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PARAMETRIC STUDIES OF BOX CULVERTS

Komal S.Kattimani[1], R.Shreedhar[2]
[1](Department of Civil Engineering, Jain College of Engineering /Visvesvaraya Technological University, India)
[2](Department of Civil Engineering, Gogte Institute of Technology/Visvesvaraya Technological University, India)

ABSTRACT: *Culverts are required to be provided under earth embankment for crossing of water course like streams, Nallas etc across the embankment, as road embankment cannot be allowed to obstruct the natural water way. The culverts are also required to balance the flood water on both sides of earth embankment to reduce flood level on one side of road thereby decreasing the water head consequently reducing the flood menace. Culverts can be of different shapes such as arch, slab and box. These can be constructed with different material such as masonry (brick, stone etc) or reinforced cement concrete. Concrete culverts in trenches have been widely used in expressways. Box type structure with single cell or multiple cells can be effectively employed as Underpasses, Grade Separator, and Minor Bridges or as a Flyover also.*

This paper deals with study of some of the design parameters of box culverts like angle of dispersion of live load, effect of co-efficient of earth pressure and depth of cushion provided on top slab of box culverts. Depth of cushion, coefficient of earth pressure for lateral pressure on walls, width or angle of dispersion for live loads on box without cushion and with cushion for structural deformation are important items where opinion of the designers vary and need to be dealt in much detail.

Keywords: *angle of dispersion, box culvert, co-efficient of earth pressure, cushion, lateral earth pressure etc*

I. INTRODUCTION

Box Culverts consists of two Horizontal and two vertical slabs built monolithically are ideally suited for a road or railway bridge crossing with high embankments crossing a stream with a limited flow. If the discharge in a drain or channel crossing a road is small, and if the bearing capacity of the soil is low, then the box culvert is an ideal bridge structure. This is a reinforced concrete rigid frame box culverts with square or rectangular openings are used up to spans of 4m. The height of the vent generally does not exceed 3m. [1]

Box culverts are economical due to their rigidity and monolithic action and separate foundation are not required since the bottom slab resting directly on the soil, serves as raft slab. For small discharges, single celled box culvert is used is used and for larger discharges, multicelled box culverts can be employed. The barrel of the box culverts should be sufficient length to accommodate the carriageway and the kerb.

For a box culvert, the top slab is required to withstand dead loads, live loads from moving traffic, earth pressure on sidewalls, water pressure from inside, and pressure on the bottom slab besides self weight of the slab. The structure is designed like a rigid frame adopting moment distribution method for obtaining final distributed moments on the basis of the relative stiffness of the slab and vertical walls. The method is well known and does not need any elucidation. A few things like depth of cushion, coefficient of earth pressure for lateral pressure on walls, width or angle of dispersion for live loads on box without cushion and with cushion for structural deformation are important items where opinion of the designers vary and need to be dealt in much detail. These affect the design significantly and therefore, required to be assessed correctly for designing a safe structure. Therefore an attempt is made to study the effects of cushion, co-efficient of earth pressure and angle of dispersion for live load. [2]

II. ADVANTAGES OF BOX CULVERTS

Box culverts are economical for the reasons mentioned below:

- The box is a rigid frame structure and both the horizontal and vertical members are made of a solid slab, which is very simple in construction.
- In case of high embankments, an ordinary culvert will require very heavy abutments that will not only be expensive but also transfer heavy loads to the foundation.
- The box type of structure is suitable for non perennial streams where scour depth is not significant but sub grade soil is weak.
- The dead load and superimposed load are distributed almost uniformly over a wider area as the bottom slab serves as raft foundation, thus reducing pressure on soil.

- The main advantage is that it can be placed at any elevation within the embankment with varying cushion which is not possible for other type of culverts.
- A multi cell box can cater for large discharge and can be accommodated within smaller height of embankment.
- It does not require separate elaborate foundation and can be placed on soft soil by providing suitable base slab projection to reduce base pressure within the safe bearing capacity of foundation soil.
- Bearings are not needed.
- It is convenient to extend the existing culvert in the event of widening of the carriageway at a later date as per future requirement, without any problem of design and/or construction.

