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ANALYSIS OF RAFT FOUNDATION USING FINITE ELEMENT APPROACH

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Abstract- Normally, a structure resting on soil having low bearing capacity and where differential settlement due to erratic nature of soil is expected, raft foundation is recommended to cope-up with mixed or poor ground condition and simultaneously to transfer heavy loads to ground while controlling the differential settlement. The essential task in the analysis of a raft foundation is the determination of the distribution of contact pressure underneath the raft which is a complex function of the rigidity of the superstructure, raft itself and supporting soil .The IS : 2950 (Part I)-1981 recommends the analysis based on the assumption of liner distribution of contact pressure. However due to complex / erratic nature of soil & flexibility of the raft, this assumption is away from reality, which will leads to erroneous results. Therefore in order to ensure precision in the analysis and to simulate the realistic condition of interface of soil mass and raft, a discretization of raft is done using finite element method and springs are used below the node points to realistically simulate the soil flexibility. The application software (SAFE 2000) is used for finite element analysis .In this study the attempt is made to evaluate the effectiveness of finite element approach by studying moments along x direction, moment along y direction and soil pressure beneath the raft. This study is carried out on three types of soil; loose, medium and hard soil. Study reveals that finite element formulation minimizes the error to the significant extent in the results due to correction in assumption of liner pressure distribution. Study also reveals that finite element approach is found effective in case of loose and medium soil as error is magnified due to the assumption of liner pressure distribution in conventional approach.

Keywords – Rigid raft Foundation, Safe bearing capacity of soil, Conventional approach, Finite element approach, Deflection, Moment, Soil pressure, Soil modulus of elasticity.

I. INTRODUCTION

A raft is a combined footing that covers the entire area beneath a structure and supports all the walls and columns. When allowable soil pressure is low, or the building loads are heavy, the use of spread footing would cover more than one-half of the area and it may prove more economical to use raft foundation. They are also used where the soil mass contains compressible layers or the soil is sufficiently erratic so that the differential settlement would be a challenge to control. The raft tends to bridge over the erratic deposits and eliminates the differential settlement. Raft foundation is used to reduce settlement above highly compressible soil, by making the weight of the structure and raft approximately equal to the weight of the soil excavated.

The essential task in the analysis of a raft foundation is the determination of the distribution of contact pressure underneath the raft which is a complex function of the rigidity of the superstructure, raft and supporting soil. This necessitates a number of simplifying assumptions to make the problem open to analysis. Once the distribution of contact pressure is determined, bending moments and shear force can be computed based on statics. IS: 2950 (PartI)-1981 recommends few methods of analysis based on certain assumptions.

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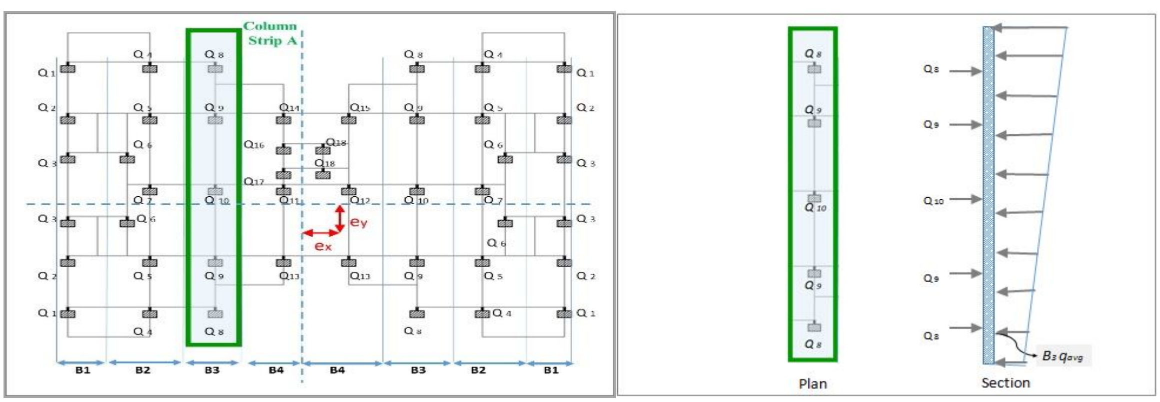
Many researchers have proposed that the behavior of raft foundation can be studied by using finite element approach. Dr.Shihada et al.[1] (2008), compared results from analysis using the conventional approach and the Finite element approach (SAP2000 software).They concluded that moment value obtained from conventional method is more than the finite element method. Dr. Mohammed Al-Ansari [2] (2009), studied the design of raft foundation in loose sand and found that using software results are more accurate. Mohamed Saad El din et al. [3] (2014), analysed raft foundation using PLAXIS programme to study the effect of opening position and different types of soil. They found that opening and type of soil have important effect on settlement of soil and moment of raft foundation. Dr.S.A.Halkude et al. [4] (2014), carried out dynamic analysis using response spectra. The soil flexibility is incorporated in the analysis using spring model for incorporating soil flexibility and FEM model for diserization of raft. They found that SSI significantly affects the response of the structure; FEM is effective approach for consideration of elastic continuum beneath foundation. Dr.S.S.Patil et al. [5] (2016), carried out the effect of soil flexibility on the performance of the building frame resting on raft foundation. They found that base shear increases due to SSI effect. The effect of SSI increases and tends to become prominent with increasing softness of the soil.

In the present study analysis of raft foundation for a 'G+7 Story' building situated in Earthquake Zone-3 is carried out for all load combinations in accordance with IS: 875-2002(Part-V). The study focuses on the evaluation of various flexural parameters such as moment along x, y direction and soil pressure beneath raft and comparison of result obtained by conventional method and finite element method. In present study springs are used to incorporate soil flexibility in place of linear variation of soil pressure beneath raft considered in conventional method. This study is carried out on three types of soil; loose, medium and hard soil.

II.FORMULATION

The analysis of raft with the conventional approach of assuming uniform soil pressure beneath the raft is discussed in following section with the help of typical building plan as shown in Figure 1 (a).

The conventional analysis is based on the assumption that foundation is rigid relative to the supporting soil and the compressible soil layer is relatively shallow. The geometry of the raft consider such that, the contact pressure variation is assumed as planar, such that the centroid of the contact pressure coincides with the line of action of the resultant force of all loads acting on the foundation.The procedure for the conventional approach consists of considering column strip beneath footing as shown in Figure 1 (a).The pressure distribution below footing is considered linearly varying as shown in Figure 1 (b).



