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Soil Interaction of Building frame Resting on Clayey Soil: Effect of Change of Aspect ratio

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Abstract: ***In General the framed structures are analyzed by considering that their bases are totally rigid (or) hinged. However, depending on relative rigidities of soil foundation and super structure the foundation undergoes deformation. In structural design the designers ignore the settlement response of the framed structure. The distribution of load on column and moment in framed structure transmitted to the foundation in the substructure has a crucial role in structural stiffness. Hence the analysis of the single bay single storied building frame resting on soil (CLAYEY SOIL) is taken for present study. The numerical analysis is carried out using ANSYS R16.0 by assuming that the base of the frame is resting on Soil (CLAYEY SOIL). The constant column height of 3M, while beam length varies of 6M,12M, &18M and their respective aspect ratio's of 2,4&6. And for each aspect ratio the modulus of sub-grade reaction for clayey soil varies from 0.01 to 0.050N/mm^3. The conventional analysis which assumes that the frame is resting on rigid support is carried out using ANSYS R16.0 by assuming the fixed base for the columns in the building frame when modulus of sub grade reaction varies from 0.01 to 0.050 N/mm^3. The following conclusions have been drawn from the study, The percentage difference of shear force and bending moment in the beam, The axial load, shear force and, bending moment values in the column, and The bending moment values (Mx)&(Mz) in the shell and footing settlements in the shell for various aspect ratios of the frame obtained from both conventional and finite element analysis are not having considerable difference. Comparing numerical analysis which considers soil interaction with the conventional method, the conventional analysis is shown higher values SF and B.M in the beam, footing and columns. In conventional analysis it is assumed that the footings are resting on a rigid medium so footing settlements are zero. While observing the footing settlements in reality they undergo with some settlement therefore these settlement values are observed for numerical analysis which are used for the design to satisfy codal requirements.***

Index ***Terms*****:** ***Ansys, Building frame clayey soils, subgrade modulus, soil structure interaction.***

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I. INTRODUCTION

Soil undergoes deformation depending upon the super structure and behaviour of the soil. Soil structure interaction is gaining more importance now days. To analyze the soil settlements, structural deformations soil structure interaction is more helpful. Structural stiffness have huge role to distribute superstructure loads to foundation of the structure. For framed structures increasing the stiffness reduces the differential settlements. Soil structure interaction is very useful to design heavy structures like hydraulic, nuclear and earth quake resistance structures. In conventional method of analysis assumes that structure resting on a rigid medium which will not deform at all.

[1] The theory of sub grade modulus is explained by J.E Bowles. Sub grade modulus is the relationship between pressure of the soil and deflection which is used in sub structure members. It is used for continuous, mats and various types of footings. The range of sub grade modulus varies with different soil. Modulus of sub- grade reaction also called as sub grade modulus.

Table I: Sub grade modulus for different soils (J.E Bowles Foundation analysis and design 5th edition)

SOILS	$k_{s,}$ KN/m^3
Loose sand	4800-16000
Medium dense sand	9600-8000
Dense sand	64000-128000
Clayey medium dense sand	32000-24000
Silty medium dense sand	24000- 48000
Clayey soil	12000-48000(varies based on q_a)

