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Analysis of raft foundation using Winkler's linear spring in SAP 2000 by considering varaying soil subgrade modulus

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Abstract — *Most of the civil engineering structures are designed by assuming rigid foundation without considering the flexibility of soil. Ignorance of considering actual stiffness of foundation may misleading estimation of forces, the bending moments, the settlements etc. It is therefore necessary to carry out the analysis considering the soil, the foundation and the superstructure, which form a single compatible unit. The various methods available for the design of raft foundation, in the conventional method the base of raft foundation consider rigid in order to control the total and diffential settlement, which result in uneconomical design. The real behavior of raft foundation can be obtained by considering the soil flexibility. Among the various option available for analysis of raft foundation an attempt has been made to study the behavior of raft foundation resting on Winkler's linear spring. A model is prepared and study is carried out with different raft size configuration with varying soil subgrade modulus.*
The Building and foundation analysis has been done using professional software (ETAB and SAP). Different multi-storey building such as 15 & 20 Storey building and their foundation (i.e. raft size 16 x 16m, 20 x 20 m, 24 x 24 m) are analyzed by considering various soil subgrade modulus(Ks=4000 kN/m^3, 5000 kN/m^3 and 6000 kN/m^3). The comparison of these models has also been carried out in the study. The parameters varied for the study are: (I) modulus of subgrade reaction of the soil, (II) number of storey and (III) size of raft. A comparison of Raft size and settlements, Soil subgrade modulus and settlement, no of storey and settlement is done. Also comparison of Raft size and bending moments, soil subgrade modulus and bending moment, no of storey and bending moment is done.

Keywords-, *Raft foundation, ETAB 2015, SAP 2000 software, Finite element technic, Winkler's spring, settlements, bending moments.*

I.INTRODUCTION

1.1. RAFT FOUNDATION

Raft foundations are also called mat foundations. These are combined foundations supporting several columns arranged in one or more rows and columns.

1.2 NEED OF RAFT FOUNDATION

Raft or Mat foundation is a combined footing that covers the entire area beneath a structure and supports all walls and columns. This raft or mat normally rests directly on soil or rock, but can also be supported on piles as well.
Raft foundation is generally suggested in the following situations:

(a) Whenever building loads are so heavy or the allowable pressure on soil so small that individual footings would cover more than floor area.
(b) Whenever soil contains compressible lenses or the soil is sufficiently erratic and it is difficult to define and assess the extent of each of the weak pockets or cavities and, thus, estimate the overall and differential settlement.
(c) When structures and equipment to be supported are very sensitive to differential settlement.
(d) Where structures naturally lend themselves for the use of raft foundation such as silos, chimneys, water towers, etc.
(e) Floating foundation cases wherein soil is having very poor bearing capacity and the weight of the super-structure is proposed to be balanced by the weight of the soil removed.

II. METHODOLOGY

2.1ANALYSIS OF RAFT FOUNDATION:

Design and analysis approach
The two approaches for the analysis and design of foundations are:
1. The conventional approach, which assumes the foundation to be rigid and the contact pressure at the interface to be planar.
2. The rational approach, which incorporates the flexibility of the footing as well as the soil contact pressure based on elastic theories using modulus of subgrade reaction.

2.2. FINITE ELEMENT METHOD FOR ANALYSIS:

The finite element method was originally developed in the aircraft industry to facilitate a refined (approximate) analysis of complex airframe structures. Though the procedure was developed as a concept of structural analysis, the wider basis of this method makes it applicable to a variety of field problems such as soil structure interaction, elasticity, structural analysis, heat conduction, fluid flow and so on. In general this method is applicable to almost all problems where a vibrational formulation of the physical phenomenon is feasible. The important characteristics of the finite element procedure are: (1) the method is a general one based on an approximate solution of an extremism problem (which makes it applicable to many problems) and (2) unlike the Ritz process, physical quantities which have an obvious meaning are chosen as the parameters.

Finite Element Procedure:

This can be divided into three phases:

1. Structural idealization
2. Evaluation of the element properties
3. Structural analysis of element assemblage.

III PROBLEM FORMATION AND ANALYSIS

In the present work an attempt has been made to carry out a parametric study Raft foundation using Winkler springs. The raft is modelled as resting on Winkler’s linear spring bed.

For the parametric study the stiffness of the soil is varied with different number of storey on different raft sizes. The compare parameter of structural and raft foundation and identify their effect on the performance of raft foundation.