(a) (b)

Figure 1 . (a) Plan of Raft Foundation (b) Plan and section of column strip

In order to derive more preciseness raft footing is analyzed using finite element method. The raft is idealized as a mesh of finite elements interconnected only at the nodes (corners), and the soil is modeled as a set of isolated springs (Winkler foundation).

III. PARAMETRIC STUDY

A case study of 7-storyed residential building located in zone III is analyzed and studied using structural design software (STAAD). See Figure 3 (a) for dimensions and geometry. Parameters are considered in STAAD are mentioned in Table 1. Different loads i.e. Dead Load, Live Load, and Earthquake load are calculated according to respective Indian Standard Codes (I.S.456 - 2002). All the loads are calculated as per as I.S.875 (Part I & Part II) and 1893 (Part III).The loads on 18 column are obtained from worst load combination i.e. (Dead Load + Live Load) x 1.5. These are used in analysis of raft foundation.

Table -1 Input Data in STAAD

Parameters	Input Data for STAAD
Type of Building	**Residential (G+7)**
Plan Dimension (m)	**23.06 x 15.18**
Total Height of Building (m)	**25.20**
Floor to floor height (m)	**3.0**
Column Size (mm)	**230x750**
Beam Size (mm)	**230 x 600 , 230 x 450**
Slab Thickness (mm)	**150**

In the present study, analysis of raft is done using column strip A, B and C as shown in Figure 2. Along strip A the columns are heavily loaded and also spacing between the columns is more along Y direction, which will lead to higher bending moments in Y direction. Therefore, column strip A is considered for evaluation of bending moment along Y direction.

Similarly, along column Strip C the columns are heavily loaded and also spacing between the columns is more in X direction, which will lead to higher bending moments in X direction. Therefore column strip C is considered for evaluation of bending moment along X direction.

For soil Pressure column strip B is considered, wherein maximum pressure is expected due to heavy load on the columns along X direction as compared to Y direction.

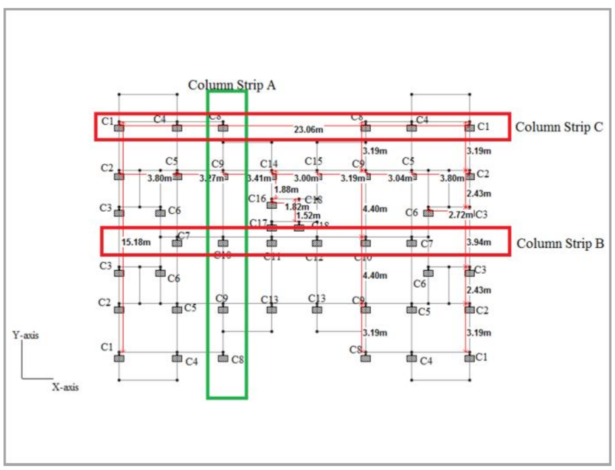
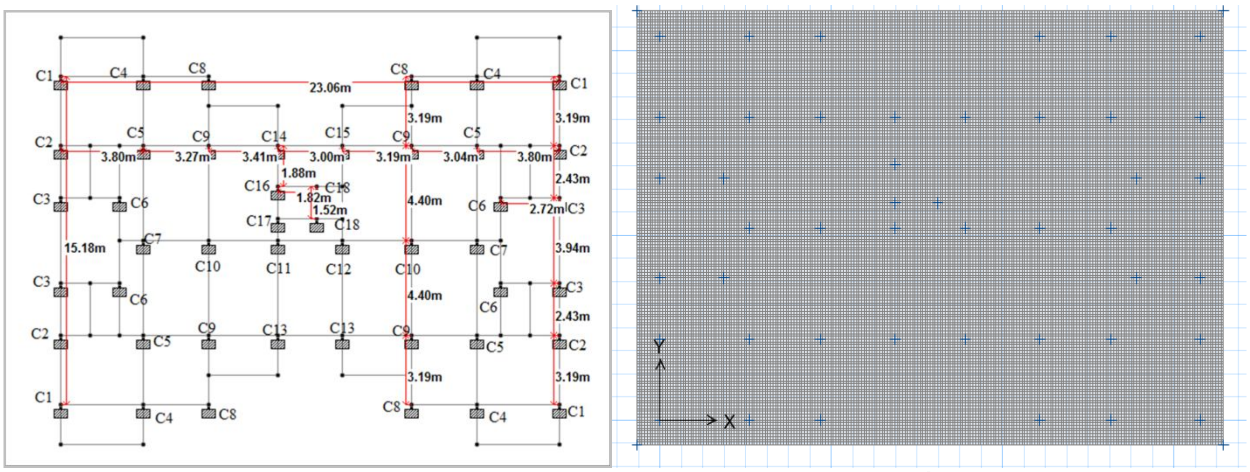


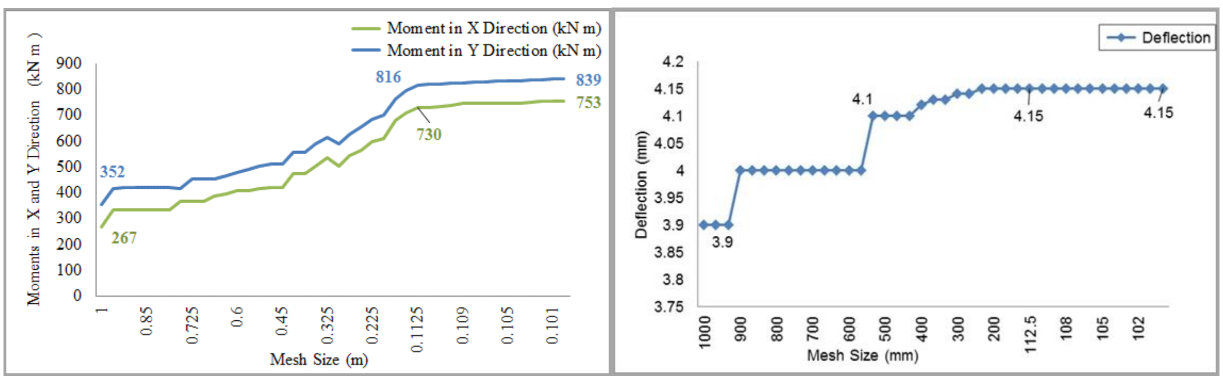
Figure 2. Building plan with column strip

The raft is modeled in SAFE software. The convergence is carried out to eliminate error due to mesh size. Element sizes from 1m x1m to 0.1125 m x 0.1125 m are considered with decrement of 0.1m in size in either direction. Based upon convergence study it is observed that, the mesh size 0.1125m x 0.1125m yields the converged results and they are opted for further parametric study. The meshing is shown in Figure 3 (b). Moment and deflection are the parameters considered for convergence study. These are indicated in Graph 1 (a) and (b).Convergence study is carried out for column strips A, B and C as shown in Figure 2.The study is carried out for computation of moment in x direction, moment in y direction and soil pressure beneath raft.



