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Deflection of the abutment due to the IRC Special Vehicle loading on the approach embankment.

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Abstract: *The road network uses flyovers and bridges to transport men and material. The Junction between the pavement and the bridge is failing in many instances causing a Camel-hump, which is a hazard to the drivers and their heavy-laden vehicles. One of the likely reasons could be the displacement and consolidation of soil at the junction due to the constant deflection of the Abutment due to lateral loads of the traffic. Hence an effort is made to study the deflection of the abutment for the movement of the Special Vehicle over the approach embankments, of various heights while varying the gradients and for different grades of concrete. It has been concluded that as the height of abutment increases the deflection increases irrespective of the grade of concrete used in the design. In case of the abutment of 5m high designed for M25 grade concrete and approach embankment having a gradient of 5%, the significant deflection observed is 5.7 mm while it is 4.5 mm for the same abutment designed for M40 grade of concrete. As the deflection of the abutment is only due to the lateral load of the Special Vehicle load which is sizeable, the deflection of the abutments would be greater with the combined lateral load of the traffic and soil pressure for a given Highway.*

Keywords*: Bridge Abutment, Special Vehicle, Modulus of Elasticity of concrete, grade of concretes M25, M30, M40. Camel-hump. Slow-moving traffic.*

1. INTRODUCTION:

The road network consisting of bridges and flyovers are increasing by leaps and bounds. Whether it is a newly built bridge or old bridges, they are still being used to transport men and material from one place to another. We have inherited bridges from the British Raj, some of which are in a dilapidated condition on one hand and on the other, the Gross weight of the vehicles has been increased with an allowable tolerance of 5%, as per the Gazette (2018) published by Government of India. In this back drop the bridges generally and especially those that are constructed for accessibility to major ports and Heavy Industrial areas need special attention. Since the junctions between the pavements and the bridges are found failing, many scientists have made an effort to study the failures of the junction between the pavement and the bridge. One of the reasons could be the settlement of soil due to dynamic forces of the vehicle load. Harvey E. Wahls (1990) has found that soil plays an important role whether in the foundation of the abutment or in the backfill of the embankment. Qiming Chen et al., (2014) have reported that the differential settlement of the concrete approach slab relative to the bridge is the main cause for the Camel-hump posing hazardous conditions for the vehicle / driver. Brent M. Phares et al., (2013) were of the opinion that the bump could be due to deterioration of the paving notch or expansion joints functioning poorly. The deflection of the abutment due to dynamic load of the heavy vehicles may be one of the causes for the displacement and consolidation of the soil leading to the failure of the junction between the pavement and the bridge.

In case of access to ports and heavy industries, the bridges are designed to carry a Special Vehicle of Gross weight of 3850 kN travelling at a gradual speed of 5kmph as per IRC: 6-(2017). Through the years, different grades of concretes have been used for the construction of bridges, abutments and sub-structure. Therefore, an effort is made to study the deflection of the abutment for various heights from 1 to 5m, for various gradients of the embankment of 2%, 2.5%, 3.3% and 5%; various grades of concrete of M25, M30 and M40. As per, IRC SP 23-(2010) and MORTH (January 2019) notes, 2% gradient is considered for the special vehicle, as the bridges constructed on these roads carry a large volume of slow-moving traffic, for aesthetics and for safety. The 2% gradient is not cost effective in all places. As per IRC: SP23-(2010) for plain terrain the cross-slope ranges from 0 to 10%, while it ranges from 10 to 25% for Rolling Terrain. As per IRC: SP87-(2019) Table 2.8 for Plain and Rolling Terrain, the Ruling gradient is 2.5% and Limiting gradient is 3.3% while as per MORTH (January 2019) Table 4.14 for the Plain and Rolling Terrain, the Limiting gradient is 5%.

2. METHODOLOGY:

An effort is made to study the deflection of the abutment for various heights of 1 to 5m, and for various modulus of elasticity of concrete subjected to Special Vehicle (SV) loading whose Gross weight is 3850kN.

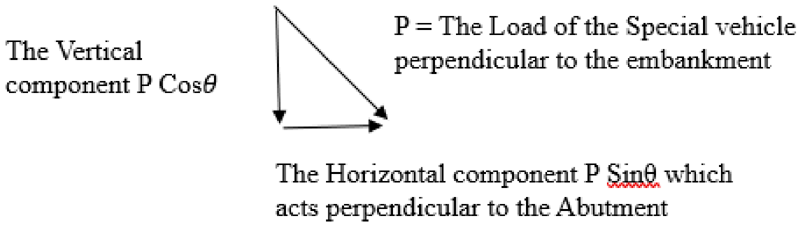

Fig1. Resolving of the forces.

