



Influence of Lateral Loads due to Vehicular Traffic on the Bridge Abutments

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Abstract: The Bridges and flyovers have become a necessary means of connectivity for Men and material between places. The junctions between Bridge and Pavement are failing frequently causing hazardous situations. The primary cause is the failure of back-fill rendering the Bridge inaccessible, causing long detours and escalation in operational costs. An attempt has been made to study the deflection of the abutment for heights 1 m to 4 m high and 16.6 m wide road, for a sample traffic load taken at a Toll gate for a National Highway, Plain/Rolling Terrain as per Ministry of Road Transport & Highways, India; for the Ruling gradient of 3.3%, for the Limiting gradient of 5% and for the Exceptional gradient of 6.7% of the approach embankments and the results are tabulated. The initial deflections though of relatively smaller magnitude can get accumulated resulting into higher magnitude of deflections with the passage of time. The deflection caused by the impact of the lateral load due to traffic could be one of the main reasons for the failure of junctions between the Bridge and the Pavement.

Keywords: Approach embankment, Approach Slab, Back-fill, Gradient, Traffic Load, lateral load, deflection.

1. Introduction: The bridges are usually designed by qualified Engineers, but the construction of the junction between the bridge and the Pavement and the kind of back-filling to be used for the approach embankments and execution of the bridge approach is left to the hands of semi-skilled or in some cases unskilled labour contractors in India. David J White *et al.*, (2007) [3], have reported that the junctions between Bridge and Pavement are failing frequently, causing hazardous situations. The Primary cause is due to the sinking of back-fill rendering the Bridges inaccessible, causing disruptions to vehicular traffic at large and escalating operational costs.

It is a known fact that the back-fill near the Abutments gets consolidated over a period of time and either forms a ditch or a Camel's back-like situation. In case of back-fill resting on black cotton soil and / or cohesive soil, the settlement is intense, and varies with the season. In order to avoid such settlement, after many years of research, the approach slab was made mandatory over the back-fill, partly resting on the Abutment and the remaining resting on the Back-fill. Hj. Mohd Irdus B *et al.*, (2013) [6] have stated that the introduction of approach slabs by many engineers has reduced some of the problems at the interface sections but only for a short period of time. Effort is made to study the deflection of the abutment due to lateral vehicular traffic load on the approach embankments of different gradients which may be one of the reasons for the failure of the back-fill.

2. Some of the implications of the failure of the Approach slab

Carlos Zanuy *et al.*, (2013) [2] have stated that the approach slab was built to have a smooth transition from the Bridge to the Pavement. In spite of this fact, the approach slab was not usually designed considering this function but are built following common practice rules or simple guidelines that do not account for the real conditions to which they are subjected to. The long-term performance of approach slab is often deficient, requiring high maintenance or repair cost.

Abdelrahman *et al.*, (2018) [5] have reported that approach Slabs do not prevent the approach embankment from settlement. The failure of an approach slab not only causes inconvenience to the commuters requiring detours, but also incurs huge maintenance costs to the local municipalities and the

Highway authorities. From reviews of budgets vs actuals, it has been noticed that instead of making necessary investments on new roads, a large chunk of funds is going into the maintenance of existing approach slabs and approach embankments.

As mentioned earlier, Qiming Chen *et al.*, (2014) [10] have reported that the camel-hump back or bump at the end of the bridge, mainly resulted from the differential settlement of the concrete approach slab relative to the bridge deck which poses safety hazard as well as being disruptive to the (vehicle driver) motorist. This condition causes accidents and eventually makes the bridge inaccessible. These conditions of the Pavement are a nightmare to the motorists and more so for multi-axle heavy trucks.

