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Reaction of Fluctuate Embankment Fill on RCC Box type Cross Drain

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Abstract

The cross drain (CD) structure near to upcoming over bridge is falling under upcoming approaches and structure is loaded due to additional fill. The aim of this paper is to compare the overburden effect (up to 6m) on the CD by using two dimensional analysis in STAAD_Pro_V8i and excel spreadsheet. Thirteen models of 1.5m x 1.5m size of CD are analyzed and study the effect of an overburden on the axial and shear force, safe bearing capacity (SBC), sagging and moments and steel requirement .All stability check as per Indian Road Congress standard are satisfied. It is seen that the uniform 0.2m thickens is required for all component of CD up to 6m overburden. Also found that the required quantity of steel is about 77 kg /m^3 for no cushion, 50 to 76 kg/m^3 for the cushion of 0.5 m to 5.5 m and 80 kg/m^3 at 6 m cushion to resist all the induced forces and moments. It is observed that the requirement of SBC at a 0 m and 6 m cushion are 70 kN/m^2 to150 kN/m^2 respectively. It is noted that ,if a height of the cushion is an increase about a 1m then live load distributed over the large area and which caused a reduction in mid span moment at certain extent .However, more than 1m depth, caused more mid span moment due to superimposed load. It is finally concluded that an effect of depth of the cushion is governing after 5m .That means no cushion case is performed as same there who have 5m depth of the cushion in identical SBC.

Keywords: overburden, cross -drain, safe bearing capacity, axial force, sagging moment, hogging moment.

INTRODUCTION

Cross-drain (CD) structures is the important part of the infrastructure. The CD structure are used below road embankment to pass the water course like streams and utilities across the road. The CD can be used to balance the flood water on left side and right side of road embankment to reduce water level on either side of road .The structural configuration of CD structure may be box type, slab& abutment or arch type. In this study the box type CD structure are considered. The box type CD can be construct with any size .In this study 1cell * 1.5m * 1.5m are considered.

The research was started on rigid and flexible box culvert At Iowa State. The load on culvert studied by Spangler [10]. The span of 1.02m culvert were tested under 6.10m of cushion and observed the loads. The load on top of box culvert was approximately 1.92 times of the soil column load above the culvert. .The Richard [9] studied the vertical force on RCC box structure below high fill, where a high fill is define as the width of box culvert less than the height of the overburden on the culvert. The pressure due to the soil overburden is much lesser than the roof pressure on box culverts. B.N. Sinha & R.P. Sharma [1] are studied the reinforce cement concrete (RCC) box culvert of size 1cell * 3m* 3m with and without cushion. The moment and shear force are come out form staad _pro software are compared with manual method of design. This moment and Shear force come out from both method is nearly same. Filed test and numerical analysis were conducted by Baoguo Chen [3] to check the reaction of soil parameter on the structural rectitude under large cushion on reinforce concrete culverts. The Failure to subgrade layer below the bottom slab of culvert are damaged not only due to high fill above culvert but also the width of foundation and depth of foundation and consolidation of soil below the foundation. The proper ground improvement can save the structural from damage. The theoretical method used to calculate the pressure and compered with experiment results by Bao-guo Chen[2].The Variations in settlement and foundation pressure were analyzed. The Finite element model (FEM) formed by considering the elastic modulus of soil below the foundation, angle of inclination of trench , dimension of box culvert, Backfill material properties , cushion over the culvert and vertical load due to fill .His research conclude that with the certain height of fill ,the soil arch are formed ,but it was not stable. The effect of a buried structure under embankments fill and static surface load in service condition are analyzed by Karinski [7].The soil interaction with buried culvert are model and relative moment between structure as rigid body and the free area .The effect of roof displacement is also considered in Model. The field experiment carried out by Bennett [4] on box culvert under high fill. The important finding of his research that the vertical load due high fill is not depend on the ratio of depth of embankment to the culvert width. The effect of expanded polystyrene blocks material in high embankment were studied by Gu An-quan [5].He validated theoretical calculation with full-scale experimental model and concluded that there is reduction of vertical load due to this material . The culvert dimension and influence of installation did not considered by Karinski [7], Bennett [4], and Gu An-quan [5] in their studies. The based on model test, the height of embankment on culvert in trench were studied by Yang and hang [11].His showed the vertical force variation on top slab of culvert due to high fill. Kim and Yoo [8] and Kang [6]