(a) (b)

Figure 3 . (a) Building Plan with column numbers (b) Mesh size 0.1125 m x 0.1125 m



(a) (b)

Graph 1. Convergence study for variation of mesh size (a) Moments (b) Deflection

Further study is carried out for the comparison of conventional approach and finite element approach. Study is carried out on three types of soil namely loose, medium and hard soil. The design parameters used for study is shown in Table 2.

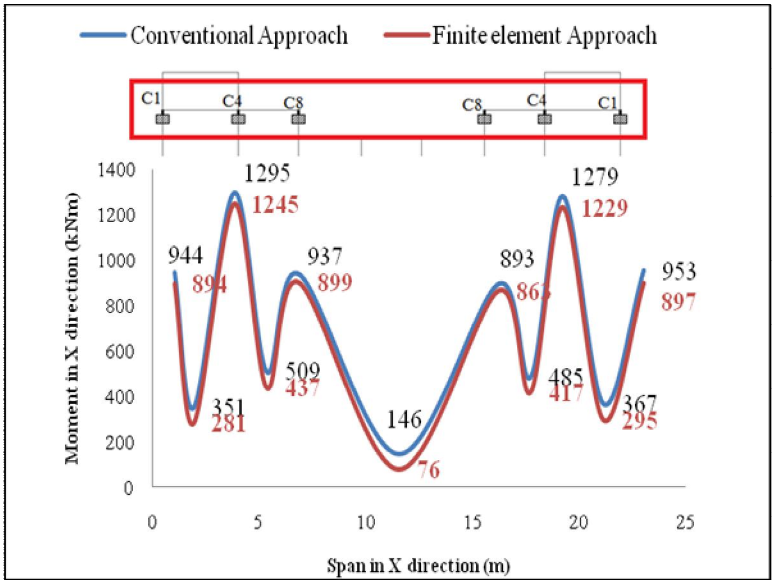
Table -2 Parameters considered in Raft Analysis

Parameters considered	Case 1	Case 2	Case 3
Soil Type	**Loose**	**Medium**	**Hard**
S.P.T value (As per IS:2950-Part I-1981)	**< 5**	**25**	**40**
S.B.C (kN / m^2)	**100**	**250**	**1000**
Maximum Permissible Settlement(mm) (As per IS:2950-Part I-1981)	**75**	**50**	**25**
Soil Modulus of elasticity (kN / m^2) (Bowles)	**1333**	**5000**	**40000**
Depth of Raft (mm)	**1500**	**1000**	**850**
Area of Raft Foundation (L x B)	**28 x 21**	**26.06 x 18.18**	**25.06 x 17.18**
Compressive Strength of Concrete Fck (N/mm^2)	**30**	**30**	**30**
Maximum Load Combination	**(1.5) D.L+L .L**	**(1.5) D.L+L .L**	**(1.5) D.L+L .L**

IV. RESULT AND DISCUSSION

After the analysis of raft by using conventional approach and finite element approach, Moment and soil pressure were studied & compared with the help of graphs presented below. It is pertinent to note that the raft considered has geometrical symmetry about either axes, however not perfectly symmetrical loading wise.

A. Moment in X Direction (Column strip C)



Graph 2.Variation of Moment in X direction (column strip C) for loose soil.

Graph 2 shows variation of moment in X direction for loose soil along column strip C (Refer Figure 2). As per as conventional approach, at column C1 a sagging bending moment is 944kNm.In between column C1 and C4, bending moment decrease from 944kNm to 351 kNm, which further increases and becomes 1295 kNm under column C4. Further bending moment decreases from1295kNm to 509 kNm at in between C4 and C8.Then the bending moment increase from 509kNm to 937 kNm at under column C8.The bending moment decrease to a minimum sagging value of 146 kNm at a center of strip C. Same trend of bending moment is observed on other half of the column strip. Therefore it can be seen that the bending moment beneath column location is higher in comparison with in between the column. Moreover bending moment beneath edge column is lower and for first intermediate column it increases, which goes on reducing towards the center of the column strip. However it is also observed that along the entire column strip the bending moment is sagging in nature.

Variation of bending moment for the same strip (column strip C), is also studied by finite element approach. It is observed that bending moment obtained by finite element approach is lesser as compared to the conventional approach. The finite element approach gives 281 kNm between C1 and C4 which is lower by 25% in comparison with conventional approach. Under column C4; bending moment obtained by finite element approach is lower by 4 % in comparison with conventional approach. At center of C4 and C8, finite element approach 437kNm (16.4%lower than conventional approach). Under column C8, finite element computes 899kNm which is 4.2% lower than conventional approach. In between two columns C8, bending moment is 92% lower than conventional approach. Overall finite element approach computes bending moment in X direction which is lower in comparison with conventional method, generally in range of 4% to 92%.
A typical stress contour of raft for loose soil using finite element approach is shown in Figure 4.

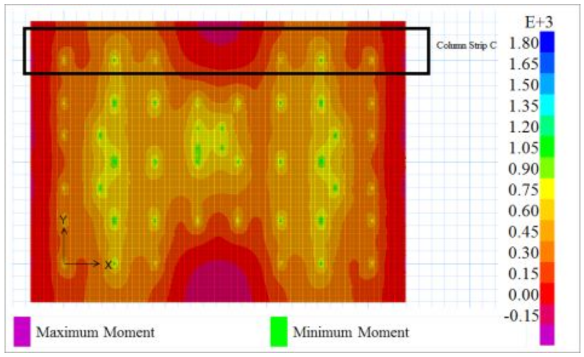
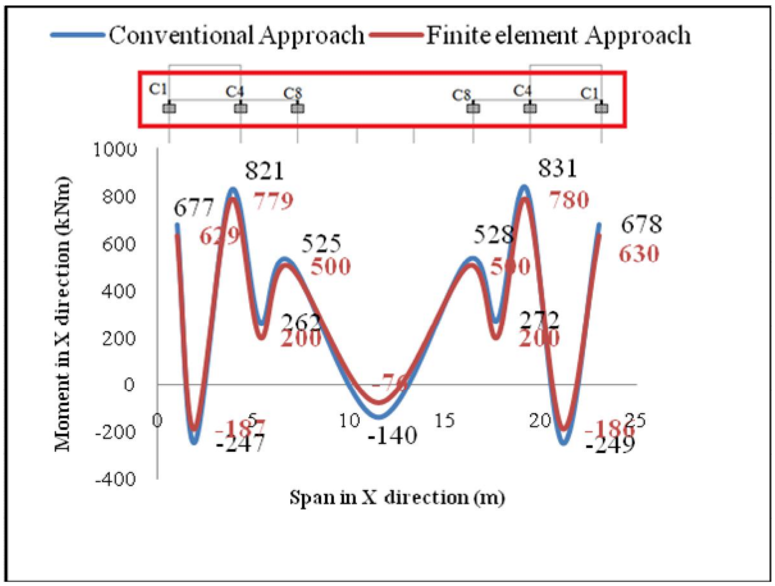


