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Comparative Study of Two Cell and Three Cell Box Culvert with Different Backfill Material at Different Aspect Ratios by Using Staad-Pro

Samruddhi P. Chikhalkar, Prof. P S Lande

Associate Professor, Department of Civil Engineering, Government College of Engineering, Amravati, Maharashtra, India

ABSTRACT: Culvert has different purposes such as for drainage storage and handling. Sometimes culvert acts as a PG student, Structural Engineering, Government College of Engineering, Amravati, Maharashtra, India
bridge. Such culverts are for pedestrian and vehicular traffic loads. Sometimes Box culvert subjected to maximum overburden pressure due to backfill and hence maximum moments and shear stress occurs on the face of box culvert. For contracting these maximum moments light weight material Geofoam is used as a backfill material on multicell box culvert. The objective of this paper is to study the structural behaviour of multicell box culvert with soil and Geofoam as a backfill material at different aspect ratios by using Staad pro software.

KEYWORDS: geofoam, multicell box culvert. IRC 6-2017, Staad pro software.

I. INTRODUCTION

Culvert is a structure which is built over some physical obstacle such as a body of water, valley, or road, and its purpose is to provide crossing over that obstacle. It is built to be strong enough to safely support its own weight as well as the weight of anything that should pass over it. Box culverts are the structures constructed below highways and railways to provide access to the natural drainage across them. They are also constructed sometimes to provide the access to the animals to cross the road. Box culverts are an essential feature of any transportation system since they are a cost-effective alternative to big bridges.

Culverts are always less expensive than bridges. Box culverts are made of reinforced concrete and can be prefabricated or cast in place. Box culverts do not require a separate extensive foundation system and they are ideally suited for medium spans. Box culverts are challenging structures structurally since they are totally buried in soil and self-stabilizing. Culverts are subjected to the same traffic activities as the pavement since they are buried across the transverse direction of the road. Culverts are subjected to traffic, vertical earth pressure from cushion (earth fill), lateral earth pressure from backfill soil, hydrostatic pressure from ground water, uplift, braking and acceleration forces, partial or full internal water pressure when the culvert is in operation, and other direct and indirect actions. Box culvert is designed firstly for a meter and then multiplied. If necessity of culverts increases as per discharge volume then multiple culverts adjoining sides could be used. It is monolithic structure having parts are top slab, bottom slab and vertical walls and wing walls. Culverts are also provided to balance the water level on both sides of embankment during floods; such culverts are termed as balancers.

The design of box culvert is based on a set of loading conditions which the component must withstand. These loads may vary depending on duration (permanent or temporary) direction of action, type of deformation ,and nature of structural action (shear, Bending,torsion) etc.The structural design of a reinforced concrete box culvert comprises the detailed analysis of rigid frame for moments, shear forces and thrusts due to various types of loading conditions outlined as Concentrated Loads , Uniform Distributed Loads , Weight of Side Walls, Water Pressure inside Culvert, Earth Pressure on Vertical Side Walls , Uniform Lateral Load on Side Walls.

II. RELATED WORK

Structural Analysis and Designing Program is referred to by its full name, STAAD Pro. STAAD Pro.is a computer program for structural analysis and design that was created in 1997 by Research Engineers International (REL) in

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Yorba Linda, California. STAAD Pro.is one of the most well-known and commonly used programs for structural analysis and design by civil engineers today. It supports all common design regulations for steel, concrete, and wood.

2.1 Problem Statement

Structure: Culvert Structure			
Span : 12 m			
Type of Culvert	Two Cell R. C. Box Culvert	Three Cell R. C. Box Culvert	
No. of Cell	2	3	
No. of Models	4	4	
Carriage Way	2	2	
Aspect Ratio (L/H)			
Cases for Two Cell Box Culvert	Length (L) in meter	Height (H) in meter	Ratio (L/H)
I	6	6	1
II	6	4	1.5
Aspect Ratio (L/H)			
Cases for Three Cell Box Culvert	Length (L) in meter	Height (H) in meter	Ratio (L/H)
I	4	4	1
II	4	2.67	1.5

III. METHODOLOGY

- Choosing culvert dimensions based on prior research and the load cases to be utilized for modeling and analysis in the STAAD Pro. programme.
- Literature Survey.
- Culvert modeling and analysis with various aspect ratios.
- Comparing the outcomes based on the moment and the shear stress.