Considering the analogy from vector, as the special vehicle travels along the gradient towards the bridge a component of P Sinθ, acts perpendicular to the abutment. By considering the abutment to act as a Cantilever which is fixed at the base and using the formula from Strength of Materials by R. K. Bansal (2004) for the deflection of the cantilever as

$$y = \frac{wL^4}{8E_c\, I}$$

where: 'w' is the weight per unit metre on the abutment considering it be of unit metre width. The total load 'P' of the Special Vehicle is 3850kN. The Horizontal component of this load is P Sinθ.

For a gradient of 2% of the approach embankment, the angle of gradient θ is 1.146°. Hence P Sinθ = $3850 \times Sin(1.146)$ = 77kN, this load acts laterally on the abutment for a length of 3m (width of the special vehicle). The Special vehicle travels only in the centre of the carriage way with a maximum offset of 300mm from the centre, as per clause 204.5.3 of IRC:6-(2017). The maximum weight per unit metre is considered only for a length of 3.0m hence w = $\frac{77}{3.0}$ =25.67 kN/m.

Similarly, for a gradient of the embankment of 2.5%, θ is 1.4321°,
P Sinθ = $3850 \times Sin(1.4321)$ = 96.22 kN; w = $\frac{96.22}{3.0}$ = 32.07 kN/m

For a gradient of the embankment of 3.3%, θ is 1.8901°,
P Sinθ = $3850 \times Sin(1.8901)$ = 126.98 kN; w = $\frac{126.98}{3.0}$ = 42.33 kN/m

For a gradient of the embankment of 5%, θ is 2.8624°,
P Sinθ = $3850 \times Sin(2.8624)$ = 192.26 kN; w = $\frac{192.26}{3.0}$ = 64.09 kN/m

L is the height of the Abutment which is 1 m, 2 m, 3 m, 4 m and 5m.

E_c is the Modulus of Elasticity of Concrete in MPa = $5000\sqrt{fck}$

For M25 grade of concrete E_c= $5000\sqrt{25} = 25000\ N/mm^2 = 25000 \times 10^6\ N/m^2$

For M30 grade of concrete $E_c = 5000\sqrt{30} = 27386.129 N/\ mm^2 = 27386.13 \times 10^6\ N/m^2$

For M40 grade of concrete $E_c = 5000\sqrt{40} = 31622.7766\ N/mm^2 = 31622.78 \times 10^6\ N/m^2$

I is the moment of Inertia of the abutment considering it to be a cantilever of breadth of b = 1m and uniform depth of the abutment d= 0.60m for bridge abutment of heights 1 to 3m

$I= \frac{b\times d^3}{12} = \frac{1\times 0.6^3}{12} = 0.018\ m^4.$

I is the moment of Inertia of the abutment considering it to be a cantilever of breadth of b = 1m and depth of the abutment d= 0.75m for bridge abutment of heights 4 and 5m

$I= \frac{b\times d^3}{12} = \frac{1\times 0.75^3}{12} = 0.035\ m^4.$

Substituting the above values, the deflection of abutment designed for M25 grade concrete of height 5 m, and having a uniform depth of 0.75 m, considering Special vehicle load on the approach embankment of 2% gradient.

w = 25.67 kN/m

L= 5 m

E_c =25000× $10^6\ m^2$

I = 0.035 m^4

$$y = \frac{wL^4}{8E_c\, I} = \frac{25.67\times 1000\times 5^4}{8\times 25000\times 10^6\times 0.035} = 2.29\times 10^{-3}\ m = 2.29\ mm$$

Similarly, the deflections are calculated for different heights of abutment of 1 m, 2 m, 3 m, 4 m and 5 m for various modulus of elasticity of concrete and for various gradients 2%, 2.5%, 3.3% and 5%.

3. RESULTS AND DISCUSSIONS:

3.1 The deflection of the abutment for heights 1m to 3m having a uniform depth 0.60m and for abutment of heights 4 and 5m having a uniform depth of 0.75 m, due to Special Vehicle lateral loading, on an embankment of gradients 2%, 2.5%, 3.3%, 5% are presented in Fig 2 for M25 grade concrete. From this Fig 2. it is observed that as the height of the abutment increases the deflection increases. As the gradient of the embankment increases the deflection of the abutment increases, irrespective of the height. In case of the abutment of height 5m the deflection is 2.29mm for 2% gradient of the embankment and it is 5.7 mm for the embankment of 5% gradient.

