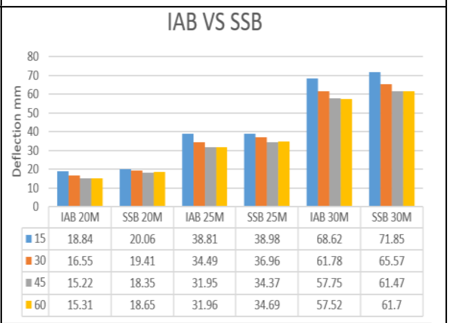
<tr><td>Self Weight</td><td>
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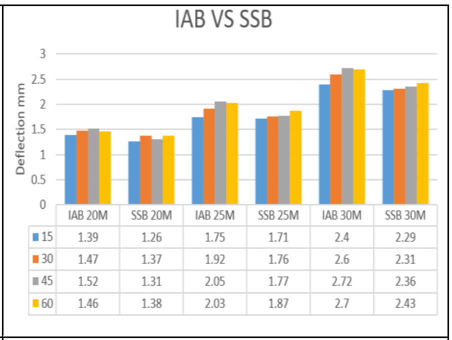
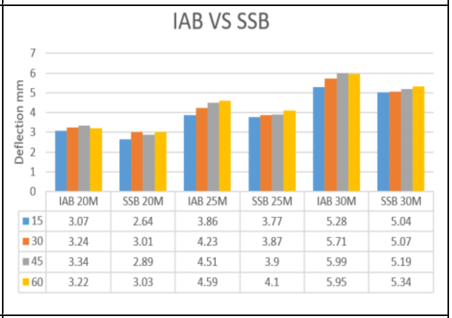
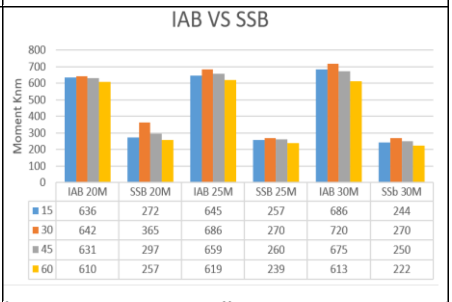
Temp Fall