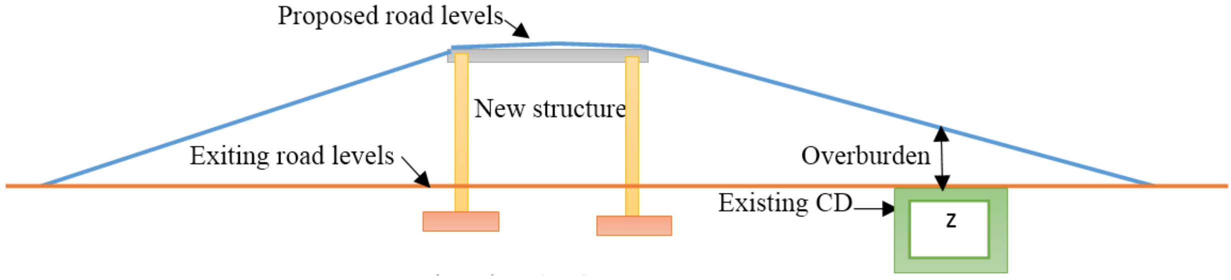

Figure 1. Arrangement of proposed and existing structure

model the soil structure interaction in FEM. The effect of culvert dimension did not investigate by him in his studies

To reduce the road accident National Highway Authority of India (NHAI) are taken the decision to construct the over bridge at black spot location. As shows in fig1, the existing structure are coming under the approach of proposed structure. The FRL of highway get raise to achieve the 5.5m vertical clearance at new structure. The additional fill called as overburden come on the existing CD box structure.

The existing structure is safe for additional load or not, how much cushion is allowed to avoid the reconstruction. Considering to situation, the model of structure with difference cushion can be made more realistically. The aim of this paper is to compare the effect of overburden loading on the cross-drain culvert by using two dimensional analysis and excel spread sheet

DESIGN VARIABLES

The six design variables are considered for modeling of the box type cross drain as shows in Fig. 2. These variables contain the thickness of top slab (T1), the thickness of bottom slab (T2), the wall thickness (T3), the cushion over culvert (T4), safe bearing capacity (SBC) (T5), the requirement of steel per kg/cum (T6). The Single Cell Box type CD is model for six lane carriageway. The overall width of box is 33.50m i.e. both side 3 lane carriageway (10.5m)plus both side paved shoulder (2m)and earthen shoulder (1.5m) plus median width 4.5m plus both side shy way distance 0.5m. The overall width on both side increase with cushion by 1:2 slope and it is 57.5m for maximum cushion 6m.The horizontal clear opening 1.5m shall be measure from inner face to inner face of outer wall and vertical clearance opening 1.5m shall be measure from top of bottom slab to bottom of top slab as shows in figure - 2. The road crust .i.e. bituminous concrete (BC) of 65mm, dense bituminous macadam (DBM), Water bound macadam (WMM), granular sub-base (GSB) and embankment are consider as cushion over the box (T6) .The cushion is increase over top slab by the increment of 0.5m and restricted up to 6m The density of the BC and all other material are 22kN/m3 and 20kN/m3 respectively.

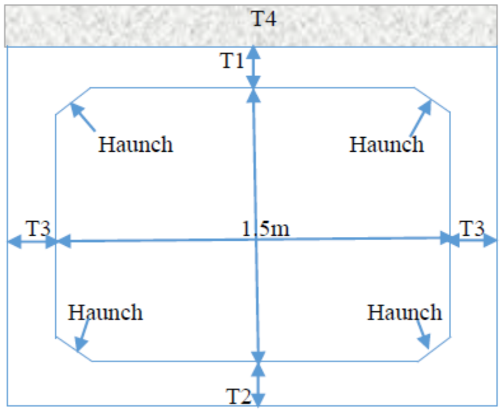

Figure 2. A box type cross-drain with design variables

The box structure are exposed surrounding environment during the service life .There environment conditions will change from area to area in a country .The very sever condition for moderate humidity are considered in this research. According to environment condition, clear cover 50 mm for top slab & inner surface of box and clear cover is considered as 75 mm for bottom slab & outer sides of walls.