Figure 4 .Contour diagram of moment in X direction for loose soil



Graph 3.Variation of Moment in X direction (column strip C) for medium soil.

Graph 3 shows variation of moment in X direction for medium soil along column strip C (Refer Figure 2).As per as conventional approach, at column C1 a sagging bending moment of 677kNm. In between column C1 and C4, bending moment decrease from 677kNm (sagging) to 247kNm (hogging), this further increases and becomes 821 kNm (sagging) under column C4. Further bending moment decreases 821kNm (sagging) to 262 kNm(sagging) at in between C4 and C8.Then the bending moment increase from 262kNm (sagging) to 525 kNm (sagging) at under column C8.The bending moment decrease to minimum hogging 140 kNm at a center of strip C. Same trend of bending moment is presented for the remaining half of the column strip. It is observed that sagging bending moment is observed at column location and hogging bending moment is observed at middle panel.

Variation of bending moment for the same strip (column strip C), it studied by finite element approach. It is observed that bending moment obtained by finite element approach is lesser as compared to the conventional approach. The finite element approach gives 187kNm between C1 and C4 which is lower by 32% in comparison with conventional approach .Under column C4; bending moment obtained by finite element approach is lower by 5.4 % in comparison with conventional approach. At center of C4 and C8, finite element approach 200kNm (31% lower than conventional approach). Under column C8, finite element computes 500kNm which is 5% lower than conventional approach. In between two columns C8, bending moment is 84% lower than conventional approach. Overall finite element approach computes its bending moment in X direction which is lower generally in range of 5% to 84%.

In both the approaches, between edge and first intermediate column it is observed that a tension zone is developed indicating raft leaving contact with the sub soil. Also at the center of column strip tension zone is observed. However the intensity of tension developed at the center of the raft is of lower in comparison with those tension zone developed near the edge.

A typical stress contour of raft for medium soil using finite element approach is as shown above in Figure 5.

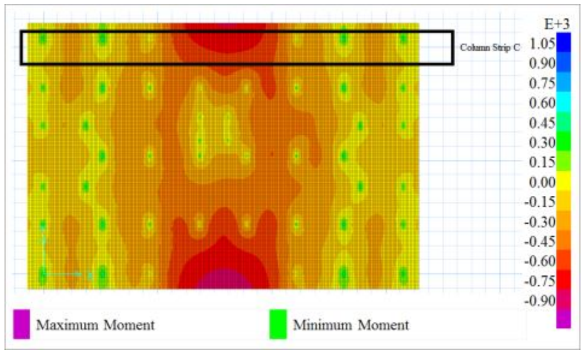
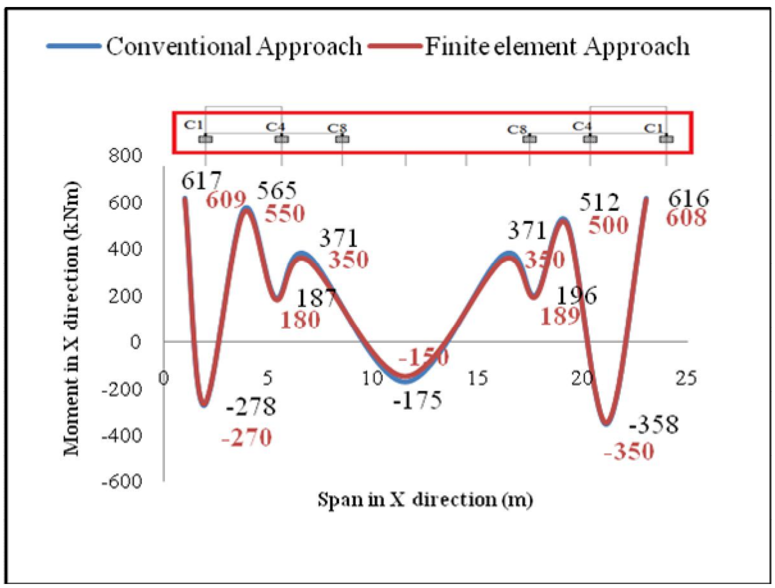


Figure 5. Contour diagram of moment in x direction for medium soil



Graph 4.Variation of Moment in X direction (column strip C) for hard soil.

Graph 4 shows variation of moment in X direction for hard soil along column strip C (Refer Figure 2). As per as conventional approach, at column C1 a sagging bending moment of 617kNm. In between column C1 and C4, bending moment decrease from 617kNm (sagging) to 278 kNm (hogging), this further increase and become 565 kNm (sagging) under column C4. Further bending moment decreases 565kNm (sagging) to 187 (sagging) kNm at in between C4 and C8.Then the bending moment increase from 187kNm (sagging) to 371(sagging) kNm at under column C8.The bending moment decrease to a minimum hogging 175 kNm at a center of strip C. Same trend of bending moment is presented for the remaining half of the column strip. It is observed that sagging bending moment is present at column location and hogging bending moment is present at middle panel.

Variation of bending moment for the same strip (column strip C), it studied by finite element approach. It is observed that bending moment obtained by finite element approach is lesser as compared to conventional approach. The finite element approach gives 270kNm at location of center of C1 and C4 which is lower by 3% in comparison with conventional approach. Under column C4, bending moment obtained by finite element approach is lower by

2.7% in comparison with conventional approach. At center of C4 and C8, finite element approach 180kNm (3.8% lower than conventional approach). Under column C8, finite element computes 350kNm, which is 6% lower than conventional approach. In between two columns C8, bending moment is 16.7% lower than conventional approach. Overall finite element approach computes its bending moment in X direction which is lower generally in range of 2.7 % to 16.7%.

