International Journal of Engineering & Technology, 7 (3.34) (2018) 813-817

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

A Study on the Behaviour of 15 Storeys 2x3bay with Soil Flexibility

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Abstract

Previous analytical study was precisely based on structures with rigid base and soil conditions where neglected which showed considerable difference in the behaviour of structures. The present study is mainly based on flexible base considering soil effect with raft foundation. The structure considered is in seismic zone 5 with different types of soil condition such as hard soil, medium soil and soft soil. Also the structural irregularity is compared such as regular structure, structure with horizontal irregularity and structure with vertical irregularity. The soil is idealised by Modified Winkler method and Continuum method with Raft foundation. Overall 9 models where analysed in each method. The results are compared between Modified Winkler method and Continuum method with regular, horizontal and vertical irregularities for all 3 types of soil (Hard soil, Medium soil and Soft soil). Results where compared for Base shear, Axial forces, Time period and Displacement which shows that Continuum method of SSI gives realistic results compared to Modified Winkler method.

Keywords: Modified winkler method, Continuum method, Raft foundation, Horizontal irregularity and Vertical irregularity**.**

1. Introduction

Most of the structures are analysed considering the rigid base where all the 3 translational elements and 3 rotational elements are restricted. In reality the structure resting on the soil behaves differently which cannot be predicted without considering the soil effect in the analysis. The behaviour of the structure changes when the soil effect is incorporated. The soil is usually idealised by 3 methods Winkler method, Modified Winkler method and Continuum method. Considering Modified winkler method the soil in this case is idealised as springs in all 3 translational and 3 rotational directions. In Continuum method the soil is considered as solid mass incorporating soil properties for each soil type. The dynamic behaviour of soil requires following details such as Density of soil, Poison's ratio, Shear modulus of soil for different types of soil such as hard soil, medium soil and soft soil. The effect of foundation also plays an important role which is neglected in conventional method with rigid base. However the results of soil structure interaction with raft footing cannot be precisely predicted for the self-weight and lateral load acting but it ensures a realistic method of analysis compared to conventional rigid base method. Present study is mainly conducted for comparison of flexible method i.e., Modified winkler method compared with Continuum method in order to analyse the best method.

2. Present Investigation

3D building of 2x3 bays 15 storey is considered with flexible base with raft footing for seismic condition zone 5. Three different types of soil are considered based on parameters Vs, N, Su which are the average values of the shear wave velocity, standard penetration test blow count, and undrained shear strength. The other parameters required are Site class, Density of soil, Poison's ratio, Specific gravity due to acceleration, Initial shear modulus, and Effective shear modulus. All these soil details along with raft footing details are incorporated in Modified winkler's method (for 3 translations and 3 rotation direction) and Continuum method. In this study comparison between flexible bases for different types of soil with different irregularities is conducted.

3. Analysis Method

The structure is modelled in SAAP 2000 V19.2; the various parameters considered for structure, footing and soil is incorporated in the model. The frame details are specified where the column and beam are taken as line element, whereas slab and footing are taken as area element. Soil is idealised by Modified winkler method and Continuum method. Response Spectrum method of analysis is performed for different types of soil conditions.

3.1 Defining Problem

3D building with 2x3 bays 15 storey of overall height 45m with 7.5m width in X-direction and 3m in Y-direction is considered for the present study.

The various parameters considered for structure analysed in seismic zone 5 is given in Table.1. The stiffness of soil and foundation is calculated based on Geztas formula given in ASCE 41-13 and FEMA 440. The spring stiffness with 6 degree of freedom Kxx, Kyy, Kzz, $K_{\Theta xx}$, $K_{\Theta yy}$, $K_{\Theta zz}$ is placed at every joint for raft footing. In addition, the structural systems are subjected to 13 different load combinations as per provision of IS 1893:2002. In Continuum method the soil is considered as"isotropic, homogenous elastic half spaces (3D) for which dynamic shear modulus and Poisson's ratio as the inputs". The finite element idealization with eight noded(SOLID) elements with three degrees of freedom of translation in the respective co-ordinate directions at each node.

3.2 Equilibrium check

Bare frame with raft footing considered are checked for equilibrium in case of Lateral forces Fx and Fy, Vertical force Fz and Moment Mx & My. It is found that Manual calculation matches with Software calculation.