III. DESIGN CONSIDERATIONS

3.1 WIDTH OR ANGLE OF DISPERSION

The maximum live load bending moment is calculated by considering the effective width of the slab. This effective width is also called the effective width of dispersion and is measured parallel to the supporting edges of slab. Dispersion of the wheel load along the span is known as the effective length of dispersion. It is also called the dispersion length. To consider the effective width the load is dispersed over an angle with respect to the vertical. If the angle with respect to vertical line or 0 dispersion increases, the effective width of dispersion of live load also increases thus reducing the intensity of live load. This angle through which live load is dispersed is varied and the effect on final moments is studied in the present study.[3,4]

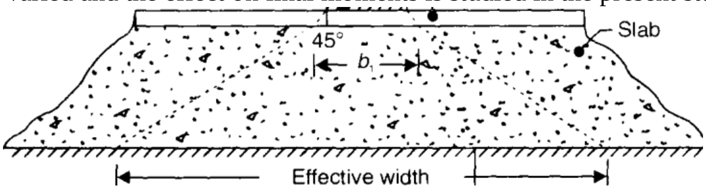


Fig 1 Representing angle of dispersion and width of dispersion

3.2 CO-EFFICIENT OF EARTH PRESSURE

The earth can exert pressure, minimum as active and maximum as passive, or in between called pressure at rest. It depends on the condition obtained at site. For example in case of a retaining wall where the wall is free to yield and can move away from the earth fill the pressure exerted by the earth shall tend to reach active state and thus be minimum. As to reach active state only a small movement is required which can normally be achieved in case of a retaining wall, also before failure of the wall by tilting, the back fill is bound to reach active state. The wall thus can safely be designed for active pressure of earth, with co-efficient applicable for active pressure. In case of an anchored bulk head, the earth pressure on the anchor plate will tend to achieve passive state because the anchor plate is dragged against earth and large displacement can be allowed, one can consider passive co-efficient for the design of anchor, of course, some factor of safety need be taken as required displacement to achieve passive state before the bulk head gives way may not be practical. In cases where the structure is constructed before back fill earth is placed in position and the situation is such that structure is not in a position to yield on either side, the earth pressure shall reach a state at rest. In such situation the co-efficient of earth pressure shall be more than the active condition. In case of box since it is confined with earth from both sides the state of earth shall be at rest and a co-efficient more than the active pressure is normally adopted in the design. The earth is filled after construction of the box further the box is not in a position to move/yield therefore the pressure shall be at rest. The value is designer's choice.[2]

The co-efficient of earth pressure in case of box is taken to be 0.333 for a soil having $\phi = 30^\circ$ equivalent to active condition by many authors in their books of design. Some authors take this value = 0.5 for normal soil having $\phi = 30^\circ$. A typical box has been designed keeping all factors to be same for the two values of earth pressure co-efficient. It is seen that these co-efficient even when taken differently have little effect on the overall design of the section. To bring out difference in more appreciable form the two designs are compared and are expressed in form of graphs. Considering the situation typical to the box, it is close to at rest condition and a co-efficient higher than active pressure should be taken. For practical considerations a value of 0.5 can be taken for earth pressure. In design this difference of earth pressure on two sides of box is not taken, as the pressure on the passive side, which depends on amount of deformation of culvert, cannot be evaluated within reasonable limits. However, the earth pressure on both sides of box before and after deformation can be assumed to be at rest/active pressure as the earth pressure co-efficient has little over all effect on the structural sizes of box members.