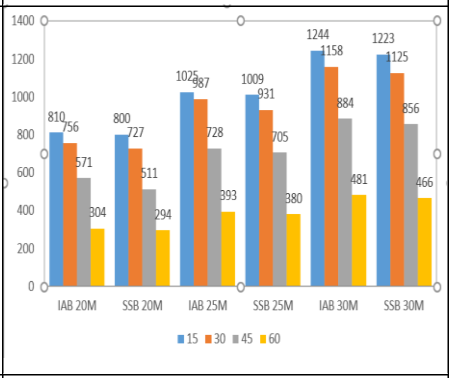
Temp Rise



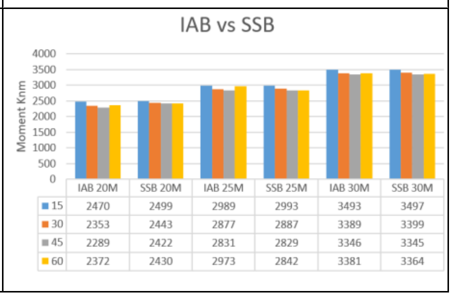
Earth Pressure — Abutment BM



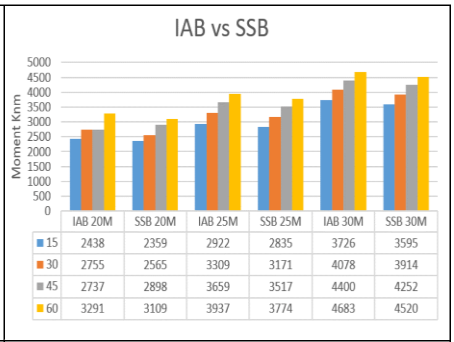
Moving Load Case1 — Abutment BM



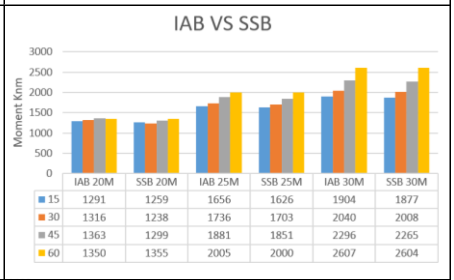
Girder Mid BM



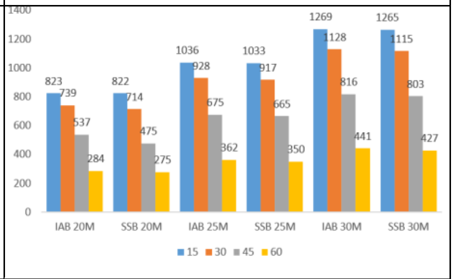
Girder Sup BM



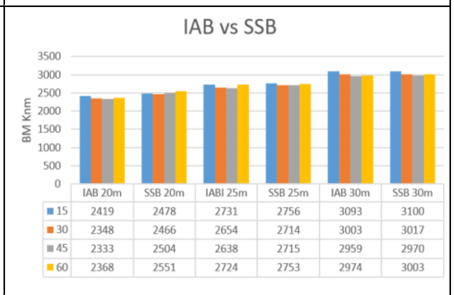
Pier BM



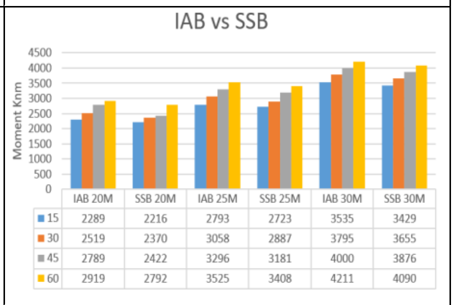
Moving Load Case 2 — Abutment BM



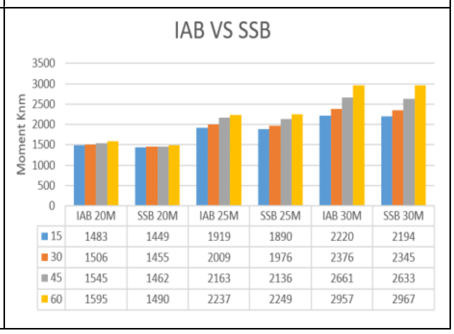
Girder Mid BM



Girder Sup BM



Pier BM



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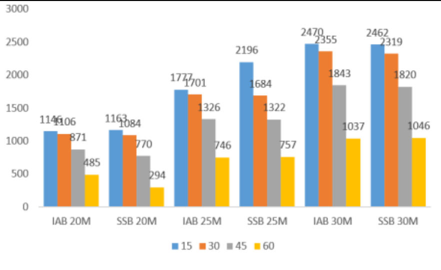
<tr><td rowspan="4">SW</td><td>Abutment BM</td><td>
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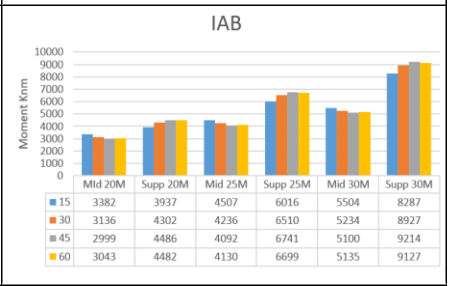
<tr><td>Girder IAB</td><td>
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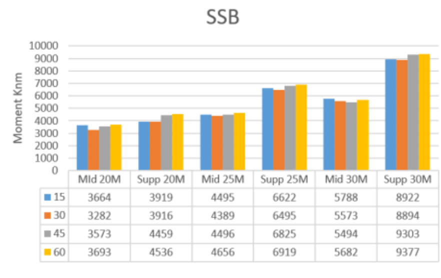
<tr><td>Girder SSB</td><td>
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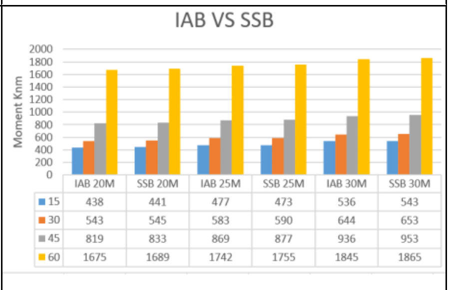
<tr><td>Pier</td><td>
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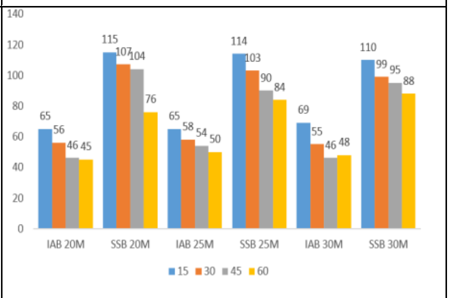
<tr><td>Rsx</td><td>Abutment BM</td><td>
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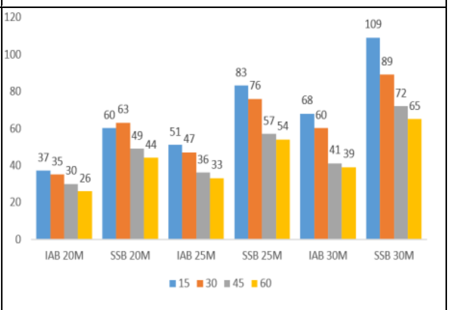
<tr><td>Rsy</td><td>Abutment Bm</td><td>
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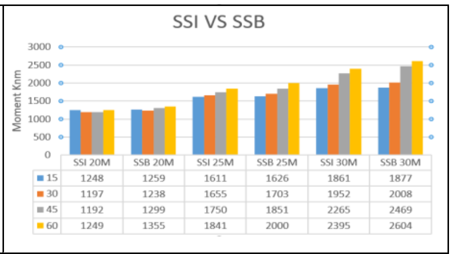
<tr><td rowspan="2">Lateral Pier Spring</td><td>Pier Bm Mv1</td><td>
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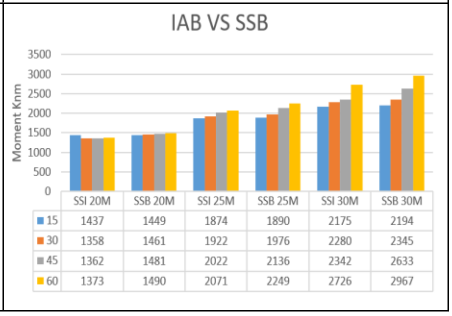
<tr><td>Pier Bm Mv2</td><td>
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8. OBSERVATION