In this consists of analysis of raft foundation for a building with 15 and 20 Story. The Procedure adopted for the present task consists of the following Analyzing building using software ETAB and obtaining maximum loads at base below column for the vertical load (DL+LL) only.

Determination of soil parameters base on taken Ks values.

Work out structural dimension of Raft and Modelling of raft in SAP 2000.

3.1 SAMPLE PROBLEM

1. PRELIMINARY DATA FOR MODEL GENERATION:

Table-1. Preliminary data for model generation

Building	15 Storey		
Plan dimension	12 x12	16 x 16	20 x 20
Raft size	16 x 16	20 x 20	24 x 24
Bay width	4m (in X and Y direction)		
Beam size	0.300 m × 0.400 m	0.300 m × 0.400 m	0.300 m × 0.400 m
Column size	0.510 m×0.510 m (GL to 10), 0.320 m×0.320 m (11 to 15)	530 x 530 (GL to 10), 320 x 320 (11 to 15)	510 x 510 (GL to 10) 310 x 310 (11 to 15)
Floor Finish	1 kN/m^2		
Live load	3 kN/m^2		
Floor height	3 m		
Slab thickness	0.120 m		
Wall load	For Floors – 0.230 m wall on periphery and 0.115 mm on inner beam		
Height of parapet wall	1.5 m		

Table.2 Preliminary data for 20 storey building for model generation

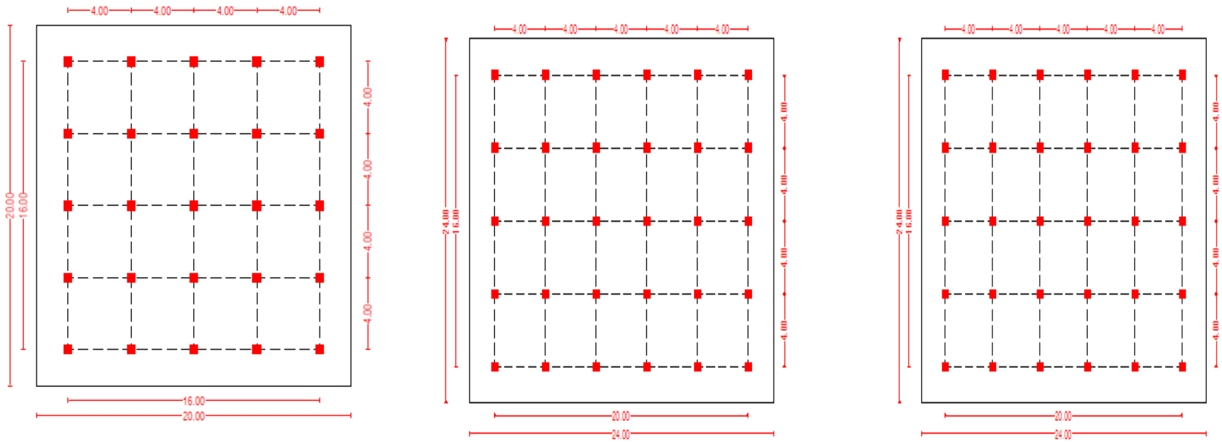
Building	20 Storey		
Plan dimension	12 x12	16 x 16	20 x 20
Raft size	16 x 16	20 x 20	24 x 24
Beam size	0.500 m × 0.400 m	0.500 m × 0.400 m	0.500 m × 0.400 m
Column size	0.580 m×0.580 m (GL to 10), 0.400 m×0.400 m (11 to 20)	600 x 600 (GL to 10), 430 x 430 (11 to 20)	630 x 630 (GL to 10) 430 x 430 (11 to 20)
Soil subgrade modulus (kN/m^3)	4000 kN/m^3, 5000 kN/m^3, 6000 kN/m^3		
Soil type	Loose sand		
Foundation type	Raft		

Table.3 Material property, soil and seismic data

Grade of concrete	M 25
Grade of Steel	Fe 415
Earthquake load	As per IS-1893(part-1):2002
Zone	III
Foundation type	Raft
Soil subgrade modulus (kN/m^3)	4000 kN/m^3, 5000 kN/m^3, 6000 kN/m^3
Soil type	Loose sand
Gross Bearing Capacity (kN/m^2)	375
Angle of internal resistance (ϕ)	300
Unit weight of soil	18 kN/m^2
Foundation depth	1.5 m from ground level
Standard penetration number	10