To estimate value of $k_{s,}$ the sub grade modulus above approximations is explained .The present study the effect of soil interaction observed in clayey soils. [2] Prakash M.Yesane (2019) Introduced the research method of soil interaction. This study gives the complexity and excessive simplification of the structure and also for soil. To summarize this attempt was made; various researchers tabulated the behavior of soil structure interaction. The live problems and future research are also examined in this field. [3] The external loads are resisted by the complete structural system which is framed by types of foundation and building frame. Major loss of human life and economy is caused by displacement of the structure which is due to the failure of the foundation in earthquake zones. The design criteria and stability of structure have a great impact based on foundation soil, footings and footing types. An attempt was made Jigyasu Chourasia (2018),to find the foundation effect and displacement of the four storied structure without and with square footing, which is a one bay frame rests on different soil conditions under dynamic loading by using Ansys Workbench R16.0, which is FEM software. During the earthquake we know that foundation fails which influences the interaction effect between foundation and soil, the interaction effect and behavior of foundation play key role in analysis of a structure. From that FEM analysis while observing the results it indicates the adding of footing in under reamed single friction pile which shows the effect on structural dynamic response when compared with piles without footing. [4] Ravi Kumar Reddy and T. D. Gunneswara Rao (2017).Presented the results of a building frame with geo textile plinth beam supported by piles under static vertical load test embedded in cohesion less soil. The above results are compared with the conventional analysis and non linear finite element analysis. By observing the results shows that conventional analysis have 50% S.F and B.M and at the top of the column about 17% and base of the column about 50-98% grater values given by nonlinear finite element analysis of the frame. [5] K. Chandra shekharaa (1998), explained in this paper by using FEM stiffness matrices are obtained for footings. By using analytical solution of the stiffness matrix obtained for reinforced soil for next reinforced zone idealized as (i) an equivalent orthotropic infinite strip (composite approach) and (ii) a multilayered system (discrete approach). In the analysis, the interface between the reinforced half plane and strip footing has been assumed as (i) frictionless and (ii) fully bonded. In soil for different footing depths and arrangement of the reinforcement, the pressure distribution and settlement reductions are given. [6], The study by Khare and Chore (2016, 3D 4 nodded shell element slabs are for all the stories including ground level, 3D 2 nodded beam elements for super structural beams and columns, for piles 3D 6 nodded beam elements are provided. For analysis of the frame finite element software ETABS was used. In this case study it is observed that the effect of one pile when it is fixed and the interaction of the soil structure effect on the super structural response, this response is considered top displacements of the frame and column moments. [7] Janardhan Shanmugam (2015). Soil structural interaction of a four storied 2 bay frame which is resting on a pile which is embedded in cohesive soil, theory of finite element is used for simple idealization. 3D 2 nodded beam elements for super structural beams and columns, for piles 3D 6 nodded beam elements are provided. ANSYS software is used for the purpose of analysis in this case study the response of the super structure with different pile diameters are evaluated. Interaction of soil and structures which involves the geotechnical and structural engineering which is an integrity field. It is assumed that for analysis columns are resting on rigid support for conventional and non interactional analysis this is repeated for foundation settlements and design without considering structural stiffness. To simplify the mathematical model the interaction effect is ignored while neglecting the interaction effect in the design considerations then the structure is not safe and effected to more cost. Soil structure interaction from time to time various researchers are evaluated possible solutions. And the study on the possible alternative solutions was made by Vivek Gargh & M.S.Hora. The detailed review of literature confirms that there is a need for the study of building frame resting on the soil media with different aspect ratios.

II. METHODOLOGY

A. Conventional Analysis: A single bay single storied building frame is modeled and analyzed using the software ANSYS R.16.0. The conventional method of analyzing assumes the base of the column to be resting on a rigid medium which will not deform at all. Hence the columns in the building frame is provided with the fixed bases in the model generated using ANSYS. sub grade reaction varies from 0.01 to 0.50 N/mm^3.

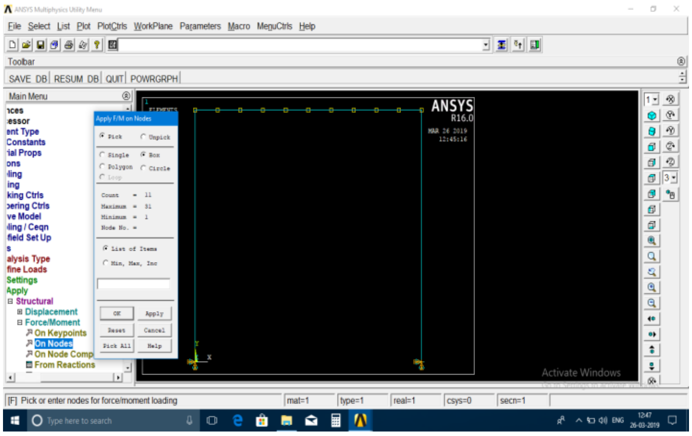

Fig. 1. Applying force moment

B. Numerical Analysis: The effect of soil interaction on the design parameters in a single bay single storied building frame with constant column height 3M and the beam length values 6M, 12M & 18M and their respective aspect ratios 2, 4 & 6 have been analyzed. For each aspect ratio the modulus of sub-grade reaction for clayey soil is varied from 0.01 to 0.05 N/mm^3.