3.3 CUSHION

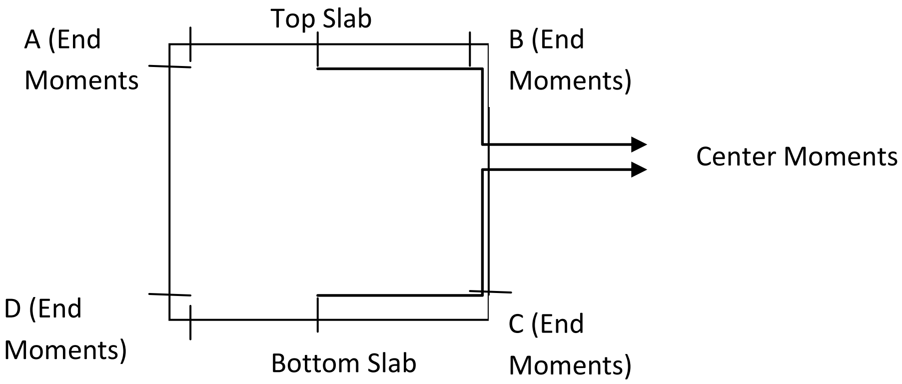
A box culvert can have more than single cell and can be placed such that the top slab is almost at road level and there is no cushion. A box can also be placed within the embankment where top slab is few meters below the road surface and such boxes are termed with cushion.

The size of box and the invert level depend on the hydraulic requirements governed by hydraulic designs. The height of cushion is governed by the road profile at the location of the culvert. This report is devoted to box culverts constructed in reinforced concrete having single cell and varying cushion including no cushion. While calculating weight of cushion on top slab, some designer take average height of earth fill coming over full length of box including sloping side fill. This is not correct and full height of cushion should be taken at the worst section of the box (central portion) will be subjected to this load and the section needs to be designed accordingly. A question has been raised frequently whether culverts designed for four lane divided carriageway are safe for more number of lanes, a situation which occurs on widening of the road and frequently encountered for road development, and whether the culvert designed for no cushion shall be safe for cushion loads which may become a necessity at a future date due to change in road profile. If so, up to what height of cushion, the box need not be reconstructed. These shall be addressed in this study giving appropriate solutions as required.

IV. PROBLEM FORMULATION

The following problem was considered and the above mentioned parameters were varied using excel and the results obtained are plotted.

Clear Span	3 m
Clear Height	3m
Top Slab Thickness	0.42m
Bottom Slab Thickness	0.42m
Side Wall Thickness	0.42m
Clear Span	3.42m
Thickness of Wearing Coat	0.065m

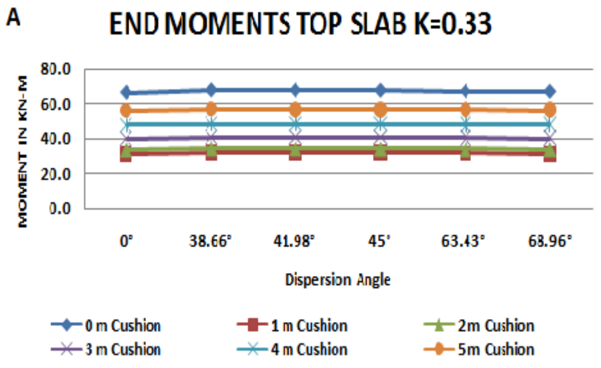


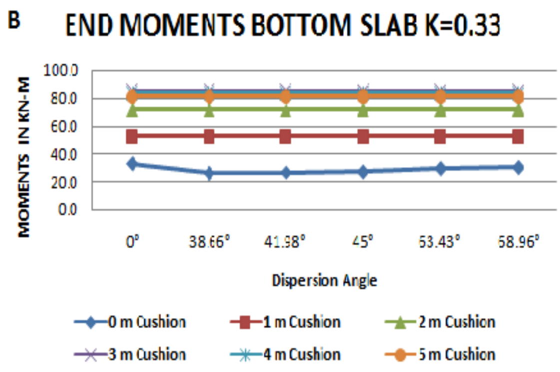
V. RESULTS AND DISCUSSIONS

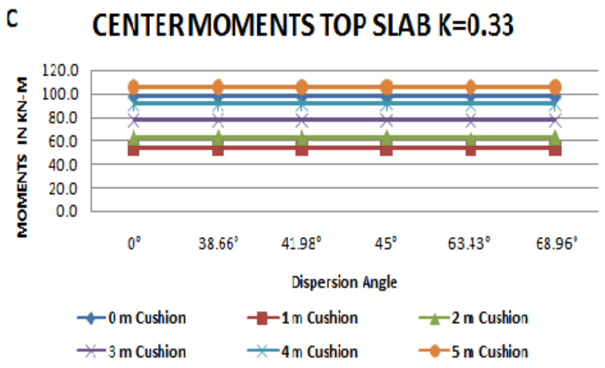
5.1 Angle of dispersion:

The slopes through which the loads get dispersed on the culvert were varied as 0, 0.8, 0.9, 1.0, 2.0, 2.6 and the corresponding angles are 0^0, 38.66^0, 41.98^0, 45^0, 63.43^0, and 68.96^0 respectively. In further part of paper, values in degrees are used. It was observed that even though the angle of dispersion has an impact on intensity of live load for 0^0 dispersion, the intensity of live load is maximum. Similarly intensity decreases with increase in angle from 38.66^0 to 68.96^0 from the vertical axis of the road or wheel. But it is found that even though intensity of live load varies with angle the overall effect when combinations of all loads are considered moments remain constant.

The following graphs represent the effect of variation of angle of dispersion for K=0.33 at the ends and center of culvert:







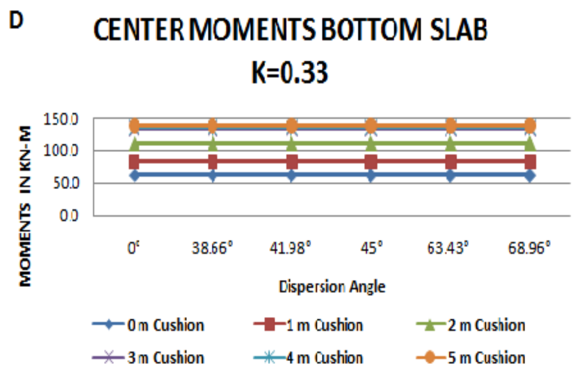
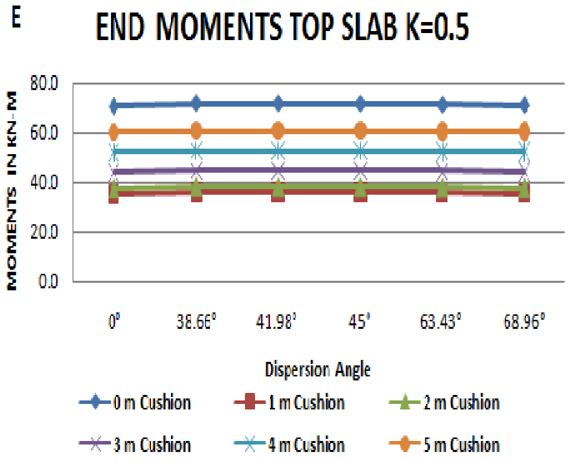
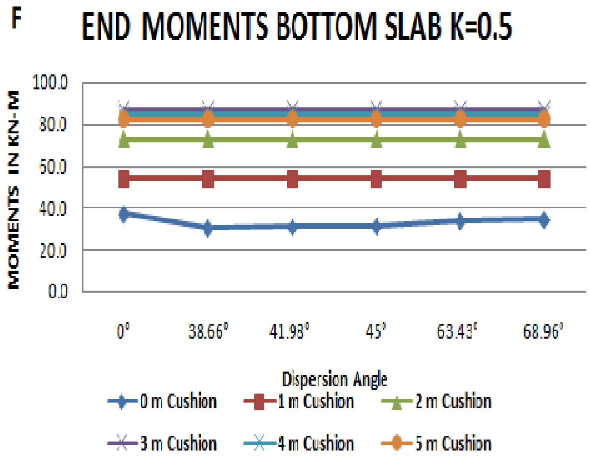
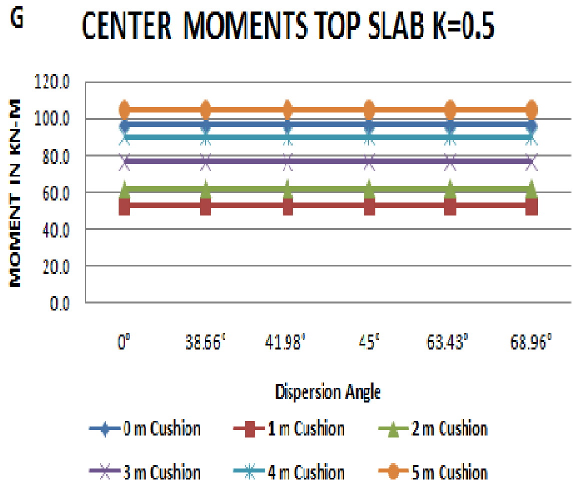