3.3 Results and Discussion

Results obtained from the analysis of 15 storey framed structure for Bare frame with flexible base are tabulated for Vertical load and Lateral load. The maximum values obtained among all the load cases and load combinations [L/C] considered are presented in Tables 2 to 6. The discussion focus on the comparison between the two methods of flexible base condition with horizontal and verticle irregularity having following parameters

a. Max. Column Forces Axial Force Fz, and Max. Column Moments Mx and My (Table 2)

b. Max. Time Period (Table 3)

c. Max. Base shear (Table 4)

d. Max. Joint Displacements in X & Y-Tran (Table 5)

1) Max. Column Force:

a) Comparing flexible methods (Modified Winkler method and Continuum method) Continuum method shows better results for same load case. The continuum method decreases by 13-16% compared to modified winkler method.

b) Compared to different types of soil the soft soil in continuum method increase by 49% with respect to hard soil and also with respect to medium soil increases by 39%.

c) Compared to Irregularities, Vertical irregularity show better results in axial force. Vertical irregularity decreases by 3-4% compared to regular and horizontal irregularity.

2) Max. Time Period:

d) Compared to 2 flexible method Continuum method shows increase in time period by 8% in regular, horizontal and vertical irregularity.

e) Compared to different soil types soft soil increases in continuum method by 1% compared to hard soil and by 0.5% compared to medium soil.

f) Compared to Regular and 2 Irregularities, vertical irregularity shows decrease in time period of 2%.

3) Max. Base Shear:

g) Comparison between 2 flexible method shows that Continuum method decreases by 15-17% with respect to Modified Winkler method.

h) Compared to soil types in Continuum method soft soil increased by 40% compared to Hard soil and also increased by 18% compared to medium *soil*

4) Max. Joint Displacement:

i) Compared to Modified Winkler method the displacement reduces by 15-17% in continuum method.

j) Compared to Regular , Horizontal and Vertical Irregularity , Vertical irregularity shows reduction in displacement by 2%

k) Compared to different soil types, Soft soil shows increase in displacement by 70% compared to hard soil similarly soft soil increases by 50% compared to medium soil.