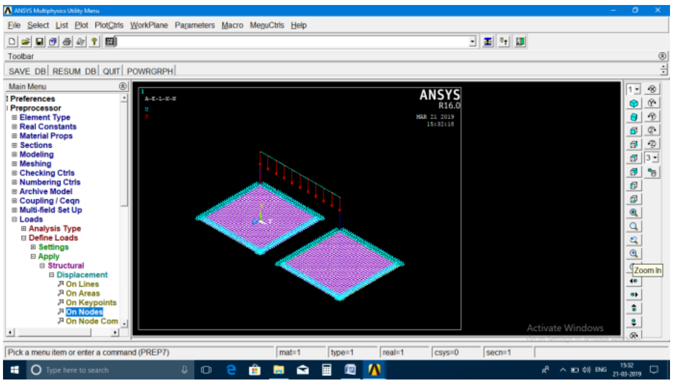

Fig. 2. Boundary conditions

III. RESULTS

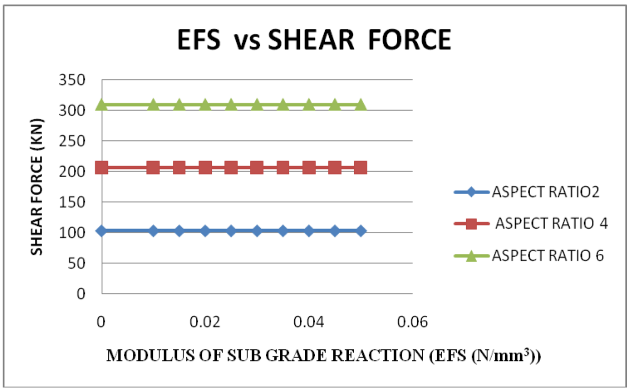

Fig. 3. Shear force in beam

From Fig. 3 By observing shear force in the beam from conventional method and numerical method of analysis is varying linearly. As the aspect ratio increases from 2 to 6 the shear force values also increased.

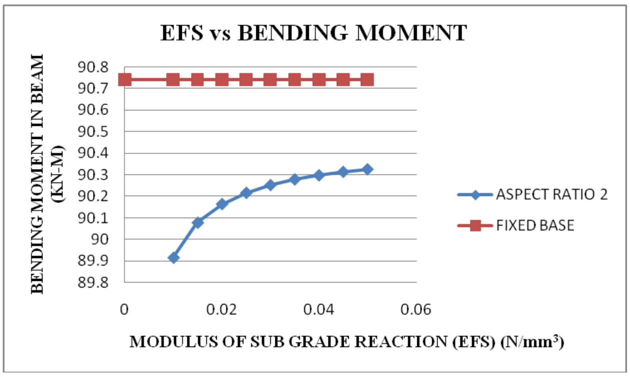

Fig. 4. Bending moment in the beam of aspect ratio 2

From Fig.4 By observing bending moment in the beam is varying nonlinearly with respect to sub grade modulus. As the sub grade modulus increased from 0.01 - 0.05 N/mm^3 the difference in bending moment between conventional and numerical is decreased by 47.6%. This indicates that, as the soil is getting rigid the bending moment from numerical analysis is approaching the conventional value. Hence if the soil is rigid enough the effect of soil interaction can be reduced.

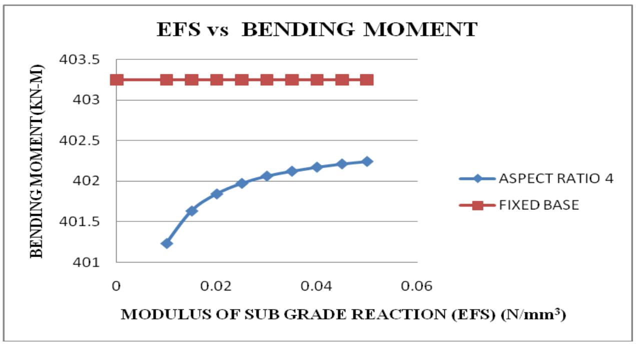

Fig. 5. Bending moment in the beam of aspect ratio 4

From Fig.5 By observing bending moment in the beam is varying nonlinearly with respect to sub grade modulus. As the sub grade modulus increased from 0.01 - 0.05 N/mm^3 the difference in bending moment between conventional and numerical is decreased by 50.09%. This indicates that, as the soil is getting rigid the bending moment from numerical analysis is approaching the conventional value. Hence if the soil is rigid enough the effect of soil interaction can be reduced.

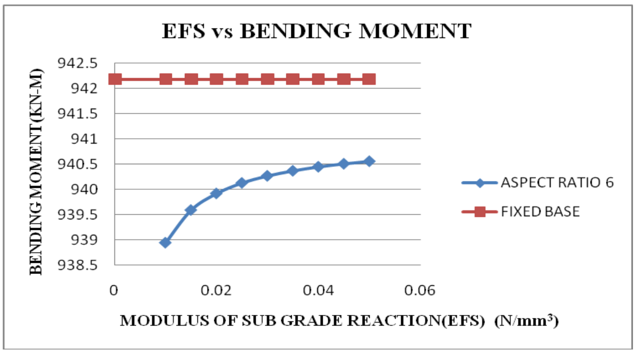

Fig. 6. Bending moment in the beam of aspect ratio 6

From Fig.6 By observing bending moment in the beam is varying nonlinearly with respect to sub grade modulus. As the sub grade modulus increased from 0.01 - 0.05 N/mm^3 the difference in bending moment between conventional and numerical is decreased by 50.14%. This indicates that, as the soil is getting rigid the bending moment from numerical analysis is approaching the conventional value. Hence if the soil is rigid enough the effect of soil interaction can be reduced.