Fig A Variation of BM with angle of dispersion at ends of top slab for K=0.33
Fig B Variation of BM with angle of dispersion at ends of bottom slab for K=0.33
Fig C Variation of BM with angle of dispersion at center of top slab for K=0.33
Fig D Variation of BM with angle of dispersion at bottom of top slab for K=0.33

The following graphs represent the effect of variation of angle of dispersion for K=0.5 at the ends and center of culvert.







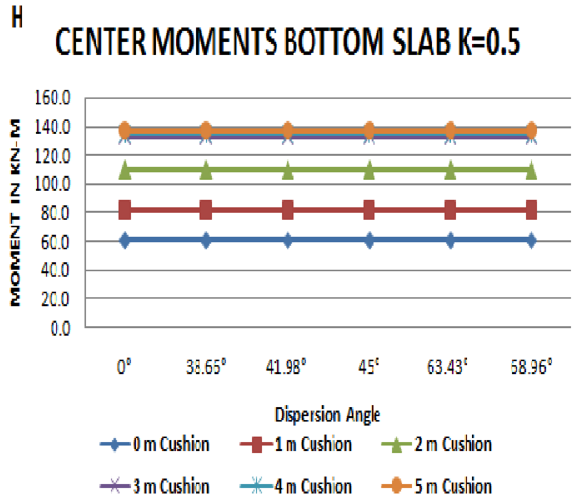
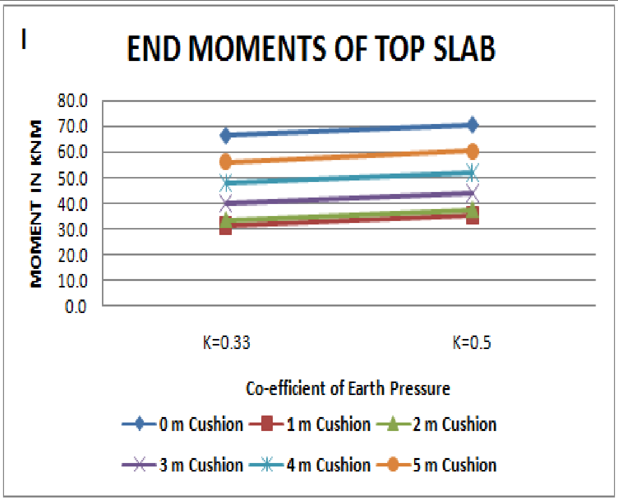
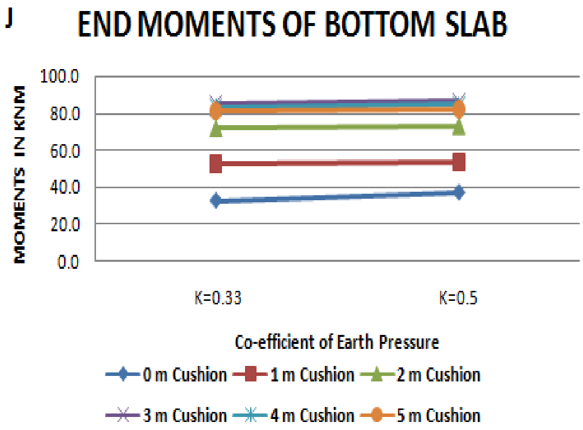