DESIGN PROCESS

The clear span and clear vertical vent is 1.5m and 1.5m respectively .The triangular haunch are provided at the junction of top slab and outer wall, bottom slab and outer wall .The size of triangular haunch is 0.150m on both side .The wall thickness fixed on assumption i.e. thickness of top slab, wall, and bottom slab clear span /7.The thicknesses for selected case are 0.2m for all component of box type drain and it is change as per the design requirement .The trial and error method are used to optimize the section. The cross-section area and section modules are find out at the mid span, support, mid and end of haunches. The centerline model are generator in STAAD_PRO software .The nodes are provided where the sectional area change. For vertical wall the section are marked as A, B, C, D, E at Face of top slab, end of hunch, mid span of wall, End of Haunch, face of bottom slab respectively. Similarly for top slab section F, G, H at face of wall, end of haunch and mid span of top slab respectively. The section I, J, K at face of wall, end of haunch and mid span of bottom slab respectively. The figure 3(a) are given the clear idea about the section .The node 1 , 7 & 18, 24 are placed at center of wall & top slab bottom slab junction , similarly node 4, 12, 13 & 21 are provide the mid span of top slab, Mid span of wall and mid span of bottom slab respectively and same way the node 2 & 6, 8 & 9, 16 & 17 and 19 & 23 are provided at middle of haunches at four corner as mention in figure 3.

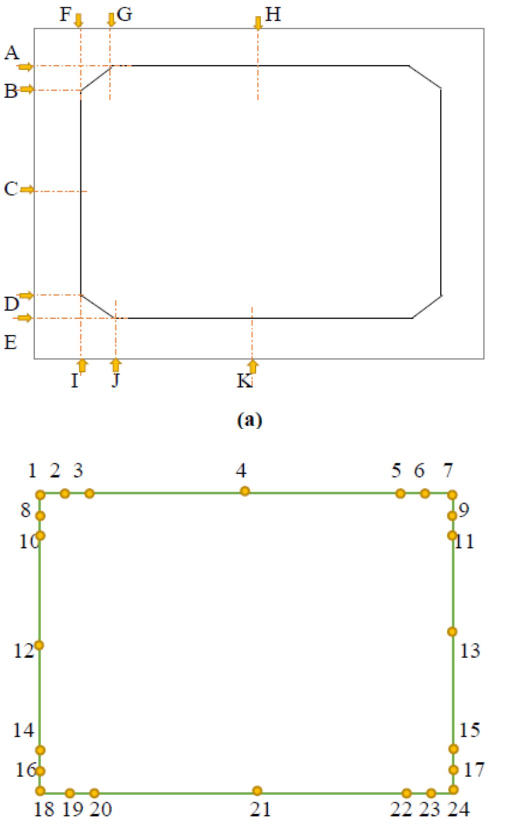

Figure 3. According to cross-section area (a) Section marking, and (b)Node marking

The Model is prepared in STAAD _PRO according to figure 3(b). The section properties are assign to respective section. The self-weight are calculated automatically in software by considering the density of 24kN/m^3. The superimposed dead load include the overburdened due to fill on top slab, railing and wearing coat. All this load are applied over top slab a software. The Coefficient of Earth Pressure as 0.50 when soil at rest & Density of Earth as 20 kN/m^3 for Dry condition. The earth pressure at rest with dry density of earth is considered to produce maximum earth pressure. The allowable safe bearing capacity (q) is considered 150kN/m^2. Factor of safety for allowable soil Pressure(s) is 2.5 and allowable deflection (δ) considered 0.25.

$$Modulus\ of\ subgrade\ reaction\ (Msgr) = q \times s / \delta$$

The modules of subgrade reaction is calculated according above equation is 15000kN/m^2 per unit width .The Spring constants (K_s) are calculated as per formula given below

$$Ks = Msgr \times ds \times wu$$

Where, d_s is the distance between two node and w_u is the unit width.

The complete model are prepared and load applied over the appropriate section as show in figure 4.