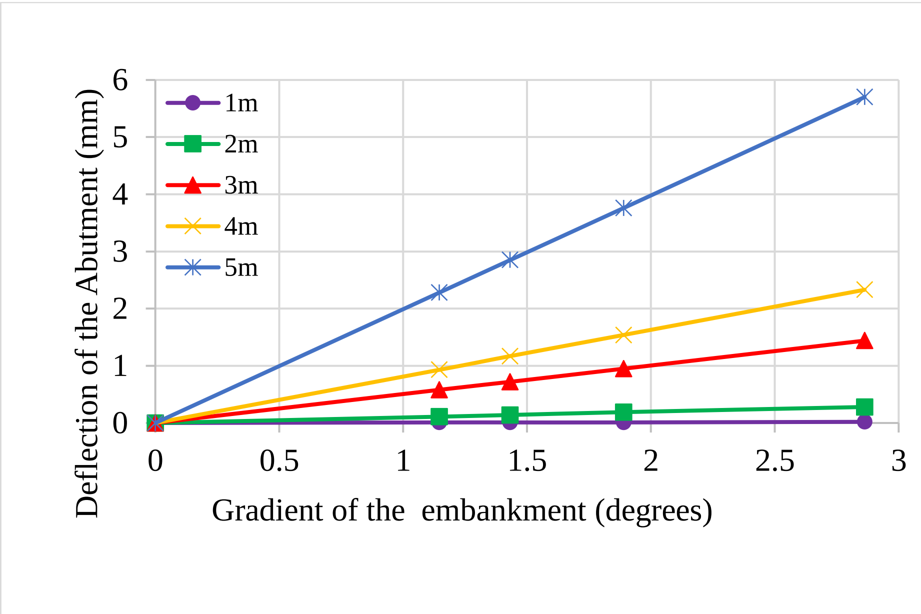

Fig No.2 Deflection of the Abutment designed for M25 grade Concrete due to the lateral load of the Special Vehicle, for various gradients.

3.2 The deflection of the abutment for heights 1m to 3m, of uniform depth 0.60m and for abutment of heights 4 and 5m having a uniform depth of 0.75 m, due to Special Vehicle lateral loading, on an embankment of gradients 2%, 2.5%, 3.3%, 5% are presented in Fig 3 for M30 grade concrete. From the Fig 3. It is observed that as the height of the abutment increases the deflection increases. As the gradient of the embankment increases the deflection of the abutment increases irrespective of the height. In case of the abutment of height 5m, the deflection is 2.08mm for 2% gradient of the embankment and it is 5.2 mm for the embankment of 5% gradient.

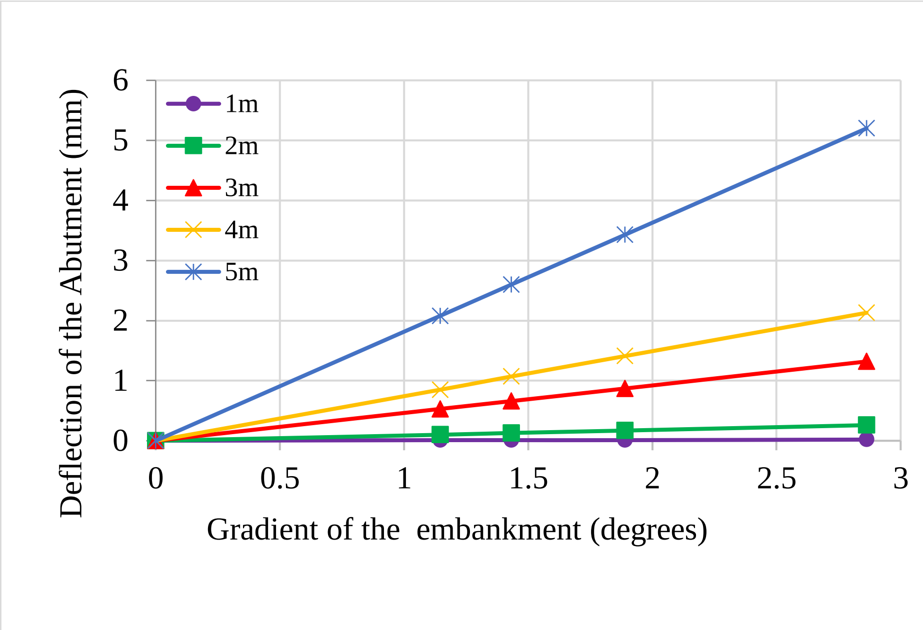

Fig No.3 Deflection of the Abutment designed for M30 grade Concrete due to the lateral load of the Special Vehicle, for various gradients.