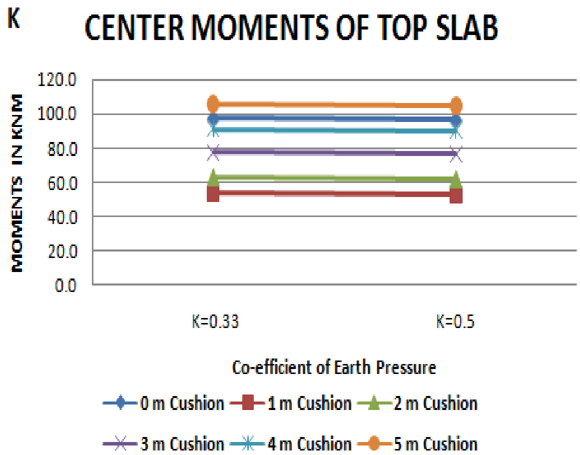
Fig E Variation of BM with angle of dispersion at ends of top slab for K=0.5
Fig F Variation of BM with angle of dispersion at ends of bottom slab for K=0.5
Fig G Variation of BM with angle of dispersion at center of top slab for K=0.5
Fig H Variation of BM with angle of dispersion at bottom of top slab for K=0.5

5.2. Co-efficient of Earth Pressure: As previously discussed the co-efficient of earth pressure is varied in between rest and active state i.e. K=0.33 and K=0.5 are studied. It is observed that even though co-efficient of earth pressure increases, the combined effect with all other load combinations remains constant except for a slight increase in end moments of top, bottom & Side Wall of structure.

The following graphs represent the effect of variation of Co-efficient of Earth Pressure at the ends and centers of top and bottom slab respectively:







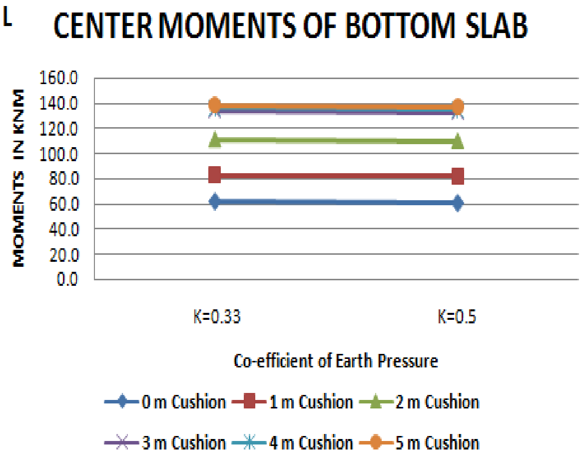
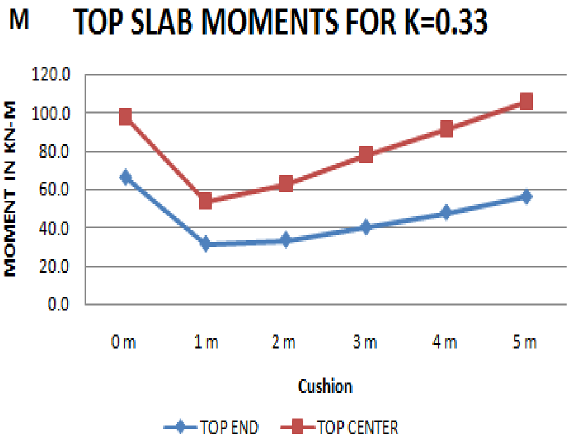


Fig I Variation of BM with co-efficient of earth pressure at end of top slab
Fig J Variation of BM with co-efficient of earth pressure at end of bottom slab
Fig K Variation of BM with co-efficient of earth pressure at center of top slab
Fig L Variation of BM with co-efficient of earth pressure at center of bottom slab