IV. LOAD CONSIDERATION FOR THE ANALYSIS OF BOX CULVERT

The weight of embankment, deck slab and the track load are considered to be uniformly distributed loads on the top slab with the uniform soil reaction on the bottom slab. For live load distribution, the width of dispersion perpendicular to the span is computed first. Width of dispersion parallel to the span is also calculated. Then the maximum magnitude of load is divided by width of dispersion parallel to span and width of dispersion perpendicular to the span to get the load intensity on the top slab.

Weight of Side Walls

The self weight of two side walls acting as concentrated loads are assumed to produce uniform soil reaction on the bottom slab.

Earth Pressure on Vertical Side Walls

The earth pressure on the vertical side walls of the box culvert is computed according to the Coloumb's theory. The earth pressure intensity on the side walls is given by $p=K_a\gamma H$, where Ka is coefficient of active earth pressure, γ is the density of soil and H is he vertical height of box.

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Uniform Lateral Load on Side Walls

Uniform lateral pressure on vertical side walls is considered due to the sum of effect of embankment loading and live load surcharge. Also the uniform lateral pressure on vertical side walls is considered due to embankment loading alone.

Effective Width

Effective width in the run of culvert (length across span) is expected to be affected by a moving live load. This width plays a significant role as far as consideration of live load in the design of culvert.

- $b_{ef} = \alpha_e (1 - a/L_0) + b_1$
- b_{ef} = The Effective width of slab on which load acts.
- L_0 = Effective span.
- a = The distance of the centre of gravity of the concentrated load from the nearer Support.
- B_1 = The breadth of concentration area of the load. α = A constant having the values depending upon ratio b / L_0.

I.R.C. Loading Cases

For class AA loading and class 70R loading,

a) For spans less than 9m:

1. for tracked vehicles: 25% for spans upto 5m linear reducing to 10% for spans of 9m.
2. for wheeled vehicles: 25%

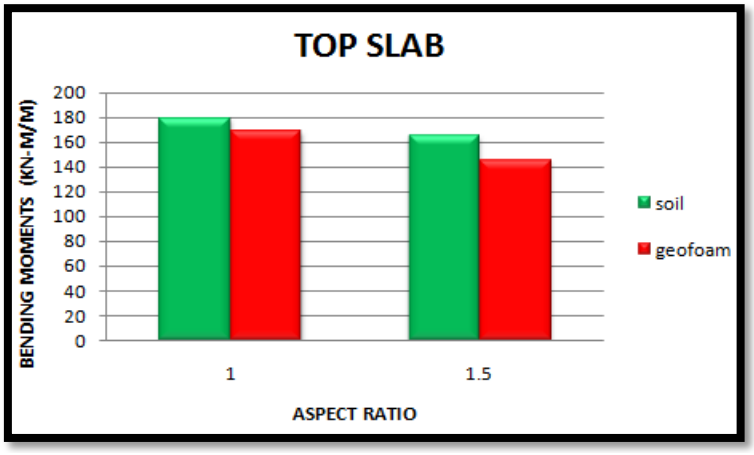
b) For spans 9m or more:

1. Reinforced concrete bridges

Tracked vehicles: 10% up to spans of 40m and in accordance with the above curve for the spans in excess of 40 m. Wheeled vehicles: 25% for spans up to 12 m and in accordance with the above curve for Spans in excess of 12 m.

2. Steel bridges Tracked vehicles: 10% for all the spans. Wheeled vehicles: 25% for spans up to 23 m and in accordance with the given above curve for spans in excess of 23 m.

V. RESULTS



Graph 1: Comparison of Moments at Top Slab for Two Cell Box Culvert by using Soil and Geofoam as backfill material