3.3 The deflection of the abutment for heights 1m to 3m, of uniform depth 0.60m and for abutment of heights 4 and 5m having a uniform depth of 0.75m, due to Special Vehicle lateral loading, on an embankment of gradients 2%, 2.5%, 3.3%, 5% are presented in Fig 4. for M40 grade concrete. From the Fig 4. It is observed that as the height of the abutment increases, the deflection increases. As the gradient of the embankment increases the deflection of the abutment increases irrespective of the height. In case of the abutment of height 5m, the deflection is 1.8mm for 2% gradient of the embankment and it is 4.5 mm for the embankment of 5% gradient.

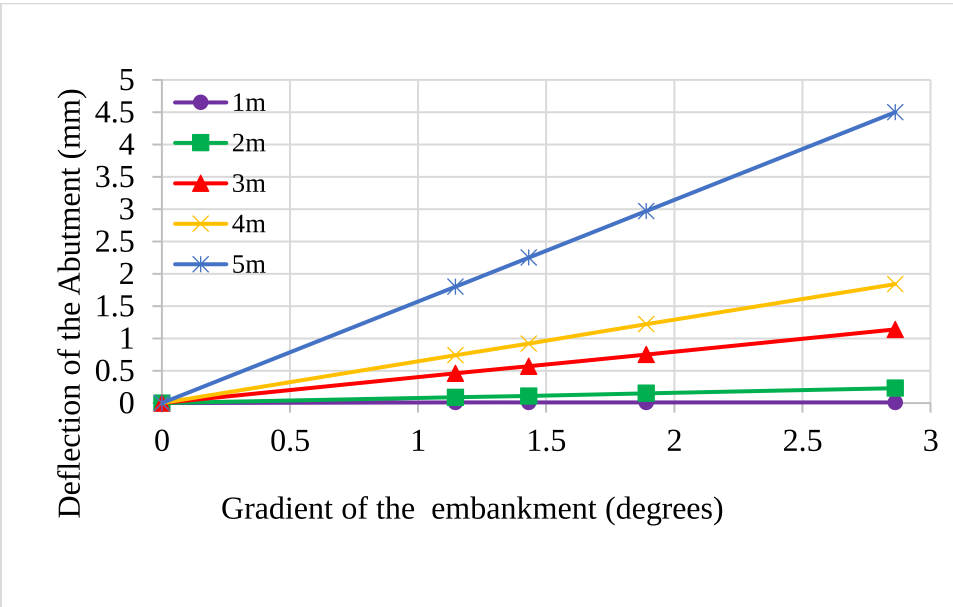

Fig No.4 Deflection of the Abutment designed for M40 grade Concrete due to the lateral load of the Special Vehicle, for various gradients.

4. CONCLUSION:

Based on the study of the deflection of the abutment of heights 1 to 5m for M25, M30 and M40 grades of concrete for the lateral load of the Special Vehicle on the approach embankment for gradients 2%, 2.5%, 3.3% and 5%, the following conclusions are presented.

1. This study substantiates the fact that there is a sizeable deflection of the abutment due to the horizontal component of the Special Vehicle Traffic Load even for gradients as low as 2%.
2. It can be concluded that the deflection of the abutment is inversely proportional to the modulus of elasticity of concrete. In case of the abutment of height 5m for a gradient 3.3% the deflection of the abutment of grade M25 is 3.76mm, while it is 3.44mm of grade M30 and 2.97 mm of grade M40. Hence there is a marginal decrease in the deflection of the abutment for the same height, gradient, and lateral load; as the grade of concrete is increased.
3. It can also be concluded that the steeper the gradient of the embankment the higher the deflection of the abutment subjected to the Special Vehicle loading.
4. Even for higher grade M40 there is a sizeable deflection of 4.5 mm for the abutment of height 5m when gradient of the embankment is 5%.
5. As the deflection of the abutment is only due to the lateral load component of the Special Vehicle load which is sizeable, the deflection of the abutments would be greater with the combined lateral loads of the traffic and soil pressure for any Highway.
6. The higher the deflection of the abutment, greater the displacement of soil, hence it can be concluded that in case of lower gradients, it takes longer time for the soil to fail and create a camel-hump while it takes shorter time for the camel-hump to be created in case of embankment for higher gradients.

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