Between edge and first intermediate column it is observed that a tension zone is developed indicating raft leaving contact with the sub soil. Also, at the center of column strip tension zone is observed. However the intensity of tension developed at the center of the raft is higher intensity in comparison with medium soil.

Considering the variation of bending moment in X direction for all type of soil, same trend is observed for all type of soil. It is observed that, in case of loose soil the bending moment remains sagging in nature along entire column strip. With increasing stiffness of soil, tension zone are getting developed. As the stiffness of the soil increases it is observed that as one travels from edge towards center, the intensity of bending moment in tension zone increases. The extent of influence of tension zone increases as well. A typical stress contour of raft for hard soil using finite element approach is shown in Figure 6.

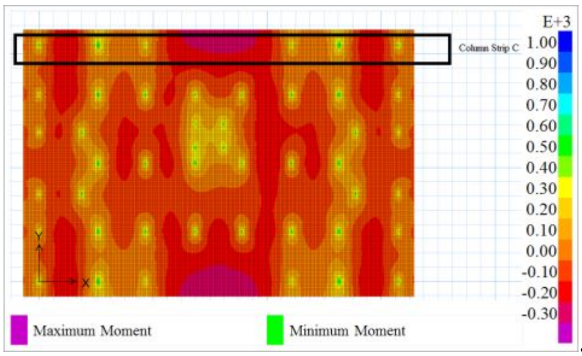
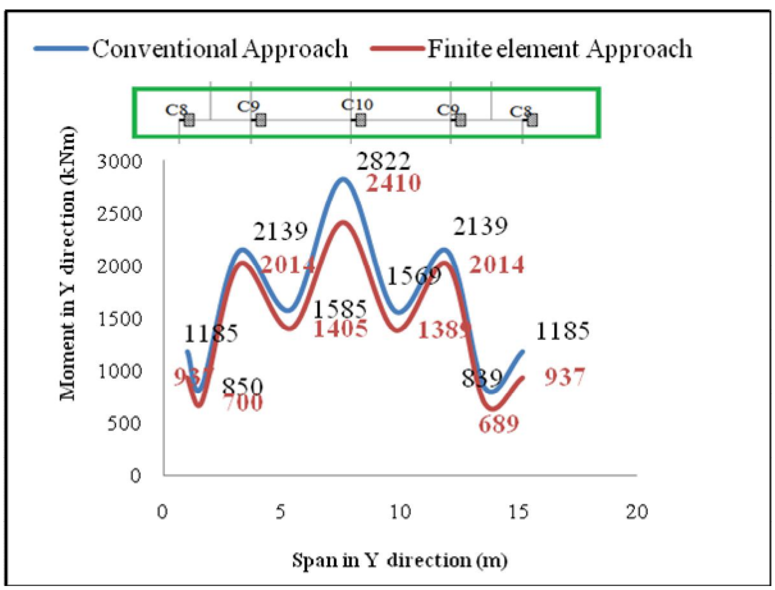


Figure 6. Contour diagram of moment in X direction for hard soil

B. Moment in Y Direction (Column strip A)



Graph 5.Variation of Moment in Y direction (column strip A) for loose soil.

Graph 5 shows variation of moment in Y direction for loose soil along column strip A (Refer Figure 2). As per conventional approach, at column C8 a sagging bending moment of 1185kNm. In between column C8 and C9, bending moment decrease from 1185kNm to 850 kNm, this is a further increase and becomes 2139 kNm under column C9. Further bending moment decreases 2139kNm to 1585 kNm at in between C9 and C10.Then the bending moment increase from 1585 kNm to 2822 kNm at under column C10. Same trend of bending moment is observed on other half of the column strip. Therefore it can be seen that the bending moment beneath column location is higher in comparison with in between the column. Moreover bending moment beneath edge column is lower and for first intermediate column it increases, which goes on increase towards the center of the column strip. However it is also observed that along the entire column strip the bending moment is sagging in nature.

Variation of bending moment for the same strip (column strip A), is also studied by finite element approach. It is observed that bending moment obtained by finite element approach is lesser as compared to conventional approach. The finite element approach gives 850 kNm between C8 and C9 which is lower by 21.4% in comparison with conventional approach. Under column C9; bending moment obtained by finite element approach is lower by 6.2 % in comparison with conventional approach. At center of C9 and C10, finite element approach 1585 kNm (12.8% lower than conventional approach). Under column C10, finite element computes 2410kNm which is 17% lower than conventional approach. Overall finite element approach computes its bending moment in Y direction which is lower generally in range of 6.2 % to 21.4%.
A typical stress contour of raft for loose soil using finite element approach is shown in Figure 7.

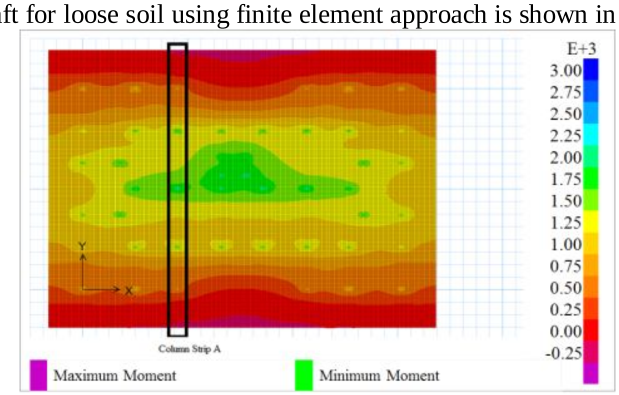
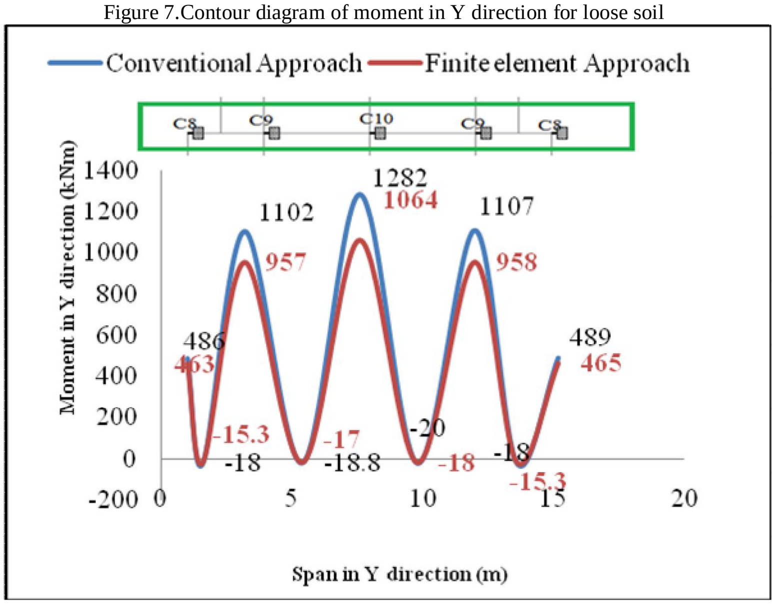


Figure 7.Contour diagram of moment in Y direction for loose soil



Graph 6.Variation of Moment in Y direction (column strip A) for medium soil.