2. PLAN DETAIL FOR BUILDING AND RAFT SIZES

Model-1 Typical layout plan of column for 15 Storey with raft size 16 x 16m
Model-2 Typical layout plan of column for 15 Storey with raft size 20 x 20 m
Model-3 Typical layout plan of column for 15 Storey with raft size 24 x 24 m



Model-1 Model-2 Model-3

Figure-1 building and raft plan of 16 x 16 m, 20 x 20 m and 24 x 24 m

3. LOADING DATA

The vertical load (DL+LL) used for getting maximum reactions below the base of column obtained from ETAB software for 15 storey with plan dimension 12 x 12 m are as shown in table-4.

Table 4. Joint reaction for 15 Storey building with raft Size 16 x 16 m

Joint Label	FZ (kN)	Joint Label	FZ (kN)
1	1830.3	9	2342.01
2	2342.01	10	2855.36
3	2342.01	11	2855.36
4	1830.3	12	2342.01
5	2855.36	13	2342.01
6	2855.36	14	1830.3
7	2342.01	15	2342.01
8	2342.01	16	1830.3

IV RESULTS AND COMPARISONS

In this study 15, 20 story building has been analyzed in ETAB and raft foundation with different sizes 16 x 16 m, 20 x 20 m, 24 x 24 m by varying soil subgrade modulus 4000 kN. /m^3, 5000 kN. /m^3, 6000 kN/m^3 has been analyzed in SAP 2000. The result regarding the settlements and bending moments are presented in below tables:

Table-5 Result for 15 Storey building, Soil subgrade modulus= 4000, 5000, 6000 kN/m3 with raft sizes 16 x 16 m, 20 x 20 m and 24 x 24 m.

Building Detail		Raft Detail			Soil Sub grade Modulus (kN/m^3)	Result	
No. of Storey	Plan Dim. (m x m)	Raft Size				Settlement (mm)	Bending Moment (kN.m/m)
		L (m)	B (m)	T (m)			
15	12 x 12	16	16	0.700	4000	38.93	1331.44
					5000	31.34	1317.35
					6000	26.29	1308.59
	16 x 16	20	20	0.715	4000	42.33	1568.90
					5000	34.04	1468.21
					6000	28.92	1458.05
	20 x 20	24	24	0.720	4000	45.42	1629.21
					5000	36.98	1577.28
					6000	31.19	1533.95

Table-6 Result for 20 Storey building, Soil subgrade modulus= 4000, 5000, 6000 kN/m3 with raft sizes 16 x 16 m, 20 x 20 m.

Building Detail		Raft Detail			Soil Sub grade Modulus (kN/m^3)	Result	
No.of Storey	Plan Dim. (m x m)	Raft Size				Settlement (mm)	Bending Moment (kN.m/m)
		L (m)	B (m)	T (m)			
20	12 x 12	16	16	0.830	4000	55.48	1780.71
					5000	44.02	1793.33
					6000	36.83	1786.09
	16 x 16	20	20	0.850	4000	58.98	2150.49
					5000	47.52	2127.01
					6000	39.86	2104.60
	20 x 20	24	24	0.865	4000	64.12	2402.49
					5000	51.80	2353.62
					6000	43.55	2308.65

COMPARISON OF RAFT SIZE AND SETTLEMENT

In the below chart comparison of raft size and settlement is shown for same raft size and same number of storey with increases soil subgrade modulus.