3.The causes for the poor performance of the approach slab

The following are some of the causes for the poor performance or failure of the approach slab resting over the embankment:

- David J White *et al.*, (2007) [3] have discussed that (i) the Subsurface void formation caused by water infiltration through unsealed expansion joints, (ii) collapse and erosion of the granular backfill, and (iii) poor construction practices could be one of the causes for approach slab failure.
- It has been noticed that the approach slab failure also occurs due to the movement of abutment caused by the soil pressure from the back-fill. The approach slab failure is also due to change in alignment with the bridge as backfill usually gets eroded due to heavy rains or improper drainage facility behind the abutment.
- Brent M.Phares *et al.*, (2013) [1] are of the opinion that the bump is typically attributed to the settlement of soil under the approach slab, deterioration of the paving notch or poorly functioning expansion joints.
- It may also be due to the lateral load of the vehicular traffic on the soil, whose pressure on the abutment is causing it to deflect and leading to failure of back-fill.

4. Deflection of the Abutment due to traffic load.

The deflection caused due to the horizontal component of the traffic load on the soil is studied for various gradients and heights of the embankment.

Sample data is collected from the Toll gate for calculating Cumulative Vehicle Load from a report entitled “Request for Proposal for Independent Engineer during Operation & Maintenance” published by the National Highways Authority of India, in the year 2018 [12]. The approximate number of Vehicles at the Toll gate for a Single trip for ‘four lanes’ Road is 43,556.

There are approximately 43,556 vehicles per month using a particular Highway,

Table I. The vehicular weight Calculation on 4-lane Highway

S.No.	Name of the vehicle	No of vehicles	approximate weight of vehicle (kN)	Total weight of vehicles (kN)
1	Car	4289	35	150115
2	LCV *	1399	52.5	73447.5
3	Bus	2349	180	422820
4	Truck	1566	190	297540
5	3 Axle	15127	285	4311195
6	MAV **	18790	490	9207100
7	Over Sized ***	36	550	19,800
Total Weight of the Vehicles				1.44,82,018

* LCV- Light Commercial Vehicle

** MAV- Multi-Axle Vehicle

*** Over Sized Vehicle- To be capped at 550kN as per Annexure -B of No. RT11028/11/2017-MVL; Ministry of Road Transport & Highways (Transport Division).[11]

The approximate total weight of the combined vehicles using a particular Highway per month is 1,44,82,018 kN.

The approximate total weight per day is $\frac{14482018}{30} = 482734$ kN per day

The approximate load per hour is $= \frac{482734}{24} = 20113.92$ kN/hr.

The approximate load $P = 20114$ kN/hour

Some of the gradients 'θ' as per IRC: SP:87-2019, [7] Table 2.8 and MORTH Pocket Book for Highway Engineers Table 4.14, are considered for the Plain/Rolling Terrain., i.e. for Ruling gradient 3.3% = 1.8901°, for Limiting gradient 5% = 2.8624° and for Exceptional gradient 6.7% = 3.8331°.

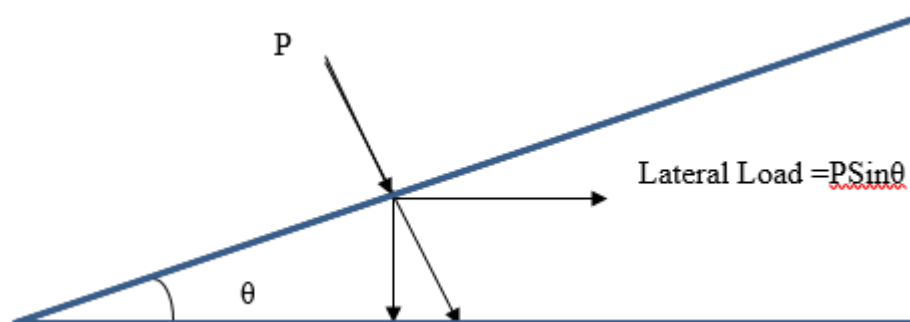


Fig1. The schematic drawing of the approach embankment

Table II. The horizontal force on the abutment for different gradients

S.No	Gradient θ (Degrees)	Force P (kN/hr)	Horizontal Force $P \sin \theta$ (kN/hr)
1	0	20114	0
2	1.8901	20114	663.41
3	2.8624	20114	1004.44
4	3.8331	20114	1344.63

The height of the Abutment for this study is considered from 1m to 4m.