1. The B.M on Abutment due to Earth Pressure, Moving Load, & self weight in Case of IAB is more as com pare to SSB
2. This type of integral bridge is greatly seismic resistant
3. The pier moment due to MV2 & Self-Weight in IAB is less as compared to SSB with the increment in the span length & skew angle, while FDue to MV, the pier moment is more in IAB as compare to SSB.
4. There is decrement in the Moving load case moment with the application of soil structure interaction.
5. The girder due to being continuos in integral bridg, they have less & more support moment due to MV1 & MV2 & more & less Mid Moment due to MV1 & MV2.
6. The girder moment in IAB is less as compared to SsB in case of Self-Weight of structure.
7. The deflection due to moving & Self-Weight is less in IAB as Compared to SSB
8. Negative moment at span should be accounted for in design so detailing of the reinforcement should be done according to the demand at the joint

REFERENCES

[1] Brooke H. Quinn, P., & and Scott A. Civjan, P. P. (April 2016)- Parametric Study on Effects of Pile Orientation in Integral Abutment Bridges. Journal of Bridge Engineering,ASCE.

[2] Dunja Peric´, M. M. (2016)- Thermally induced soil structure interaction in the existing integral bridge. Elsevier, 484-494.

[3] HENG, M. (2018)- The application of semi-continuous post-tension pre-stressing Box Girder Bridges in Africa. 37th Annual Southern African Transport Conference (SATC 2018). Pretoria.

[4] Justin Vander Werff, & Sritharan, A. S. (2015)- Girder Load Distribution for Seismic Design of Integral Bridges. Journal of Bridge Engineering,ASCE.

[5] Mairéad Ní Choine, A. J. (2015)- Comparison between the Seismic Performance of Integral and Jointed Concrete Bridges. Journal of Earthquake Engineering,ASCE, 19:1, 172-191.

[6] Scott A. Civjan, P. P., Bonczar, C., Breña, S. F., DeJong, J., & Crovo, a. D. (January 2007). Integral Abutment Bridge Behavior- Parametric Analysis of a Massachusetts Bridge. Journal of Bridge Engineering,ASCE, 64-70.

[7] Sreya Dhar, K. D. (June 2019) - Seismic Soil Structure Interaction for Integral Abutment Bridges: a Review. Springer, 249-267.

[8] WooSeok Kim, J. A. (January 2010)- Integral abutment bridge response under thermal loading. Elsevier, 1495-1508.

[9] IRC: 6 (2016) Standard Specifications and Code of Practice for Road Bridges Section: 2 Loads and Load Combinations (Seventh Revision)

[10] IRC:SP-115 (2018) Guidelines for Design of Integral Bridges

[11] IRC: 112 (2020) Code of Practice for Concrete Road Bridges

[12] IRC: SP:105 Explanatory Handbook to IRC: 112-2011 Code of Practice for Concrete Road Bridges