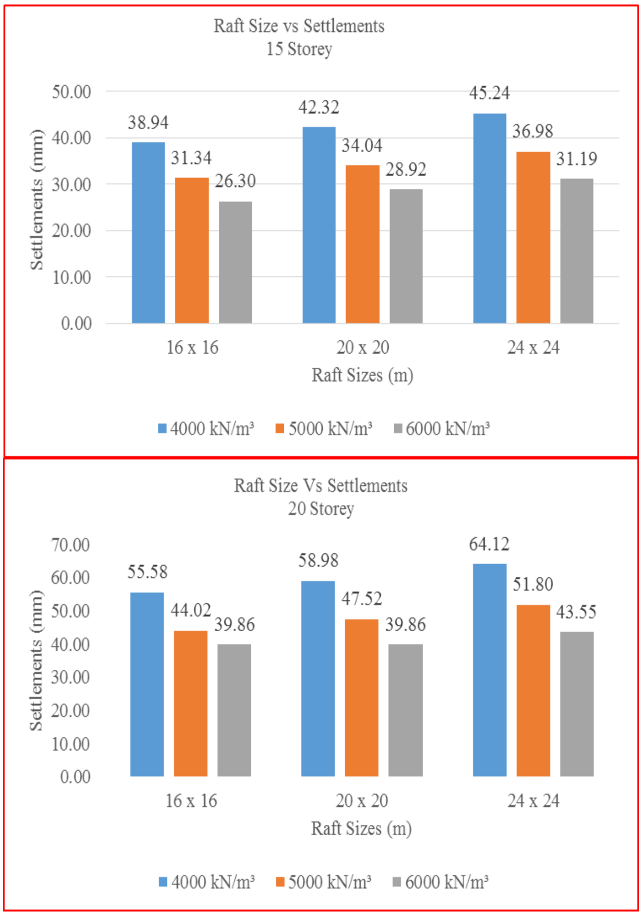


Fig-2. 16 x 16 m, 20x 20 m, 24 x 24 m raft size and settlement for 15 storey and 20 story

COMPARISON OF SOIL SUBGRADE MODULUS AND SETTLEMENTS

In the below chart comparison of Soil subgrade modulus and settlements is shown for same raft size and same number of storey with increases soil subgrade modulus.

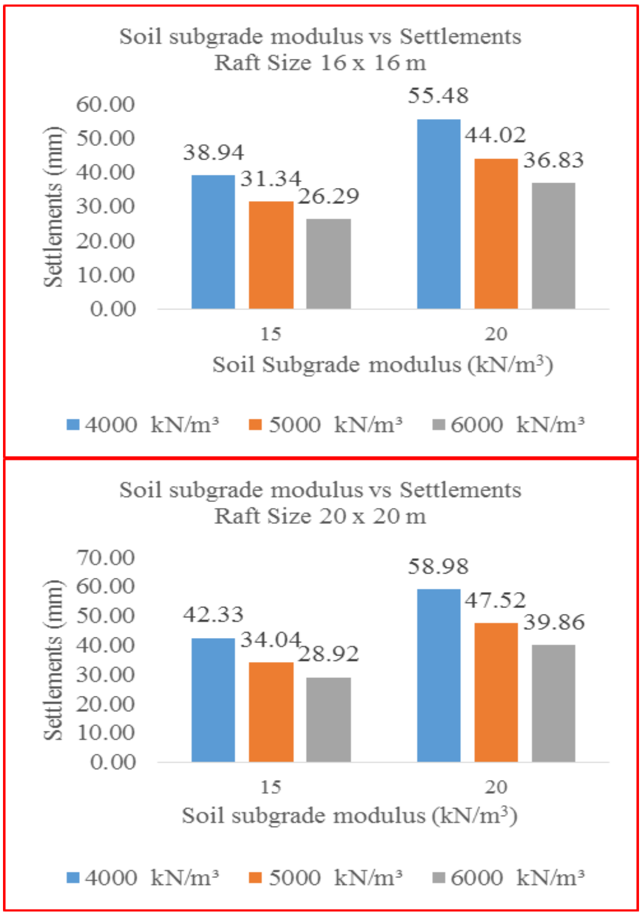


Fig-3. Soil subgrade modulus and settlements for raft size 16 x 16 m, 20 x 20 m

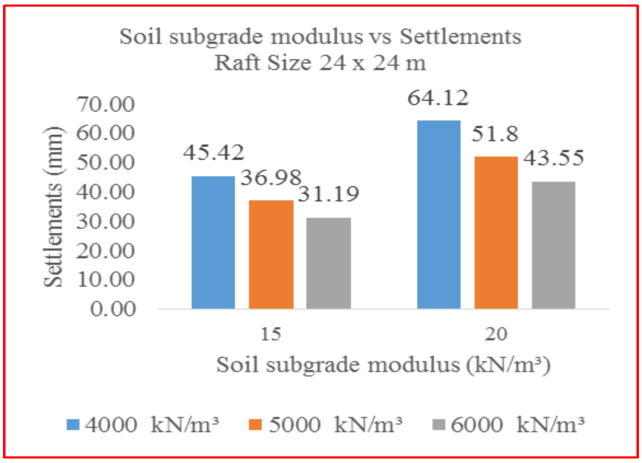


Fig-4. Soil subgrade modulus and settlements for raft size 24 x 24

COMPARISON OF NO OF STOREY AND SETTLEMENTS

In the below chart comparison of No of storey and settlements is shown for same raft size and same Soil subgrade modulus with increases No of storey