Graph 6 shows variation of moment in Y direction for medium soil along column strip A (Refer Figure 2).As per conventional approach, at column C8 a sagging bending moment of 486 kNm. In between column C8 and C9, bending moment decrease from 486kNm (sagging) to 18 kNm (hogging), this further increase and become 1102 kNm (sagging) under column C9. Further bending moment decreases 1102kNm (sagging) to 18.8 kNm (hogging) at in between C9 and C10.Then the bending moment increase from 18.8kNm (hogging) to 1282 kNm (sagging) at under column C10. Same trend of bending moment is presented for the remaining half of the column strip. It is observed that sagging bending moment is present at column location and hogging bending moment is present at middle panel.

Variation of bending moment for the same strip (column strip A) , it studied by finite element approach. It is observed that bending moment obtained by finite element approach is lesser as conventional approach. The finite element approach gives 15.3 kNm between of C8 and C9which is lower by 17.6% in comparison with conventional approach. Under column C9; bending moment obtained by finite element approach is lower by 15.1% in comparison with conventional approach. At center of C9 and C10, finite element approach 17kNm (10.5% lower than conventional approach). Under column C10, finite element approach is lower by 20 % in comparison with conventional approach. Overall finite element approach computes its bending moment in Y direction which is lower generally in range of 10 % to 17.6%.

Between edge and first intermediate column it is observed that a tension zone is developed indicating raft leaving contact with the sub soil. Also at the center of column strip tension zone is observed. However, the intensity of tension developed at the center of the raft is of lower intensity in comparison with the tension zone developed near the periphery. A typical stress contour of raft for medium soil using finite element approach is shown in Figure 8.

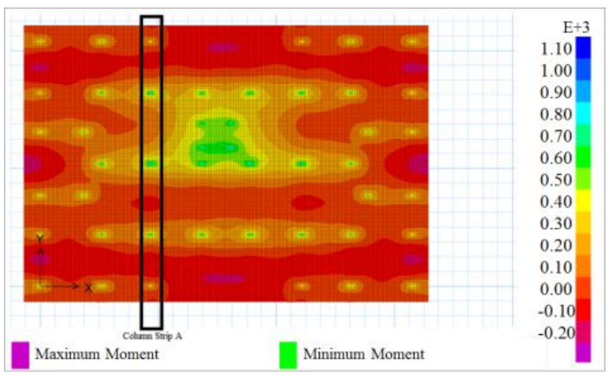
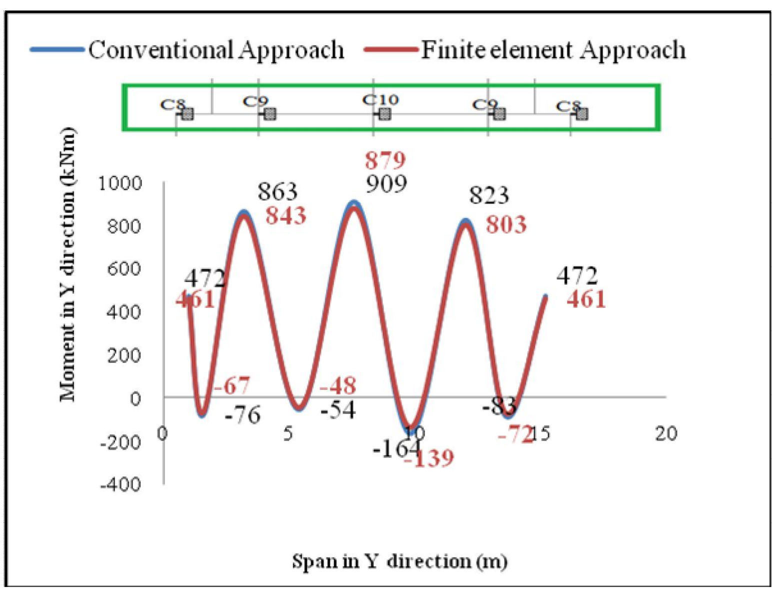


Figure 8. Contour diagram of moment in Y direction for medium soil.



Graph 7.Variation of Moment in Y direction (column strip A) for hard soil.

Graph 7 shows variation of moment in Y direction for hard soil along column strip A (Refer Figure 2). As per conventional approach, at column C8, a sagging bending moment of 472 kNm. In between column C8 and C9, bending moment decrease from 472kNm (sagging) to 76 kNm (hogging), this further increase and become 863 kNm(sagging) under column C9. Further bending moment decreases 863kNm (sagging) to 54 kNm (hogging) at in between C9and C10.Then the bending moment increase from 54kNm (hogging) to 909 kNm (sagging) at under column C10. The bending moment decrease to a minimum hogging 164 kNm at a center of strip C. Same trend of bending moment is presented for the remaining half of the column strip. It is observed that sagging bending moment is present at column location and hogging bending moment is present at middle panel.

Variation of bending moment for the same strip (column strip A), it studied by finite element approach. It is observed that bending moment obtained by finite element approach is lesser as compared to conventional approach. The finite element approach gives 67kNm between of C8 and C9 which is 13.4% in comparison with conventional approach. Under column C9; bending moment obtained by finite element approach is lower by 2.3 % in comparison with conventional approach. At center of C9 and C10, finite element approach 48kNm (12.5 % lower than conventional approach). Under column C10, finite element approach is lower by 3.4 % in comparison with conventional approach. Overall finite element approach computes its bending moment in Y direction which is lower generally in range of 2.3 % to 13.4%.