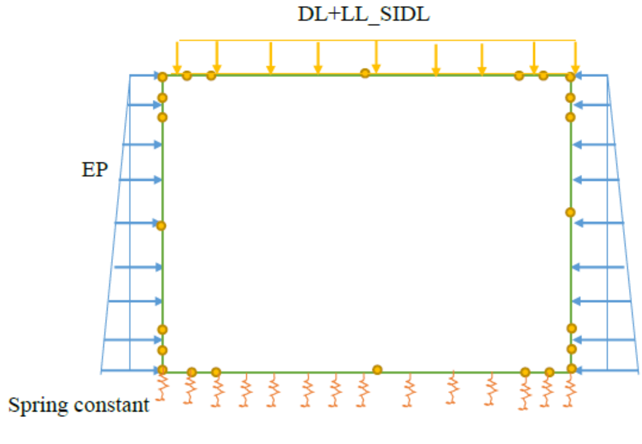

Figure 4. STAAD_PRO Modelling and loading

The live load analysis has carried out for Class A, class 70R tracked, class 70R wheeled & 70R boggie load specified in IRC6:2014. The various combinations having possibilities of producing worst shear force and bending moments in the elements of RCC box type structure inclusive of the Impact factor. Live Load positions are identified for maximum bending moments at different sections and corresponding load intensities per meter width are evaluated according to effective width method as explained in IRC: 112-2011 Annexure: B-3. Equation (1) is used to calculate the effect width.

$$beff = \alpha \times a(1 - \frac{a}{l0}) + b1$$

Where beff is the effective width if sab on which the load acts, l0 is the effective span as indicated in section B3-4 of IRC 112-2011, 'a' is the distance of the center of gravity of the concentrated load from the nearer support , b1 the breadth of concentration area of the load i.e. the dimensions of the tyre contact area over the road surface of the slab in a direction at right angles to the span plus twice the thickness of the wearing coat or the surface finish above the structural slab .

These considered combinations of vehicles' wheel loads have been dispersed in transverse as well as longitudinal direction according to IRC: 112 – 2011 [12].The live load analysis are run in STAAD.Pro software .The partial safety factors for different load combinations considered for the analysis are as per IRC: 6 - 2014 Annex B[15] as per Table: 3.2, Table: 3.3 and Table 3.4 for ULS, SLS and Base Pressure respectively. The load due to self-weight , weight of cushion and earth pressure including the associated effects of Vehicular Live load are combined in excel sheet and partial safety factors mentioned above are applied and run in STAAD. The impact factor are consider while run the vehicles load in STAAD. Results are extracted from STAAD files and all the component of box type cross-drain shown in figure 2 are checked for ULS (ultimate Limit State) ,Stresses in concrete and steel and Crack width for SLS (Serviceability Limit State) as per provision of IRC: 112 – 2011.

The 2D analysis of box structure is carried out by considering a slice of unit meter width. The box has been analyzed for its own weight, superimposed load due to cushion over the box, earth pressure on side wall and vehicular live load coming over top of cushion .The 2D modeling done in STAAD. Pro software and design are carried out in excel spread sheet. The Indian road congress (IRC) standard are used in analysis and design.

RESULTS AND DISCUSSION

The envelope of the all the load inclusive of dead load and live load take to find out the maximum result. The maximum axial force are observed in side wall. The critical shear force are found in bottom slab and top slab near to face side wall. The location of maximum hogging moment are at face of wall in case of top slab, face of top and bottom slab in case of side wall and face of wall in case of bottom slab. Similarly the location of maximum sagging moment are at mid span of top slab, side wall and bottom slab. The summery of critical axial and shear forces, maximum sagging and hogging moment are represent graphical format. The regression value is for all the forces are greater than 0.9 .The linear and polynomial equation are used to correlate cushion and various force sated as earlier