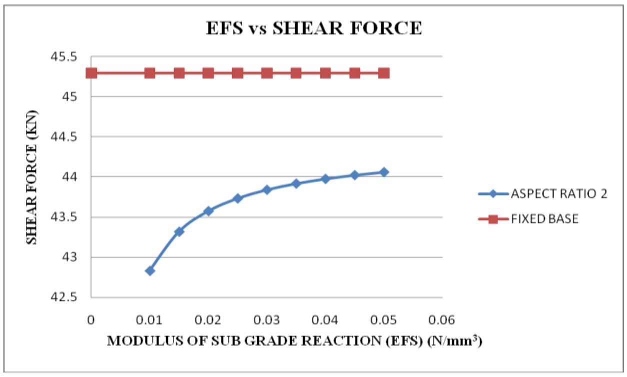

Fig. 7. Shear force in the coloumn of aspect ratio 2

From Fig.7 By observing shear force in the column is varying nonlinearly with respect to sub grade modulus. As the sub grade modulus increased from 0.01 - 0.05 N/mm^3 the difference in bending moment between conventional and numerical is decreased by 51.47%. This indicates that, as the soil is getting rigid the bending moment from numerical analysis is approaching the conventional value. Hence if the soil is rigid enough the effect of soil interaction can be reduced.

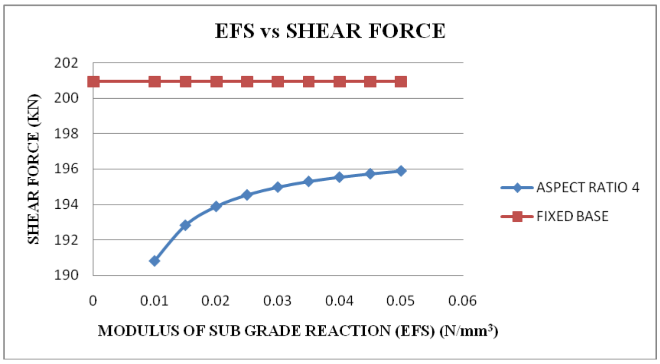

Fig. 8. Shear force in the coloumn of aspect ratio 4

From Fig.8 By observing shear force in the column is varying nonlinearly with respect to sub grade modulus. As the sub grade modulus increased from 0.01 - 0.05 N/mm^3 the difference in bending moment between conventional and numerical is decreased by 51.48%. This indicates that, as the soil is getting rigid the bending moment from numerical analysis is approaching the conventional value. Hence if the soil is rigid enough the effect of soil interaction can be reduced.

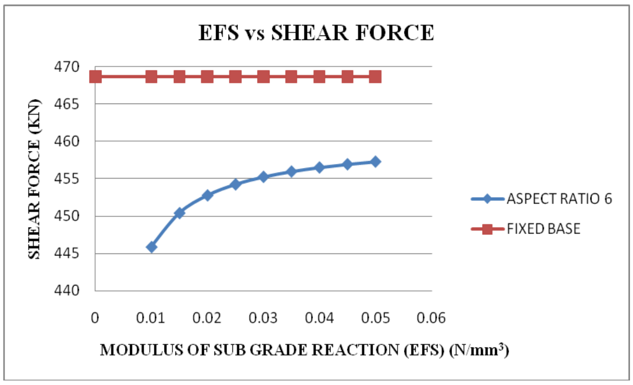

Fig. 9. Shear force in the coloumn of aspect ratio 6

From Fig.9 By observing shear force in the column is varying nonlinearly with respect to sub grade modulus. As the sub grade modulus increased from 0.01 - 0.05 N/mm^3 the difference in bending moment between conventional and numerical is decreased by 51.56%. This indicates that, as the soil is getting rigid the bending moment from numerical analysis is approaching the conventional value. Hence if the soil is rigid enough the effect of soil interaction can be reduced.

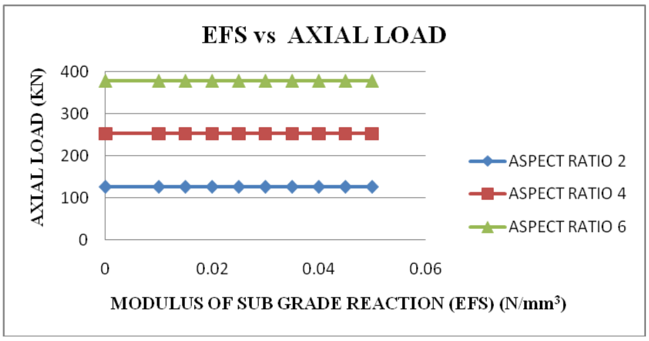

Fig. 10. Axial load in column

From Fig. 10 By observing axial load in the beam from conventional method and numerical method of analysis is varying linearly and equal. Where EFS value increases in numerical method axial load value is 126160N for ASPECT RATIO 2, the axial load value is252320N for ASPECT RATIO 4 and the axial load value is 378490N for ASPECT RATIO 6.