For the Abutment of height 1m and a gradient of 1.8901° and assuming the width of the carriage way as 16.6m as per IRC6:2017 [8] table 6A for a 4 lane.

The pressure on the abutment for a 16.6m wide road and 1m high Abutment, for a gradient of 1.8901° is $\frac{663.41}{16.6} = 39.964$ kN/m/hour.

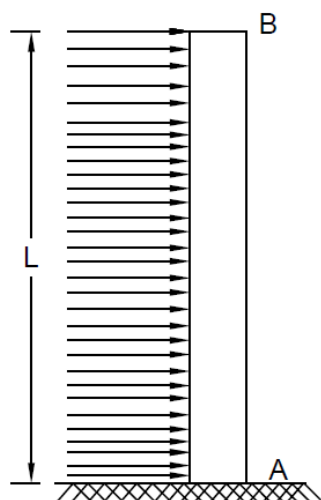
assuming the abutment to be a cantilever of 0.5m width and length 1m.

The moment of Inertia of the cantilever considering breadth(b) as 1m and depth (d) as 0.5m

$$\text{Moment of Inertia} = \frac{b \times d^3}{12} \quad (1)$$

$$I = \frac{b \times d^3}{12} = \frac{1.0 \times 0.5^3}{12} = 0.014167 \text{ m}^4.$$

considering the grade of concrete as M30 grade of Concrete. The Modulus of Elasticity of Concrete $E_c = 5000 \sqrt{f_{ck}} = 27386.13 \text{ N/mm}^2 = 27386.13 \times 10^6 \text{ N/m}^2$.



assuming the abutment to be a cantilever of $L=1\text{m}$., the deflection of the abutment with the uniformly distributed load of 39.964kN/m/hr for gradient of 1.8901° only due to the horizontal component of the traffic load apart from the Soil Pressure is

$$y_B = \frac{wL^4}{8E_cI} \quad (2)$$

$$= \frac{39.964 \times 1000 \times 1^4}{8 \times 27386.13 \times 10^6 \times 0.0104167}$$

$$= 0.000017511\text{m per hour} = 0.017511\text{mm per hour}$$

Fig2. The abutment of length L m.

The calculations for deflection of the Abutment of height 1m are shown in the Table 3, for gradients $3.3\% = 1.8901^\circ$, $5\% = 2.8624^\circ$ and $6.7\% = 3.8331^\circ$ of the approach embankment.

Table III. The deflection of the Abutment for a height of 1m					
S.No	Approach embankment gradient θ in degrees	Horizontal force $P\sin\theta$ (kN/hr)	Pressure on the abutment (kN/m/hr)	Deflection of the abutment (m/hr)	Deflection of the abutment (mm/hr)
1	1.8901°	663.41	39.964	$1.75115\text{E-}05$	0.0175
2	2.8624°	1004.443	60.509	$2.65136\text{E-}05$	0.027
3	3.8331°	1344.627	81.002	$3.54931\text{E-}05$	0.035

The calculations for deflection of the Abutment of height 2m are shown in the Table 4, for gradients $3.3\% = 1.8901^\circ$, $5\% = 2.8324^\circ$ and $6.7\% = 3.8331^\circ$ of the approach embankment

Table IV. The deflection of the Abutment for a height of 2m					
S.No	Approach embankment gradient θ in degrees	Horizontal force $P\sin\theta$ (kN/hr)	Pressure on the abutment (kN/m/hr)	Deflection of the abutment (m/hr)	Deflection of the abutment (mm/hr)
1	1.8901°	663.41	39.964	0.000280185	0.28
2	2.8624°	1004.44	60.509	0.000424217	0.424
3	3.8331°	1344.63	81.002	0.00056789	0.568

The calculations for deflection of the Abutment of height 3m are shown in the Table 5, for gradients $3.3\% = 1.8901^\circ$, $5\% = 2.8324^\circ$ and $6.7\% = 3.8331^\circ$ of the approach embankment.