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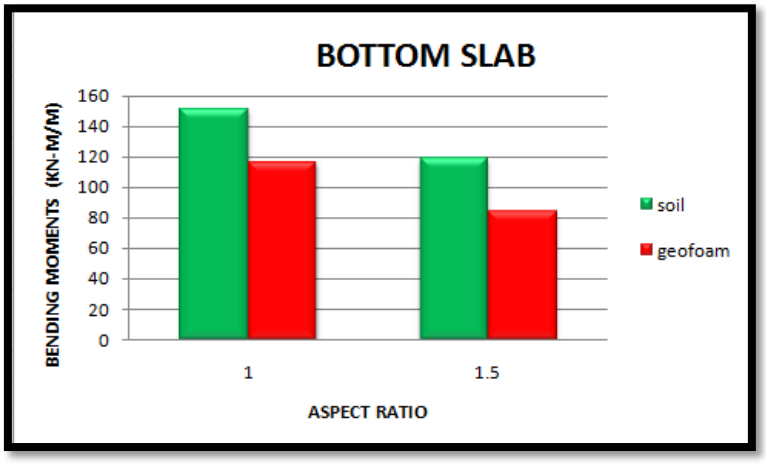
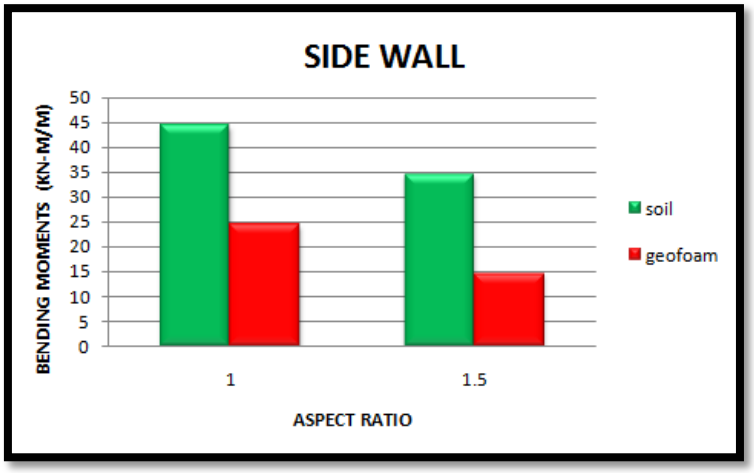
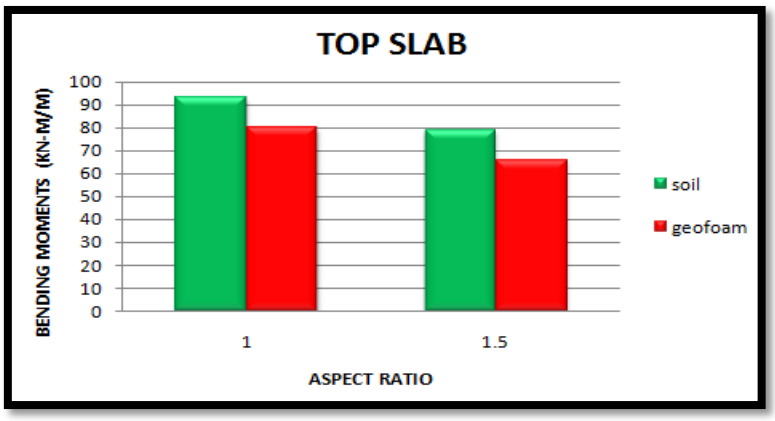


Graph 2: Comparison of Moments at Bottom Slab for Two Cell Box Culvert by using Soil and Geofoam as backfill material



Graph 3: Comparisons of Moments at Side Wall for Two Cell Box Culvert by using Soil and Geofoam as backfill material



Graph 4 Comparison of Moments at Top Slab for Three Cell Box Culvert by using Soil and Geofoam as backfill material