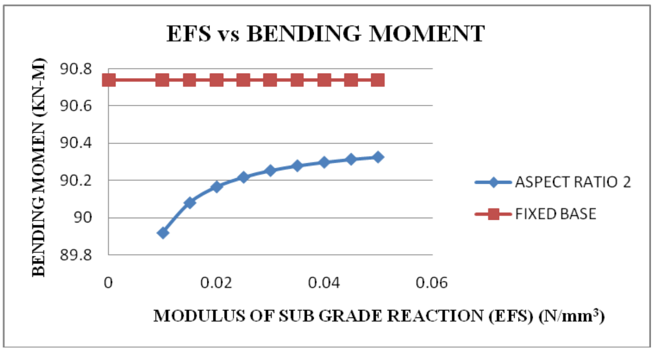

Fig. 11. Bending moment in the column of aspect ratio 2

From Fig.11 By observing bending moment in the column is varying nonlinearly with respect to sub grade modulus. As the sub grade modulus increased from 0.01 - 0.05 N/mm^3 the difference in bending moment between conventional and numerical is decreased by 47.6%. This indicates that, as the soil is getting rigid the bending moment from numerical analysis is approaching the conventional value. Hence if the soil is rigid enough the effect of soil interaction can be reduced.

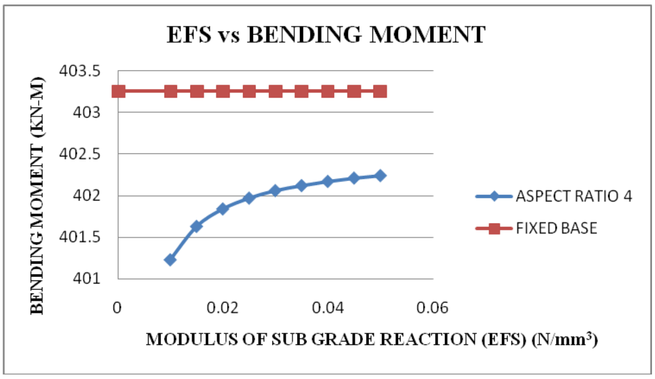

Fig. 12. Bending moment in the column of aspect ratio 4

From Fig.12 By observing bending moment in the column is varying nonlinearly with respect to sub grade modulus. As the sub grade modulus increased from 0.01 - 0.05 N/mm^3 the difference in bending moment between conventional and numerical is decreased by 50.09%. This indicates that, as the soil is getting rigid the bending moment from numerical analysis is approaching the conventional value. Hence if the soil is rigid enough the effect of soil interaction can be reduced.

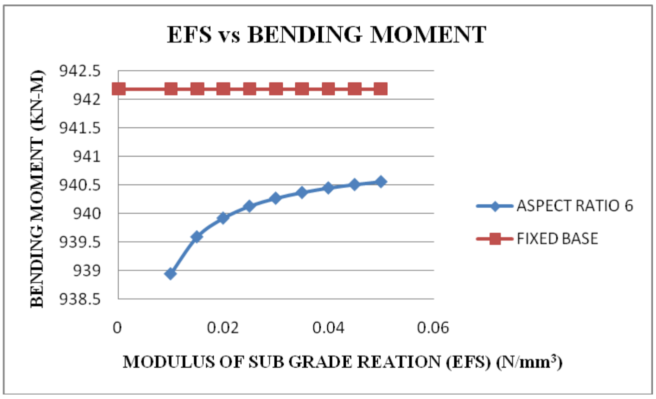

Fig. 13. Bending moment in the column of aspect ratio 6

From Fig.13 By observing bending moment in the column is varying nonlinearly with respect to sub grade modulus. As the sub grade modulus increased from 0.01 - 0.05 N/mm^3 the difference in bending moment between conventional and numerical is decreased by 50.14%. This indicates that, as the soil is getting rigid the bending moment from numerical analysis is approaching the conventional value. Hence if the soil is rigid enough the effect of soil interaction can be reduced.