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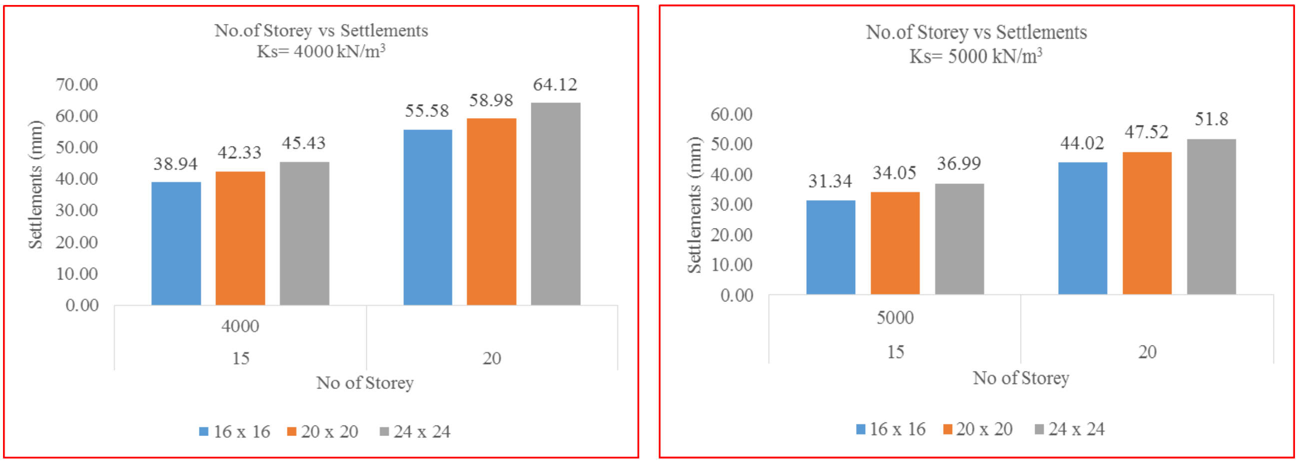

Fig-5. No of storey and settlement for soil subgrade modulus Ks = 4000 kN/m^3 and Ks = 5000 kN/m^3

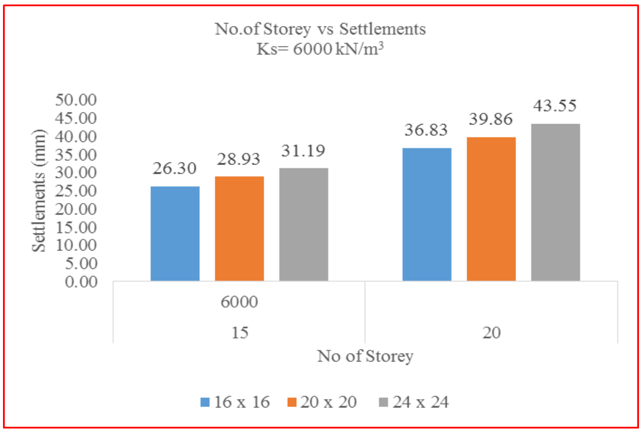

Fig-6 No of storey and settlement for soil subgrade modulus Ks = 6000 kN/m^3

COMPARISION OF RAFT SIZES AND BENDING MOMENTS

In the below chart comparison of raft size and bending moments is shown for same raft size and same number of storey with increases soil modulus.