3.4 Figures and Tables

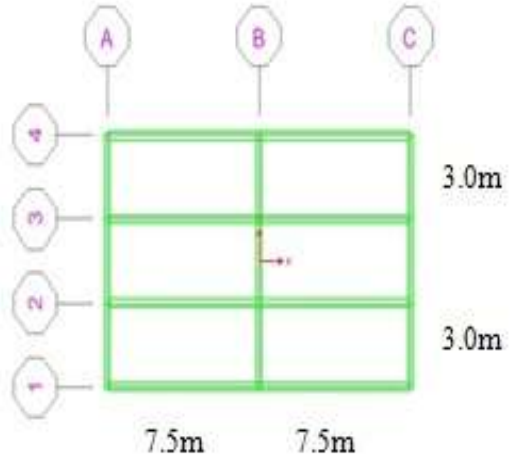

Fig.1: Plan

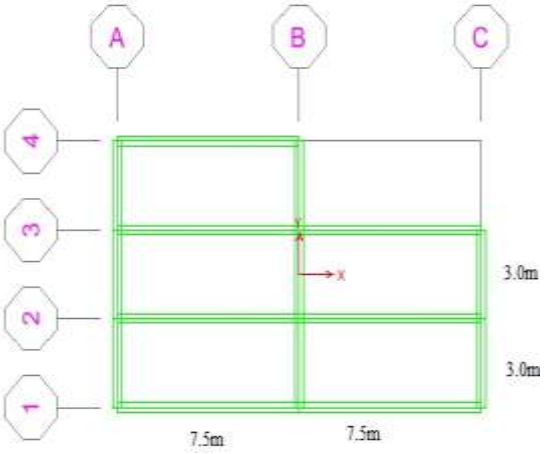

Fig.2: Horizontal Irregularity

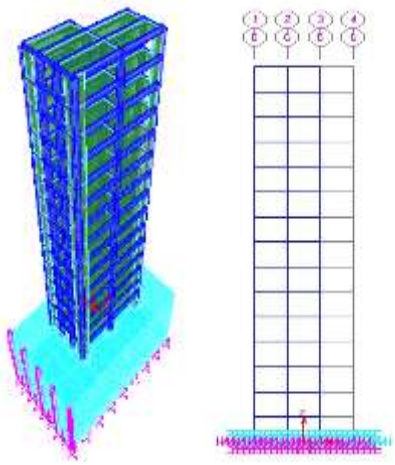

Fig. 3: Continuum model with Horizontal Irregularity

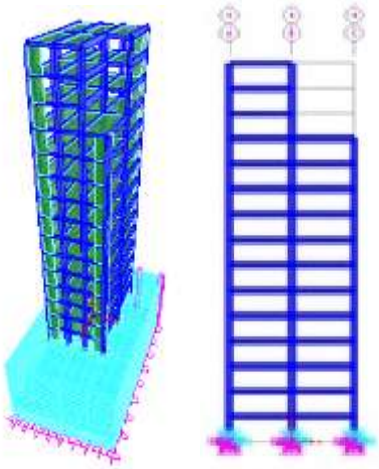

Fig.4: Continuum model with Vertical Irregularity

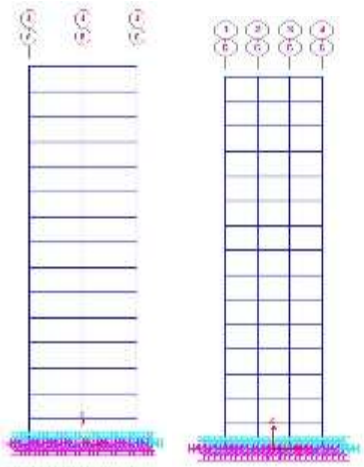

Fig.5: Modified Winkler model –Regular building

4. Conclusions

In the present analytical study of 15 storeys 2x3 bays with soil structure interaction where soil is idealized by 2 methods i.e., Continuum method and Modified Winkler method of analysis and also comparison of irregularities in building is analyzed following conclusion can be drawn from the results obtained.

1. Continuum method gives realistic result compared to Modified Winkler method because the soil is modeled as 3d model specifying soil properties for different types of soil.
2. Time period increases in continuum method compared to Modified winkler method.
3. Displacement and Axial forces are relatively less in continuum method compared to Modified Winkler method so continuum method can be followed for future design of structures.
4. Comparing the irregularities vertical irregularity shows better results compared to horizontal irregularity.

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TABLE I Parameters considered

	Particulars	**Size**
	Main beam in x-direction	0.30x 0.75m
	Main beam in y- direction	0.30x 0.375m
	Column	0.90x0.45m
	Column height	3.0m
	Slab thickness	0.125m
	Number of stories	15
	Storey Height	3m

TABLE.3 MAX. TIME PERIOD FOR 15 STOREY, 2X3 BAY, 7.5MX3.0m

MODIFIED WINKLER METHOD										
Frame Type Raft footing	Regular building				Horizontal Irregularity			Verticle irregularity		
	Mode no.	Period in sec	Frequency in cyc/sec	Eigen Value rad^2/sec	Period in sec	Frequency in cyc/sec	Eigen Value rad^2/sec	Period in sec	Frequency in cyc/sec	Eigen Value rad^2/sec
Hard soil	1	8.970	0.111	0.491	8.969	0.111	0.491	9.413	0.106	0.446
Medium	1	8.970	0.111	0.491	8.969	0.111	0.491	8.721	0.115	0.519
Soft soil	1	8.970	0.111	0.491	8.969	0.111	0.491	8.721	0.115	0.519
CONTINUUM METHOD										
Hard soil	1	9.693	0.103	0.420	9.642	0.104	0.425	9.446	0.106	0.442
Medium	1	9.729	0.646	0.417	9.675	0.103	0.422	9.481	0.105	0.439
Soft soil	1	9.783	0.642	0.412	9.723	0.103	0.418	9.533	0.105	0.434