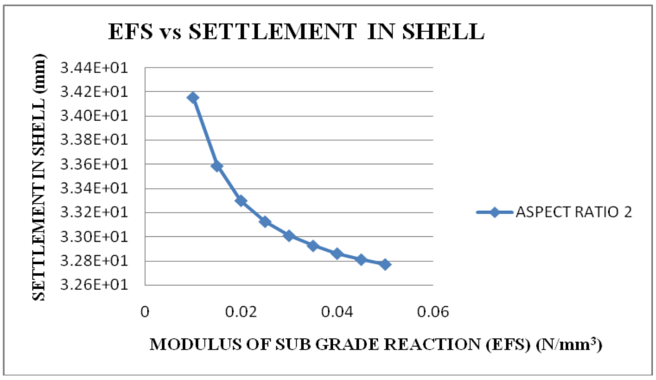

Fig. 14. Settlement in shell of aspect ratio 2

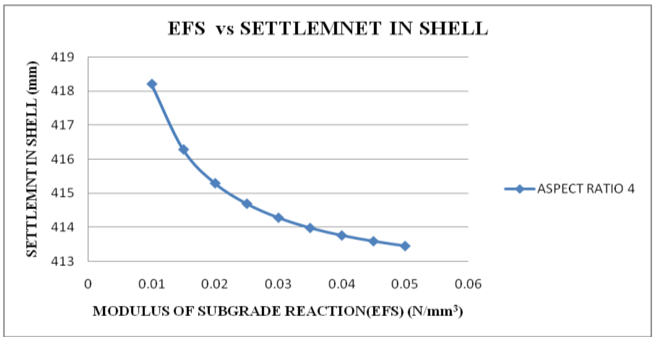

Fig. 15. Settlement in shell of aspect ratio 4

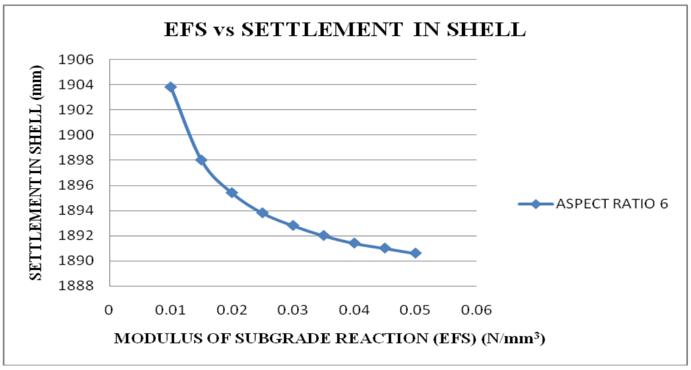

Fig. 16. Settlement in shell of aspect ratio 6

From Figs. 14, 15&16 By observing settlement in the shell is varying nonlinearly with respect to sub grade modulus. As the sub grade modulus increased from 0.01-0.05 N/mm^3 the difference in settlement is decreased by 83.45% from aspect ratio increased 2-6.

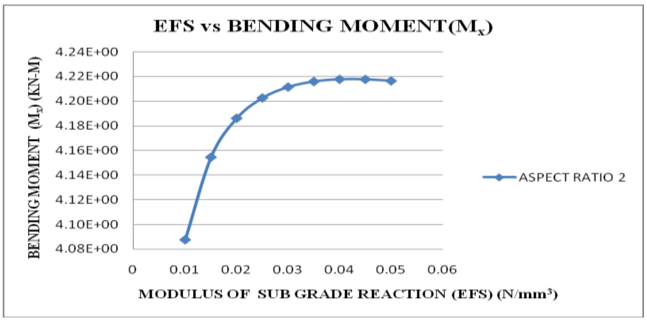

Fig. 17. Bending moment (m_x) in shell of aspect ratio 2

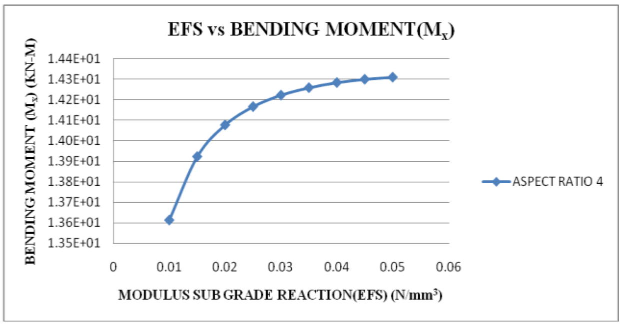

Fig. 18. Bending moment (m_x) in shell of aspect ratio 4

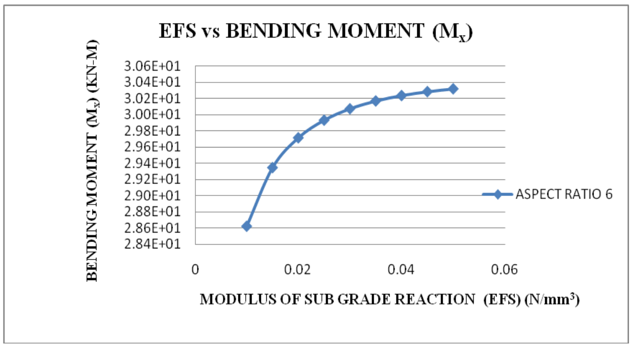

Fig. 19. Bending moment (m_x) in shell of aspect ratio 6

From Fig.17, 18 & 19 By observing bending moment (M_x) is in the shell is varying nonlinearly with respect to sub grade modulus.