Between edge and first intermediate column it is observed that a tension zone is developed indicating raft leaving contact with the sub soil. Also, at the center of column strip tension zone is observed. However the intensity of tension developed at the center of the raft is higher intensity in comparison with medium soil.

Considering the variation of bending moment in Y direction for all type of soil, same trend is observed for all type of soil .It is observed that, in case of loose soil the bending moment remains sagging in nature over entire column strip. With increasing stiffness of soil, tension zone are getting developed. As the stiffness of the soil increases it is observed that as one travels from edge towards center, the intensity of bending moment in tension zone increase. As well the extent of influence of tension zone increases. A typical stress contour of raft for hard soil using finite element approach is shown in Figure 9.

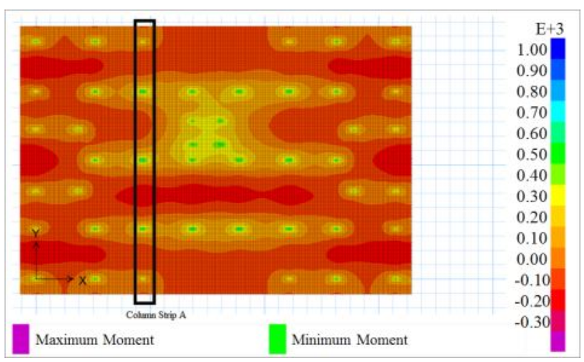
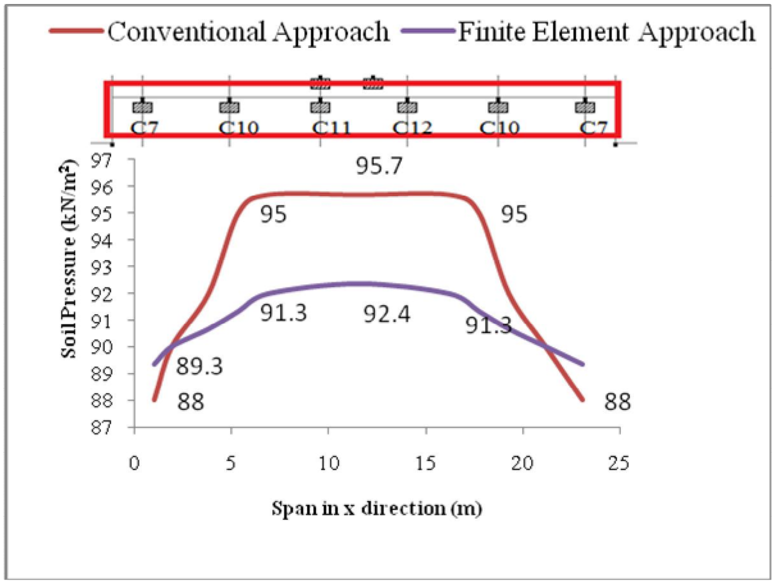


Figure 9. Contour diagram of moment in Y direction for hard soil.

C. Soil Pressure (Column strip B)



Graph 8.Variation of soil pressure in X direction (column strip B) for loose soil.

Graph 8 shows variation of soil pressure in X direction for loose soil along column strip B (Refer Figure 2). As per conventional approach, near edge soil pressure is as low as 88 kN/m^2 which further increase steeply to 95 kN/m^2 beneath column C7. There afterwards it is nearly constant up to the center of column strip. Same trend is observed on other side also. In between column C7and C10, soli pressure increases from 88 kN/m^{2}to 95 kN/m^2.By finite element method the same trend is observed .However as we travel towards center the rate of increase of soil pressure is becoming milder. It is observed that soil pressure obtained finite element methods are very much lower especially in central portion of column strip in comparison with conventional method.

Variation of soil pressure for the same strip (column strip B), is also studied by finite element approach. It is observed that soil pressure obtained by finite element approach is lesser as compared to conventional approach. The finite element approach gives 89.3kN/m^2 at center of C7 which is more by 1.47 % in comparison of conventional approach. Under column C10, soil pressure obtained by finite element approach is lower by 4% in comparison of conventional approach. Overall finite element approach computes soil pressure in X direction which is lower generally in range of 1.47 % to 4 %.

A typical stress contour of raft for loose soil using finite element approach is shown in Figure 10.

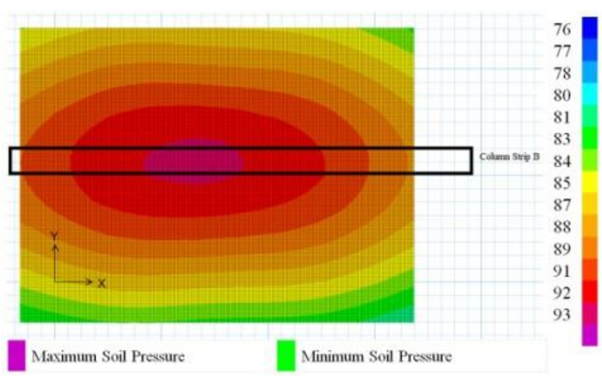
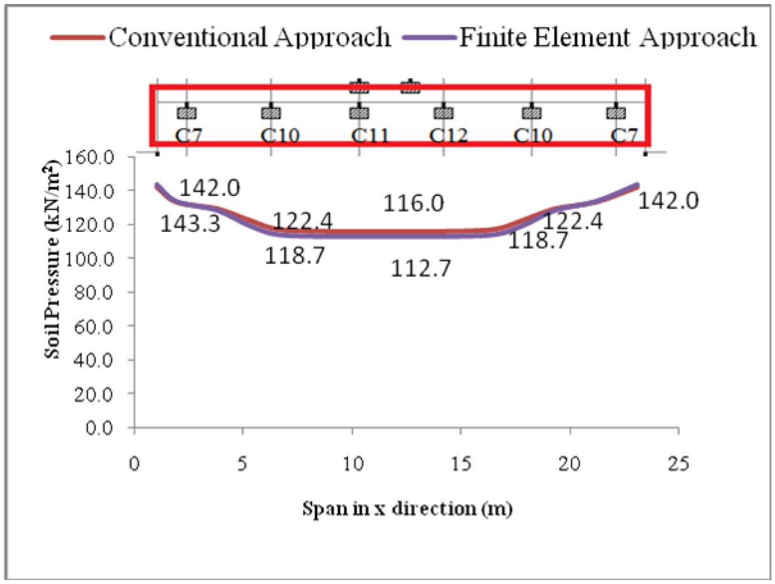


Figure 10. Contour Diagram of soil pressure for loose soil.