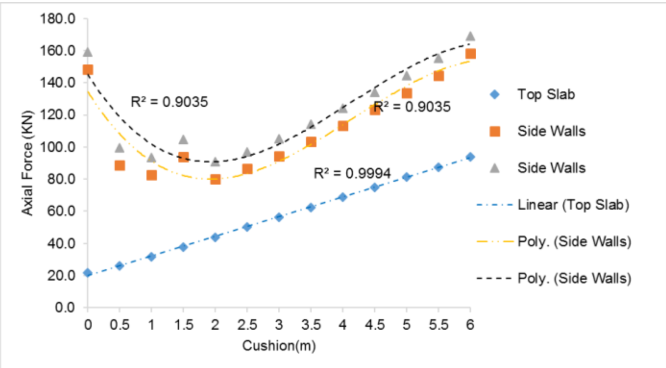

Figure 5. Comparison of axial force Vs cushion in CD box type structure

The axial force variation in different component of box type CS are shows in figure 5. In top slab the axial force for linearly get up with increase in cushion. In top and bottom slab, the axial force for zero overburden is higher .The value to axial force in top and bottom slab get down up to the 2m overburden. It means, the vehicle load are govern in case of minimum cushion. The axial force for minimum cushion and 5.5m cushion are nearly same.
The Shear force variation in different component of box type CS are shows in figure 6. In side wall the shear force for linearly get up with increase in cushion. In top and bottom slab, the shear force for zero overburden is higher .The value to shear force in top and bottom slab get reduce up to the 2m overburden. It means, the vehicle load are govern in case of minimum cushion. The shear force for minimum cushion and 5.0m cushion are nearly same.

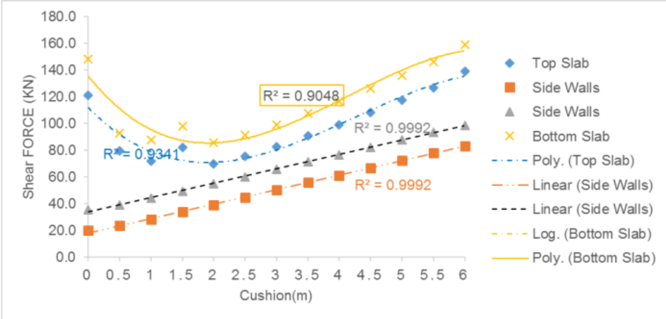

Figure 7. Comparison of shear force Vs cushion in CD box type structure

The hogging moment variation in different component of box type CS are shows in figure 7. In top slab the hogging bending moment is linearly get up with increase in cushion. In side wall and bottom slab, the hogging moment for zero overburden is higher .The value to hogging moment in top and bottom slab get reduce up to the 2m overburden. It means, the vehicle load are govern in case of minimum cushion. The hogging moment for minimum cushion and 3.5m cushion are nearly same.

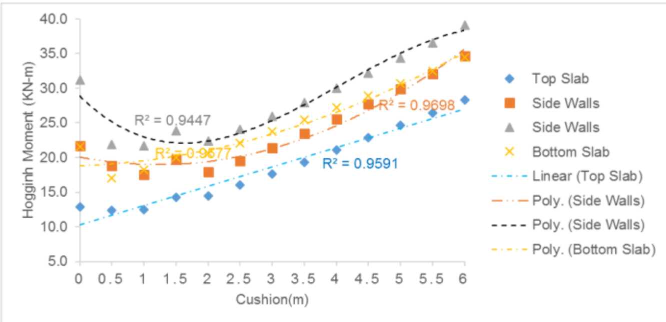

Figure 6. Comparison of Hogging bending moment Vs cushion in CD box type structure

The Sagging moment variation in different component of box type CS are shows in figure 8. In side wall the mid span bending moment is linearly get up with increase in cushion. In top and bottom slab, the mid span moment for zero overburden is higher .The value to sagging moment in top and bottom slab get reduce up to the 2m overburden. It means, the vehicle load are govern in case of minimum cushion. The hogging moment for minimum cushion and 3.5m cushion are nearly same.

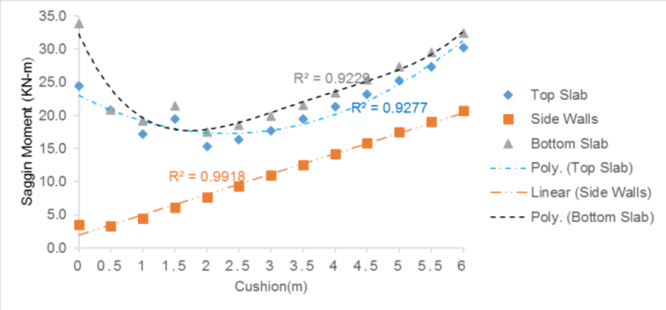

Figure 8. Comparison of sagging bending moment Vs cushion in CD box type structure

All the sections from Section 'A' to Section K' as shown in figure 2(a) are design for ULS (ultimate Limit State) and check for Stresses and Crack width for SLS (Serviceability Limit State) as per provision of IRC: 112 - 2011 (including ERRATA and latest amendments).The SBC requirement and steel indices Kg/cum are summarized in table 1.