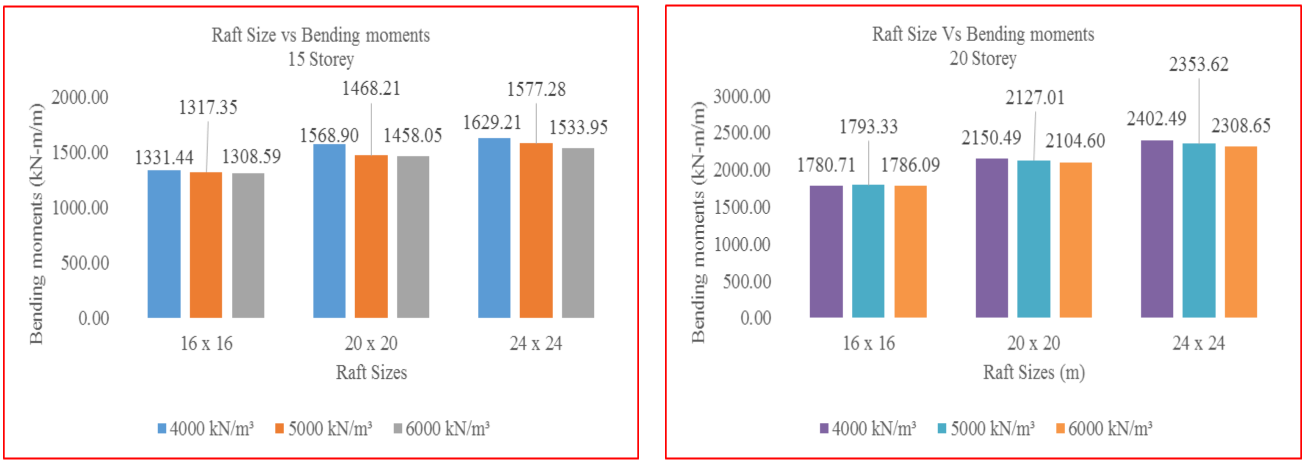

Fig-7 16 x 16 m, 20x 20 m, 24 x 24 m raft size and bending moment for 15 storey and 20 storey

COMPARISON OF SOIL SUBGRADE MODULUS AND BENDING MOMENTS

In the below chart comparison of Soil subgrade modulus and bending moments is shown for same raft size and same number of storey with increases soil subgrade modulus.

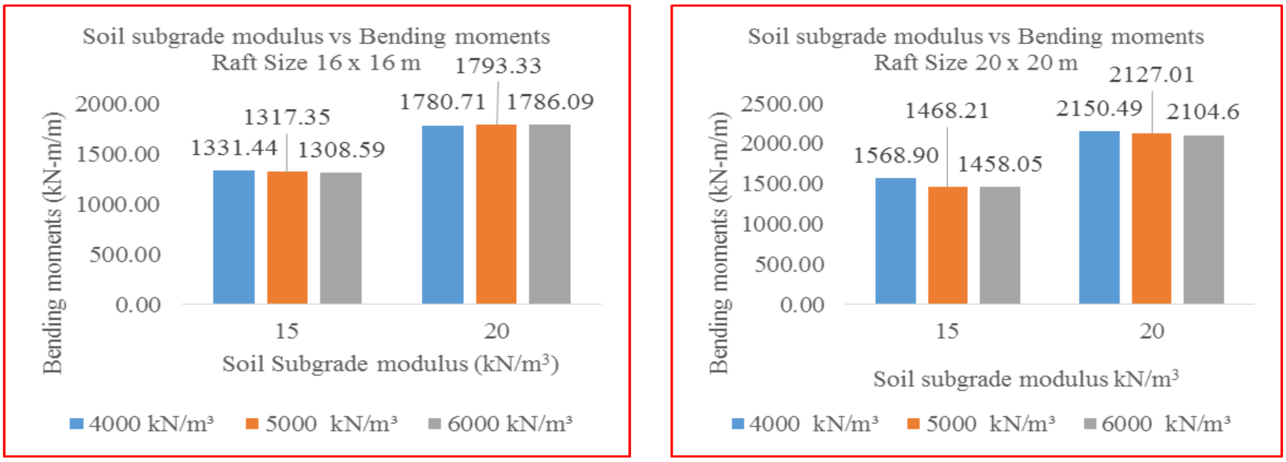

Fig-8. Soil subgrade modulus and bending moment for raft size 16 x 16 m and 20 x 20 m

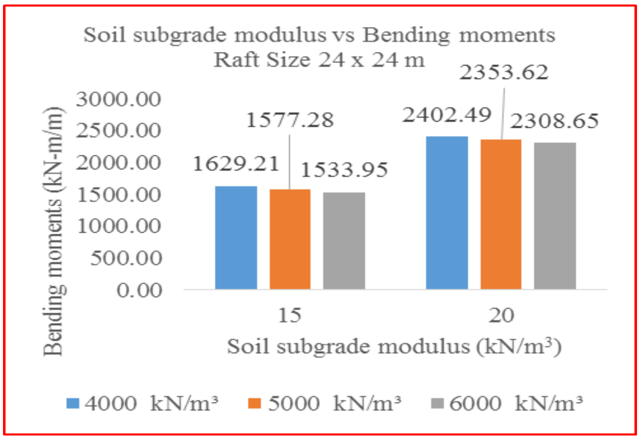

Fig-9. Soil subgrade modulus and bending moment for raft size 24 x 24

COMPARISONS OF NO OF STOREY AND BENDING MOMENTS

In the below chart comparison of No of storey and bending moments is shown for same raft size and same Soil subgrade modulus with increases No of storey