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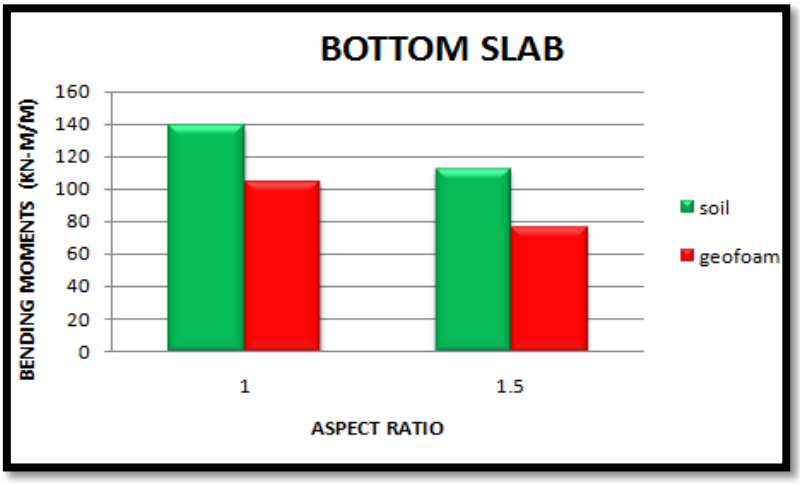
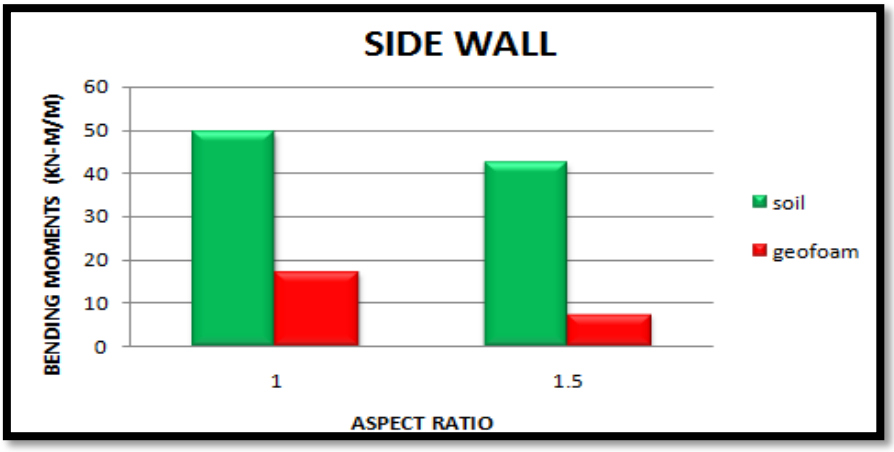
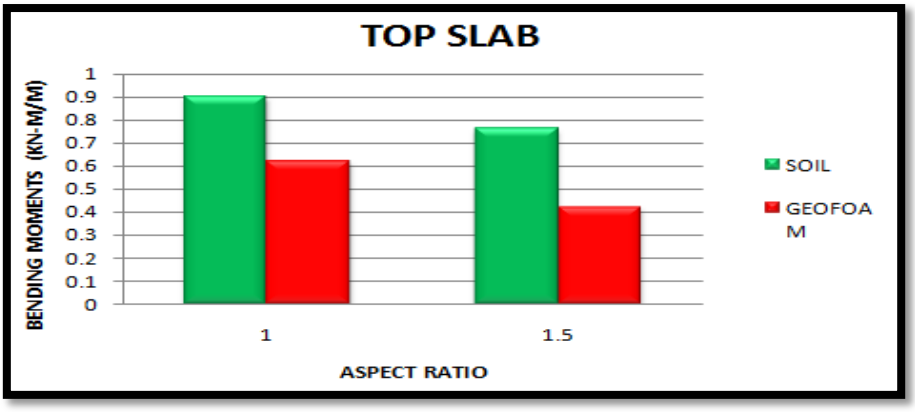


Graph 5 Comparison of Moments at Bottom Slab for Three Cell Box Culvert by using Soil andGeofoam as backfill material



Graph 6 Comparison of Moments at Side Wall for Three Cell Box Culvert by using Soil and Geofoam as backfill material



Graph 7:Comparison of Shear Stressesat Top Slab for Two Cell Box Culvert by using Soil and Geofoam as backfill material