TABLE.2 COLUMN FORCES FOR 15 STOREY, 2X3 BAY , 7.5MX3.0m

COLUMN FORCES - MODIFIED WINKLER METHOD															
Soil type - Raft footing	Max Axial Force Fx KN				Max Moment My KNm						Max Moment Mz KNm				
	Load Case	Regular	Horizontal Irregularity	Verticle Irregu	Load Case	Regular	Load case	Horizontal Irregularity	Load case	Verticle Irregu	Load Case	Regular	Load case	Horizontal Irregularity	Verticle Irregu
Hard soil	SQY	2005.38	2041.53	1866.65	0.9DL+1.5SQY	620.98	0.9DL+1.5SQY	616.90	0.9DL+1.5SQY	636.66	1.5(DL+SQX)	776.90	0.9DL+1.5SQX	797.27	795.21
Medium	SQY	2727.32	2776.47	2615.60	1.5(DL+SQY)	844.79	0.9DL+1.5SQY	839.44	1.5(DL+SQY)	823.39	1.5(DL+SQX)	1056.58	0.9DL+1.5SQX	1084.44	1105.19
Soft soil	SQY	3348.98	3409.36	3211.80	1.5(DL+SQY)	1037.04	0.9DL+1.5SQY	1031.08	1.5(DL+SQY)	1010.91	1.5(DL+SQX)	1297.42	0.9DL+1.5SQX	1331.74	1357.15
CONTINUUM METHOD															
Hard soil	SQY	1685.18	1670.39	1616.73	1.5(DL+SQY)	565.30	1.5(DL+sQY)	545.77	1.5(DL+SQY)	551.29	1.5(DL+SQX)	690.26	1.5(DL+SQX)	673.95	683.47
Medium	SQY	2287.07	2266.23	2193.07	1.5(DL+SQY)	771.13	1.5(DL+sQY)	743.71	1.5(DL+SQY)	752.97	1.5(DL+SQX)	953.25	1.5(DL+SQX)	931.04	943.49
Soft soil	SQY	2806.25	2780.36	2692.27	1.5(DL+SQY)	946.89	1.5(DL+sQY)	912.65	1.5(DL+SQY)	926.69	1.5(DL+SQX)	1167.19	1.5(DL+SQX)	1138.66	1151.84

TABLE 4. BASE SHEAR FOR 15 STOREY, 2X3 BAY, 7.5MX3.0m

Frame Type-Raft footing	MODIFIED WINKLER METHOD					
	Regular		Horizontal Irregularity		Verticle Irregularity	
	SQX	SQY	SQX	SQY	SQX	SQY
Hard soil	1901.55	1901.55	1679.36	1679.36	1856.90	1856.90
Medium	2586.11	2586.11	2283.92	2283.92	2524.23	2524.23
Soft soil	3175.59	3175.59	2804.53	2804.53	3099.60	3099.60
CONTINUUM METHOD						
Hard soil	1648.84	1648.84	1425.64	1427.26	1608.01	1608.01
Medium	2242.42	2242.42	1940.25	1940.25	2186.71	2186.71
Soft soil	2753.57	2753.57	2753.57	2753.57	2685.38	2685.38

TABLE 5. MAX. DISPLACEMENT FOR 15 STOREY, 2X3 BAY, 7.5MX3.0m

MODIFIED WINKLER METHOD												
Frame Type Raft footig	X Translation in mm						Y Translation in mm					
	Load Case	Regular	Load Case	Horizontal Irregularity	Load Case	Verticle Irregularity	Load Case	Regular	Load Case	Horizontal Irregularity	Load Case	Verticle Irregularity
Hard soil	1.5(DL+SQX)	1.05	0.9DL+1.5SQX	1.08	0.9DL+1.5SQX	1.04	0.9DL+1.5SQY	2.36	0.9DL+1.5SQY	2.54	0.9DL+1.5SQY	2.72
Medium	1.5(DL+SQX)	1.43	0.9DL+1.5SQX	1.47	0.9DL+1.5SQX	1.44	1.5(DL+SQY)	3.21	0.9DL+1.5SQY	3.47	0.9DL+1.5SQY	3.24
Soft soil	1.5(DL+SQX)	1.76	0.9DL+1.5SQX	1.80	0.9DL+1.5SQX	1.77	1.5(DL+SQY)	3.94	0.9DL+1.5SQY	4.27	0.9DL+1.5SQY	3.98
CONTINUUM METHOD												
Hard soil	1.5(DL+SQX)	0.92	0.9DL+1.5SQX	0.92	0.9DL+1.5SQX	0.90	1.5(DL+SQY)	2.39	0.9DL+1.5SQY	2.44	0.9DL+1.5SQY	2.36
Medium	1.5(DL+SQX)	1.26	0.9DL+1.5SQX	1.26	0.9DL+1.5SQX	1.24	1.5(DL+SQY)	3.27	0.9DL+1.5SQY	3.35	0.9DL+1.5SQY	3.24
Soft soil	1.5(DL+SQX)	1.58	0.9DL+1.5sQX	1.56	1.5(DL+SQX)	1.54	1.5(DL+SQY)	4.07	0.9DL+1.5SQY	4.16	0.9DL+1.5SQY	4.03