As the sub grade modulus increased from 0.01 - 0.05 N/mm^3 the difference of bending moment is increased by 88.53% from aspect ratio 2-6.

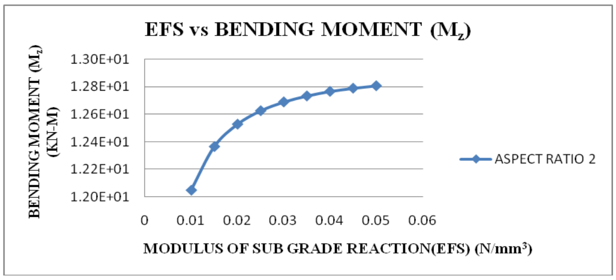

Fig. 20. Bending moment (m_z) in shell of aspect ratio 2

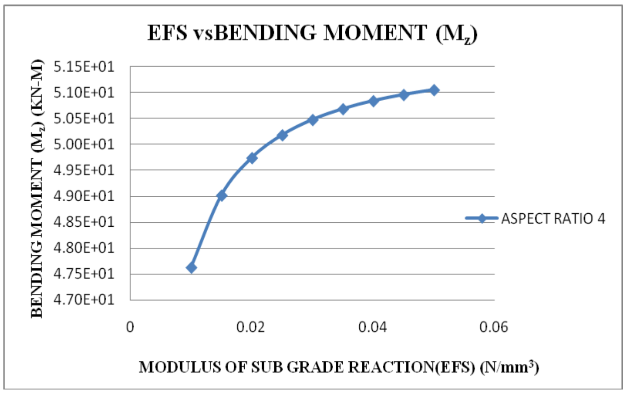

Fig. 21. Bending moment (m_z) in shell of aspect ratio 4

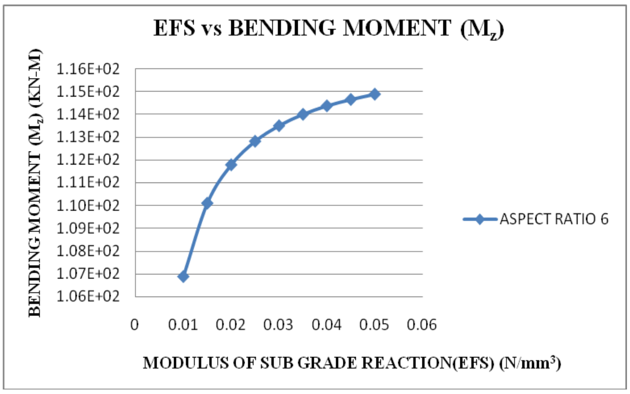

Fig. 22. Bending moment (m_z) in shell of aspect ratio 6

From Fig 20, 21 & 22 By observing bending moment (M_z) is in the shell is varying nonlinearly with respect to sub grade modulus. As the sub grade modulus increased from 0.01 - 0.05 N/mm^3 the difference of bending moment is increased by 18.22% from aspect ratio 2-6.

CONCLUSION

The following conclusions have been drawn from the study mentioned herewith,

- **Shear force in beam:** As the aspect ratio increased from 2 to 6 the difference in shear force in beam from conventional and numerical analysis is increased by 66.67%.
- **Bending moment in Beam**: As the aspect ratio increased from 2 to 6 the difference in bending moment in beam from conventional and numerical analysis is decreased by 62.4%.
- **Bending moment in column:** As the aspect ratio increased from 2 to 6 the difference in bending moment in column from conventional and numerical analysis is decreased by 62.4%.
- **Shear force in column:** As the aspect ratio increased from 2 to 6 the difference in shear force in column from conventional and numerical analysis is decreased by 12.95%.
- **Axial load in column:** As the aspect ratio increased from 2 to 6 the difference in axial load in column from conventional and numerical analysis is increased 66.67%.
- **Settlement in footing:** As the aspect ratio increased from 2 to 6 the difference in settlement in shell from numerical analysis is decreased by 83.44%.
- **Bending moment in footing:** As the aspect ratio increased from 2 to 6 the difference in bending moment in footing from numerical analysis is increased 88.53%.

Hence Soil interaction is observed to be effective in influencing the design parameters considerably.