Table V. The deflection of the Abutment for a height of 3m

S.No	Approach embankment gradient θ in degrees	Horizontal force $P\sin\theta$ (kN/hr)	Pressure on the abutment (kN/m/hr)	Deflection of the abutment (m/hr)	Deflection of the abutment (mm/hr)
1	1.8901°	663.41	39.964	0.001418435	1.418
2	2.8624°	1004.44	60.509	0.002147598	2.148
3	3.8331°	1344.63	81.002	0.002874945	2.875

The calculations for deflection of the Abutment of height 4m are shown in the Table 6, for gradients 3.3% = 1.8901°, 5% = 2.8624° and 6.7% = 3.8331° of the approach embankment.

Table VI. The deflection of the Abutment for a height of 4m

S.No	Approach embankment gradient θ in degrees	Horizontal force $P\sin\theta$ (kN/hr)	Pressure on the abutment (kN/m/hr)	Deflection of the abutment (m/hr)	Deflection of the abutment (mm/hr)
1	1.8901°	663.41	39.964	0.002594302	2.594
2	2.8624°	1004.44	60.509	0.003927934	3.928
3	3.8331°	1344.63	81.002	0.005258244	5.258

The Combined graph showing the deflection of the Abutment for heights 1, 2, 3 and 4m and for gradients 3.3% = 1.8901°, 5% = 2.8624° and 6.7% = 3.8331° of the approach embankment.

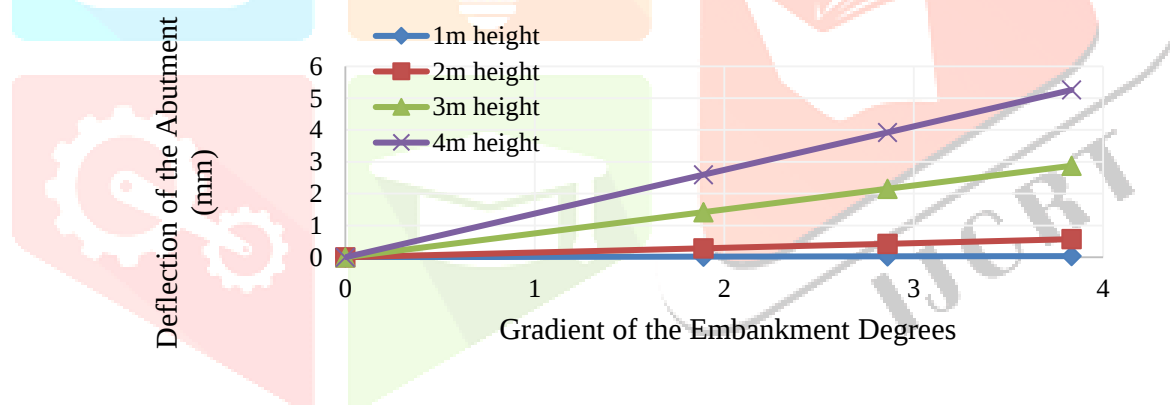


Fig. 3. The comparative variation of deflection of Abutment for heights 1 m to 4m

5. Conclusion: The following are some of the conclusions drawn from the study of the Influence of Lateral Loads due to Vehicular Traffic on the Bridge Abutment.

1. It can be concluded the steeper the gradient the higher the lateral force of the vehicular traffic load on the soil and hence the increase in deflection of the abutment.
2. As the height of the abutment increases for the same gradient the deflection increases.
3. The lateral component of the vehicular traffic load is one of the main reasons for the disturbance of soil in the embankment, whose pressure on the abutment is causing sizeable deflection. This soil is continuously re-aligning itself and creating voids even under the Approach slab. These voids are also responsible for the failing of the Approach slab.
4. The lateral component of the vehicular traffic load also needs to be taken cognizant of, for designing the Bridge abutment.

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