Table 1. Safe bearing capacity and concrete steel indices

Sr. No	L (m)	H(m)	T4 (m)	T1 (m)	T2 (m)	T3 (m)	T5 (kN/ m2)	Indices	
								Concrete (m3/m2)	T6 (kg/Cum)
1	1.5	1.5	0	0.2	0.2	0.2	70	0.76	77
2	1.5	1.5	0.5	0.2	0.2	0.2	70	0.76	59
3	1.5	1.5	1	0.2	0.2	0.2	80	0.76	58
4	1.5	1.5	1.5	0.2	0.2	0.2	90	0.76	59
5	1.5	1.5	2	0.2	0.2	0.2	90	0.76	58
6	1.5	1.5	2.5	0.2	0.2	0.2	100	0.76	61
7	1.5	1.5	3	0.2	0.2	0.2	110	0.76	63
8	1.5	1.5	3.5	0.2	0.2	0.2	120	0.76	64
9	1.5	1.5	4	0.2	0.2	0.2	120	0.76	66
10	1.5	1.5	4.5	0.2	0.2	0.2	130	0.76	70
11	1.5	1.5	5	0.2	0.2	0.2	140	0.76	74
12	1.5	1.5	5.5	0.2	0.2	0.2	140	0.76	76
13	1.5	1.5	6	0.2	0.2	0.2	150	0.76	80

The grade concrete and steel used in design is M25 and Fe 500D respectively .The 0.2m thickness for top slab thickness, Side wall thickness and bottom slab thickness are satisfied the stress in concrete check .The Crack width in service condition and stresses in steel check are satisfied with variation by adjusting the reinforcement in section .The required Safe bearing capacity (SBC) is less than and equal to Available (Assume) SBC. The Graph below give the clear idea for effect of cushion over various parameter discus earlier.

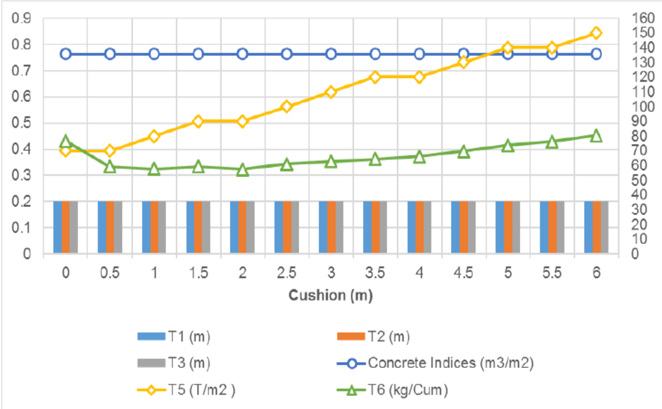

Figure 9. Effect on cushion over section and concrete steel indices

CONCLUSIONS

The Box type cross Drain of size 1.5m x 1.5m without cushion to 6m cushion with 0.5m increment are analyze. The Shear & axial force, maximum sagging and hogging bending moment get for the envelope of all load applied over the structure. In this study, it was numerically shown that overburden loading has a great effect on the safe bearing capacity and internal forces. It was determined that The Axial force in top slab get increase & in bottom slab it get decrease with increasing the overburden. The shear force in top slab& bottom slab for minimum cushion is get decrease with increase in cushion up to 2m and it get increase when cushion over the top slab more than 5m,It means , the top slab & bottom slab section designed for minimum cushion is safe in shear up to the 5m cushion. After the analysis, it is clearly seen that the wall & bottom slab section designed for minimum cushion is safe in hogging moment up to the 2.5m cushion. The wall & bottom slab section designed for minimum cushion is safe in sagging moment up to the 4.5m cushion. The requirement of safe bearing capacity (SBC) is more with increase in cushion and it is just touch to the available SBC for 6m cushion. The Steel indices for minimum cushion is get decrease with increase in cushion up to 2.5m and it get increase when cushion over the top slab more than 5m. It means, the Top slab, outer wall, & bottom slab section designed for minimum cushion is up to the 5m cushion .The Variable T1, T2, T3 remain same for all cushion and T5 & T6 get change with change in Variable T4.The Section design for minimum cushion can be used up to the 5m cushion. However the Pattern of provided steel need to be studied before taking any decision.

DATA AVAILABILITY STATEMENTS

Data generated or analyzed during the studies are made available on request from the corresponding author.

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