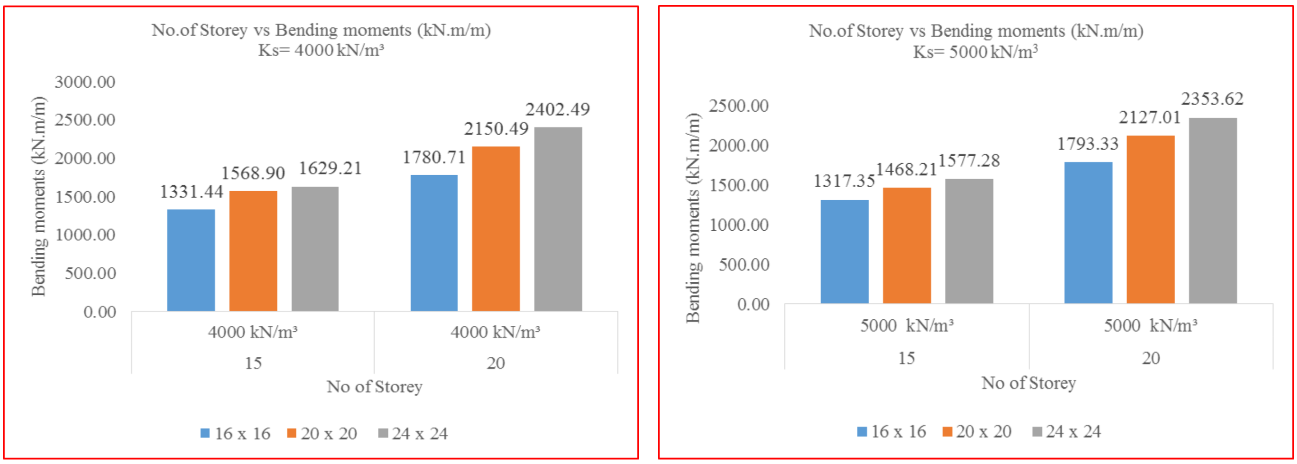

Figure-10. No of storey and bending moment for soil subgrade modulus Ks = 4000 kN/m^3 and Ks = 5000 kN/m^3

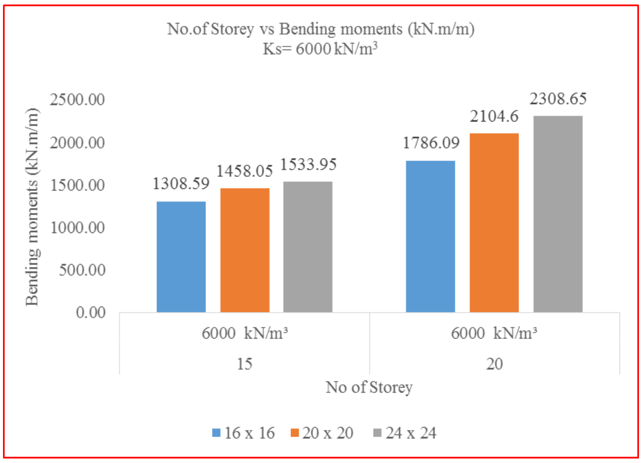

Figure-11 No of storey and bending moment for soil subgrade modulus Ks = 6000 kN/m^3

V. CONCLUSIONS

The various conclusions drawn from present study are as follows:

1. Analysis is carried out for 15 storey and 20 storey for 16 mx 16 m, 20 mx20 m and 24 m x 24 m raft sizes. It is found that for same raft size and number of storey, with increase in soil subgrade modulus, settlement of raft increases.
2. It is found that for same raft size and No of Storey, with increase in soil subgrade modulus, settlements of raft decreases.
3. Also for same value of soil subgrade modulus, with increases no of storey, settlements of raft increases.
4. It is found that for same raft size and number of storey, with increase in soil subgrade modulus, bending moments of raft increases.
5. It is found that for same raft size and No of Storey, with increase in Soil Subgrade modulus, bending moments of raft decreases.
6. Also for same value of soil subgrade modulus, with increases no of Storey, bending moments of raft increases.

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