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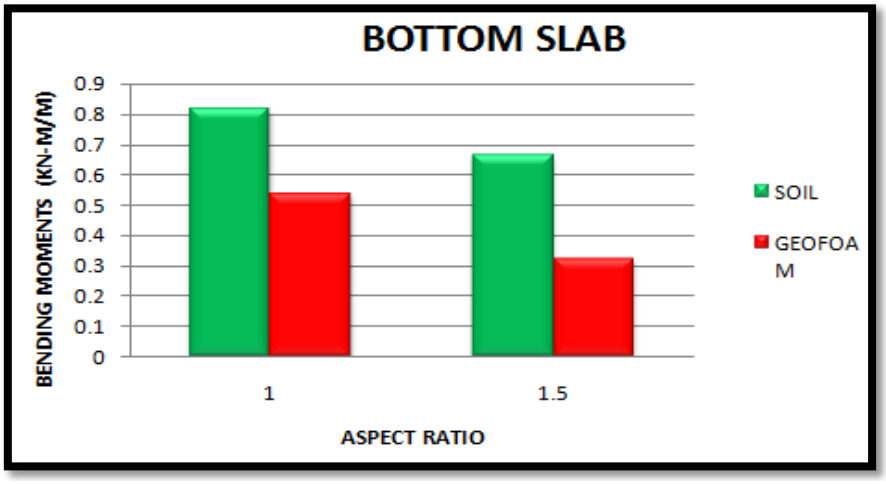
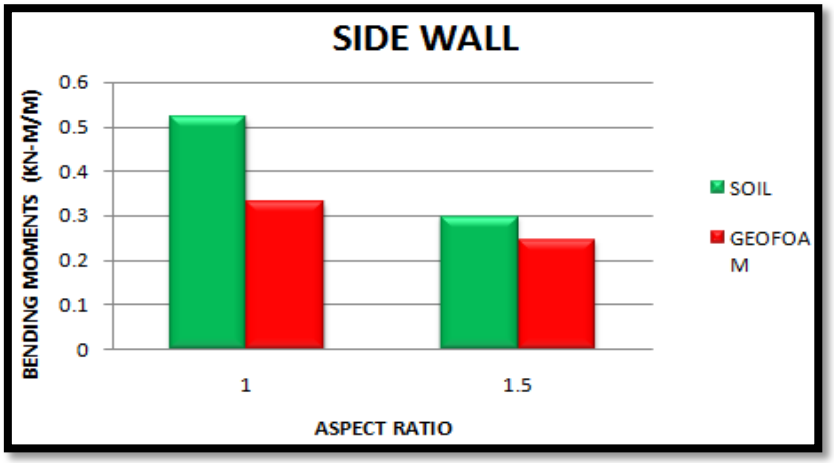
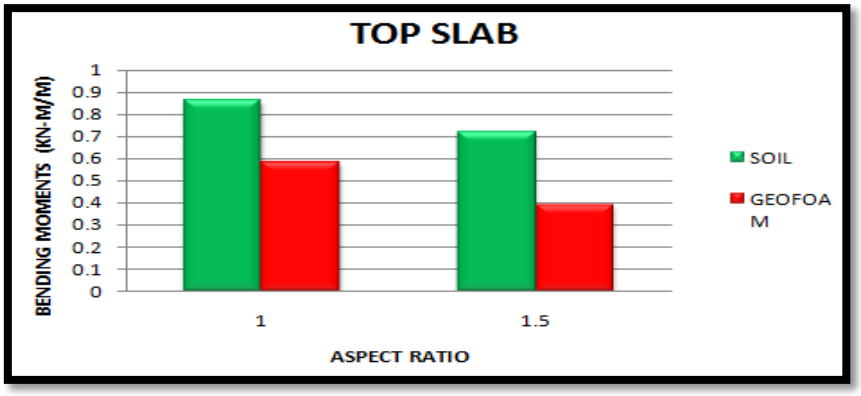


Graph 8: Comparison of Shear Stresses at Bottom Slab for Two Cell Box Culvertby using Soil and Geofoam as backfill material



Graph 9: Comparison of Shear Stresses at Side Wall for Two Cell Box Culvert by using Soil and Geofoam as backfill material



Graph 10: Comparison of Shear Stresses at Top Slab for Three Cell Box Culvert by using Soil and Geofoam as backfill material