REFERENCES

1. JOSEPH E. BOWLES, "FOUNDATION ANALYSIS AND DESIGN 5th EDITION" The McGraw-Hill companies Inc.
2. PRAKASH.M.YESANE , Y.M. GHUGAL & R.L. WANKHADE " Study on soil structure interaction" International journal of engineering research , volume 5,issue 3,ISSN:2319-6890,2016,PP – 737-741.
3. JIGYASU CHOURASIA ,UMESH PENHARKAR &RAGHAVENDRA SINGH "Dynamic analysis of pile foundation with footing in different foundation soils" International research journal of engineering and technology(IRJET) ISSN online: 2395-0056, ISSN print : 2395- 0075, volume 5. Issue 1,2018.
4. C.RAVIKUMAR REDDY , T.D. GUNNESWARA RAO "Experimental study of geotextile as plinth beam in a pile group supported modeled building frame" International advanced structural engineering (2017) 9: PP 353-363.
5. K. CHANDRASHEKHARAA , S. JOSEPH ANTONYB & DEBASHISH "Semi – analytical finite element analysis of a strip footing on an elastic reinforced soil" Applied mathematical modeling, volume 22, issue 4-5,1998,pp – 331-349.
6. RakshaJ.khare , H.S chore " interaction of building frame with pile" journal of electrical electronics & computer system .ISSN (online): 2347-2820 vol 1, issue 1, 2013 pp 27-32
7. JANARDHAN SHANMUGAM, P.A. DODE & H.S. CHORE "Analysis of soil structure interaction in framed structures" International journal of computer application(0975-8887) international conference on quality up – gradation in engineering science and technology(ICQUEST) , 2015.
8. RAKSHAKHARE & Dr. H.S. CHORE " Analysis of building frame considering soil structure interaction" International journal of modern trends in engineering and research(IJMTER) VOL. 03, issue 04,(2016).ISSN(Online):2349-9745 pp – 1-21.
9. VIVEK GARG & M.S. HORA " A review on interaction behavior of structure – foundation – soil system" International journal of engineering research and applications(IJERA) ISSN: 2248- 9622 , volume 2, issue 6, 2012, pp – 639-644.
10. MANJEETHORA " Elasto plastic soil structure interaction analysis of building frame soil system" 2008 International conference on case histories in geotechnical engineering, pp – 1 -11.
11. VERNIKA SRIVASTAVA, H.S. CHORE, P.A. DODE " Interaction of building frame with pile foundation" Open journal of civil engineering 2016, volume 6, pp – 195-202.
12. Rakshaj, khare, DR.H.S .chore " Interaction of building frame " International journal of electrical, electronics & computer systems(IJEECS) ISSN: 2347- 2820,volume 1,issue 1,2013,pp – 27-32.
13. C. RAVI KUMAR REDDY & T.D. GUNNESWARA RAO "Building frame supported by pile groups embedded in cohesive less soil: A study of effect of rigidity of frame" KSCE journal of engineering, 2014, pp – 1-10.

14. C. RAVI KUMAR REDDY & T.D. GUNNESWARA RAO " Experimental study of a modeled building frame supported by pile groups embedded in cohesion less soil" interaction in multi scale mechanics , volume 4, issue 4, 2011pp – 321- 336.
15. Dr. C. RAVI KUMAR REDDY , Dr. M. ANJANEYA PRASAD , Y.V. BHAVANI SAI KUMAR, T. NARENDRA & Y. NAGA SATYESH "modeling of building frame on pile groups embedded in sand" International journal of applied engineering research ISSN 0973-4562 , volume 10, issue3, 2015, pp – 2181-2183.

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1. **Chapati Ravi Kumar Reddy**, "Building Frame - Pile Foundation - Soil Interaction", Lambert Academic Publishing, 1st edition, Moldova, 2017.

2. **Ravi Kumar Reddy, C**., and GunneswaraRao, T. D, "Experimental study of geotextile as plinth beam in a pile group-supported modeled building frame", *International Journal of Advanced Structural Engineering*, **Springer**, December 2017, Vol. 9, pp.353–363, DOI: 10.1007/s40091- 017-0171-z.

3. K. S. Vivek and **C. Ravi Kumar Reddy**, "Effect of web taper ratio on free vibration behavior of steel cantilever channel beams**"**, The IUP journal of Structural Engineering, 2017, Vol. 10, No. 4, pp.19-29

4. K. S. Vivek, **C. Ravi Kumar Reddy** and H. TejaKiran Kumar, "Bending Behaviour of Functionally Graded Metal- Ceramic Triangular Plate**"**, Global Journal of Engineering Science and Researches, October 2017, Vol. 4, No. 10, pp.273-280

5. S. Tanuja, **C. Ravi Kumar Reddy** and M. Satish Kumar, "Effect of Change of Bay Length on Soil Interaction of Building Frame Resting on Clay", International Journal of Civil Engineering and Technology, Vol. 9, Issue. 5, May 2018, pp. 1237–1243

6. K. S. Vivek, **C. Ravi Kumar Reddy** and K. S. Sai Ram, "Lateral - Torsional Buckling of Various Steel Trusses**"**, i-manager's Journal on Structural Engineering, Vol. 7, No. 1,March - May 2018, pp.6-12