Graph 10.Variation of soil pressure in X direction (column strip B) for medium soil.

Graph 10 shows variation of soil pressure in X direction for medium soil along column strip B (Refer Figure 2).With soil becoming soil pressure distribution beneath the strip is tending towards uniformity. However now the pressure near the edge is highest and decreases as we proceed toward center. In the central portion the soil pressure is found to be nearly uniform. It is observed that soil pressure obtained finite element methods are very much lower in comparison with conventional method.

Variation of soil pressure for the same strip (column strip B), is also studied by finite element approach. The finite element approach gives142 kN/m^2 at center of C7 which is 0.91 % more than conventional approach. Under column C10, soil pressure obtained by finite element approach is 3.1% more than conventional approach. Overall finite element approach computes soil pressure in X direction which is generally in range of 0.91 % to 3.1%.
A typical stress contour of raft for medium soil using finite element approach is shown in Figure 11.

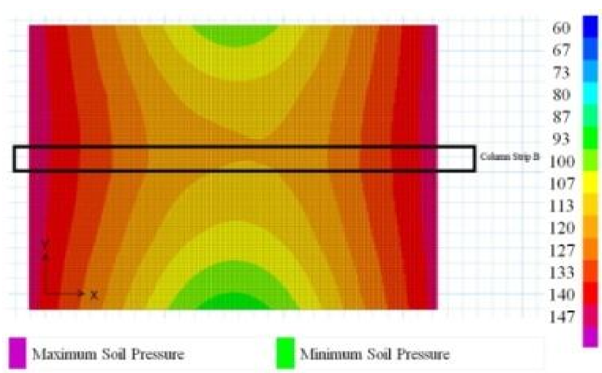
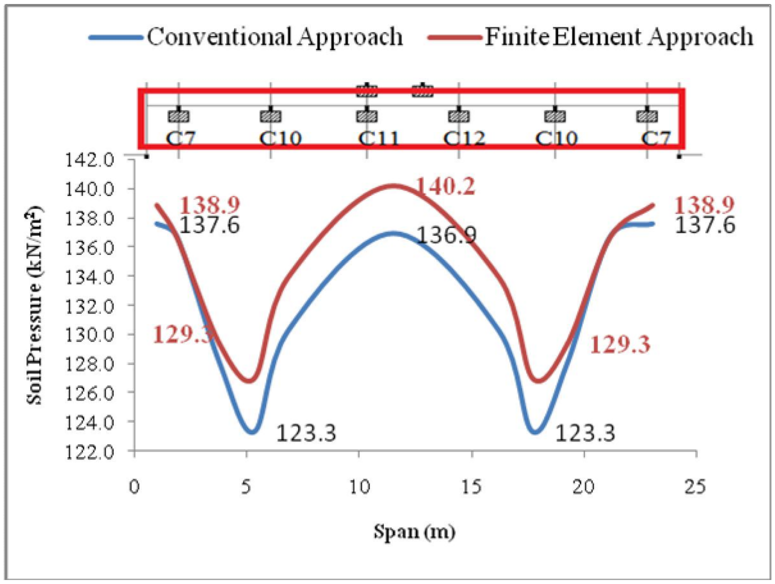


Figure 11. Contour Diagram of soil pressure for medium soil.



Graph 11.Variation of soil pressure in X direction (column strip B) for hard soil.

Graph 11 shows variation of soil pressure in X direction for hard soil along column strip B (Refer Figure 2). As per conventional approach, near edge soil pressure is as more as 137.6 kN/m^2 which further decreases steeply to123.3 kN/m^2 beneath column C10. Then after words in between column C10 to C11 soil pressure suddenly increase from 123.3 kN/m^2 to 136.9kN/m^2. Same trend is observed on other side also. By finite element method the same trend is observed. It is observed that soil pressure obtained finite element methods are very much lower in comparison with conventional approach.

Variation of soil pressure for the same strip (column strip B), is also studied by finite element approach. The finite element approach gives 138.9kN/m^2 at center of C7 which is 0.94% more than conventional approach. Under column C10 to C12, soil pressure obtained by finite element approach is 4.8% to 2.4% more than conventional approach. Overall finite element approach computes soil pressure in X direction which is generally in range of 0.94 % to 4.8%. This revels that finite element approach computes soil pressure for every node and it is more accurate as compared to conventional approach. A typical stress contour of raft for hard soil using finite element approach is shown in Figure 12.

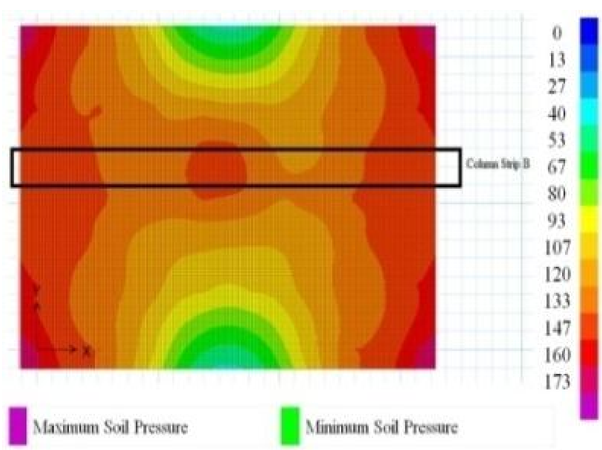


Figure 12.Contour Diagram of soil pressure for hard soil.

V. CONCLUSION

From the present investigation following conclusion is drawn;

1. The results obtained from, conventional approach and finite element approach are of same nature and trend. However, finite element approach computes lesser bending moment in compression to conventional approach-in X and Y direction.
2. For loose soil bending moment is sagging in nature; over entire of raft. However, as soil stiffness increases tension zone is created. From the edge as we proceed toward centre the intensity and extent of tension zone goes increasing. However, the effect is more in X direction as compared to Y direction.
3. For loose soil, pressure distribution beneath the raft is lower at edge and goes on increasing towards the centre. In the central zone, in between column, it remains almost constant. For medium soil, at the edge, pressure distribution is high and goes on reducing towards the centre with very mild rate. For hard soil, pressure distribution at the edges is high, reduces under the edge columns and then after increases in the central part.
4. Overall it is observed that, the conventional approach overestimates the bending moment in X and Y direction for loose and medium soil. However, as stiffness of the soil increases the difference between conventional approach and finite element approach reduces and becomes almost negligible in case of hard soil. Therefore, finite element approach for loose and medium soil is recommended for getting more precise results.

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