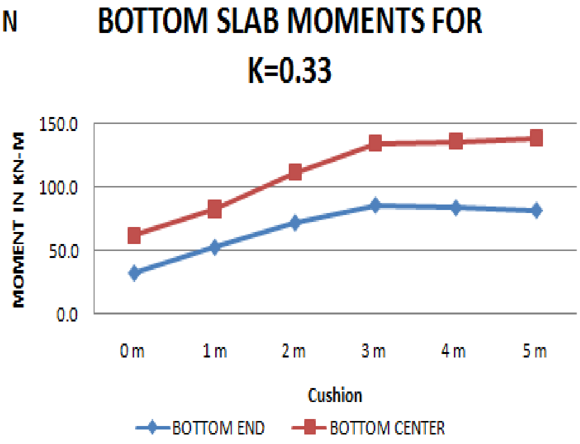
5.3 Cushion: In the present study the cushion is varied from 0m to 5m with 1m interval. It is observed that greater stresses are found in box structures without cushion (0 cushion). In case of box with cushion the live load surcharge is supposed to disperse through such cushion in both directions thereby reducing intensity of load on top slab. Therefore by this study we can conclude that up to what height of cushion, the box need not be reconstructed during widening of roads. Here the moments for 0^0 dispersion is almost equal to moments with 5 meter cushion.

The following graphs represent the effect of variation of cushion on top and bottom slab respectively for K=0.33and K=0.5:

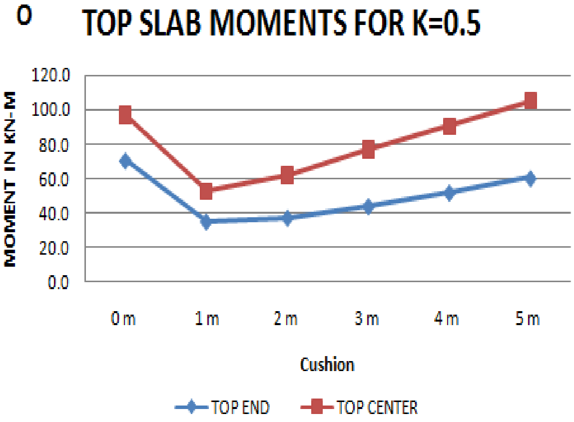
M



N



O



P

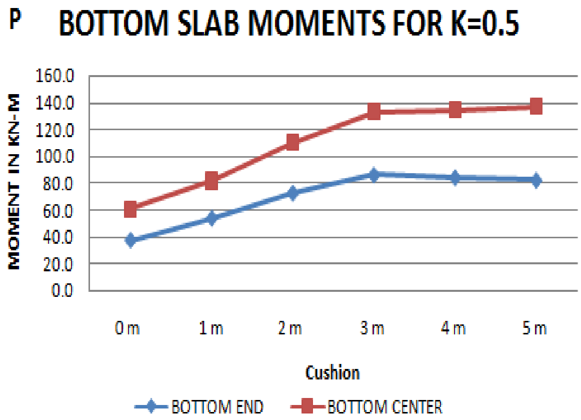


Fig M Variation of BM with cushion for top slab at K=0.33
Fig N Variation of BM with cushion for bottom slab at K=0.33
Fig O Variation of BM with cushion for top slab at K=0.50
Fig P Variation of BM with cushion for bottom slab at K=0.50

VI. CONCLUSIONS

From the parametric studies that is by variation of angle of dispersion, co-efficient of earth pressure and cushion depth we can conclude that

1. The angle of dispersion increases the intensity of live load but when overall effect of all loads is taken, the moments remain constant. Therefore the angle of dispersion as considered in IRC 6-2000 which is 45^0 can be considered for design.
2. The co-efficient of earth pressure has a little influence on the final moments therefore for safer design the co-efficient of earth pressure can be taken 0.5 which gives higher results than 0.33.
3. By the studies on cushion depth it is feasible to design box type of structure with 0 meter or no cushion which shall be safe for cushion loads which may become a necessity at future date due to change in road profile. From the study it is seen that the moments for no cushion are higher than the moments for a cushion of 5 meters.

VII. ACKNOWLEDGMENT

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