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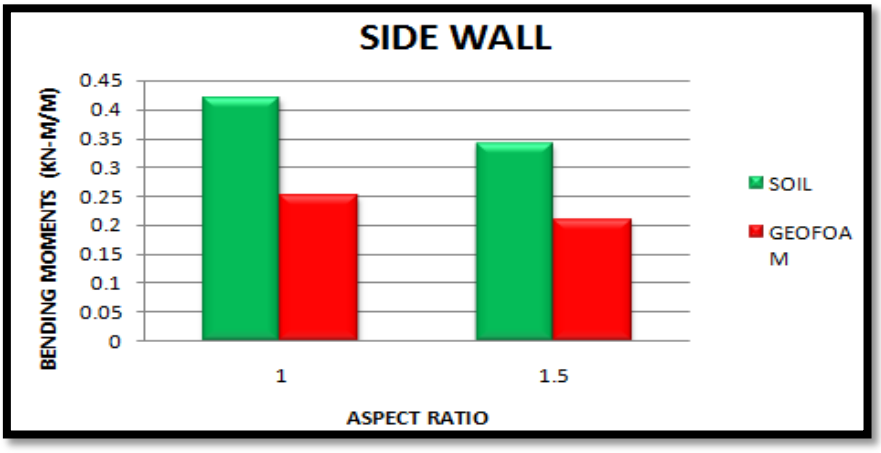
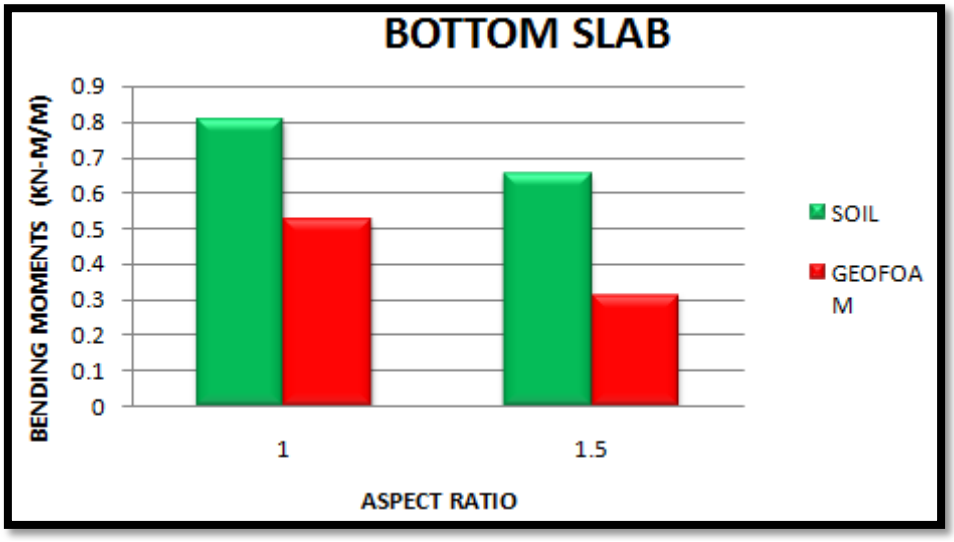


Graph 11: Comparison of Shear Stresses at Side Wall for Three Cell Box Culvert by using Soil and Geofoam as backfill material



Graph 12: Comparison of Shear Stresses at Bottom Slab for Three Cell Box Culvert by using Soil and Geofoam as backfill material

After comparing and analyzing the models of the two cells and three cells box culverts for different aspect ratios with different backfilling materials for moments and shear stresses all the results are found satisfactory.

VI. CONCLUSION

In this analysis of Two Cell Box Culvert and Three Cell Box Culvert for different L/H ratio all the models are analyzed with different backfilling materials. In this analysis the moments and shear stress values for the slabs of both the cells of culvert are obtained.

Here, comparing the moments and shear stresses values of both the two cells and three cell culverts for different L/H ratio on same span length. The following conclusions are based on the research work as follows:

1. In this analysis, the maximum moment values are reduced significantly for box culvert having Geofoam as a backfill as compare to soil.

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2. For aspect ratio of 1.5 of Two Cell R.C. Box Culvert the maximum moment for bottom slab is reduced to 29.17% and for side wall is 50.61% and for top sab 11.93% as compare to soil.
3. For aspect ratio of 1of Two Cell R.C. Box Culvert the maximum moment for bottom slab is reduced to 23% and for side wall is 44.03 %and for top slab 5.53%as compare to soil.
4. For aspect ratio of 1 of Three Cell R.C. Box Culvert the maximum moment for bottom slab is reduced to 25.03% and for side wall is 65.40% and for top slab 14.24%as compare to soil.
5. For aspect ratio of 1.5 of Three Cell R.C. Box Culvert the maximum moment for bottom slab is reduced to 32.07% and for side wall is 16.63% as compare to soil.
6. For shear stresses analysis the values are again reduced for Two Cell R.C. Box Culvert for Geofoam as backfill as compare to soil. The values reductions in percentage are for bottom slab is 34.31% and for side wall is 36.54% and for top slab 31.1% for aspect ratio 1.
7. For shear stresses analysis the values are again reduced for Two Cell R.C. Box Culvert for Geofoam as backfill as compare to soil. The values reductions in percentage are for bottom slab is 51.28% and for side wall is 17.24% and for top slab 44.74%for aspect ratio 1.5.
8. For shear stresses analysis the values are again reduced for Three Cell R.C. Box Culvert for Geofoam as backfill as compare to soil. The values reductions in percentage are for bottom slab is 34.83% and for side wall is 40.48% and for top slab 32.56%for aspect ratio 1.
9. For shear stresses analysis the values are again reduced for Three Cell R.C. Box Culvert for Geofoam as backfill as compare to soil. The values reductions in percentage are for bottom slab is 52.23% and for side wall is 40.88% and for top slab 45.83% for aspect ratio 1.5.

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