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INTERACTION OF FRAME WITH PILE FOUNDATION

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ABSTRACT: *The effect of soil structure interaction on response of the three storeyed building frame supported on pile foundation is reported in this paper. The three storeyed frame comprises of two bays and columns of the frames are supported by a pile. The pile is assumed to be embedded in the cohesive soil mass. For the purpose of the analysis, simplified idealizations made in the theory of finite elements. The slab of the frame is idealized as two dimensional plate elements, beams and columns of the superstructure frame and pile of the sub-structure are idealized as the one dimensional bem-column elements. The soil mass is idealized by equivalent springs. The effect of different pile diameters is evaluated on the response of superstructure through a parametric study. The response of the superstructure considered includes the displacement of the frame.*
Keywords - *Foundation, Frame, Pile, Simplified Models, Soil-Structure Interaction (SSI), Displacement*

I. INTRODUCTION

The framed structures are normally analyzed with their bases considered to be either completely rigid or hinged. However, the foundation resting on deformable soils also undergoes deformation depending on the relative rigidities of the foundation, superstructure and soil. Interactive analysis is, therefore, necessary for the accurate assessment of the response of the superstructure. Numerous interactive analyses have been reported in the 1960-70's studies such as Chameski [1], Morris [2], Lee and Harrison [3], Lee and Brown [4], King and Chandrasekaran [5], Buragohain *et al*. [6], and in more recent studies such as Subbarao *et al*. [7], Deshmukh and Karmarkar [8] and Dasgupta *et al*. [9]. While a majority of these analyses have been presented either for the interaction of frames with isolated footings or for the interaction of frames with raft foundation, few of them were focused on the interaction of frames with combined footings. In the meantime, much work is available on pile foundation (single as well as pile group), but comparatively little work, except Buragohain *et al.* [6], was reported on the analysis of framed structures resting on pile foundations to account for the soil-structure interaction.

The work reported by Buragohain *et al*. [6] was based on simplified approach. Ingle and Chore [10] emphasized the necessity of interaction analysis for building frames resting on pile foundation based on a more rational approach and realistic assumptions and subsequently, Chore [11] reported the comprehensive interaction analysis of a single storeyed building frame having two bays and supported on the pile groups. Pursuant to this, Chore and co-authors [12] reported the interaction analyses for the building frame considered in the afore-mentioned work (Chore, [13,14, 15, 16, and 17]). These analyses include the coupled and uncoupled approaches. The building frame was modeled using 3-D finite element idealizations while the sub-structure was idealized using 3-D as well as simplified idealizations based on the theory postulated by Desai et al [18]. The published work considered linear as well as non-linear behavior (p-y curve approach) of the soil.

However, on the backdrop of the relatively lesser work found on the interaction analysis of multi-storeyed frames resting on pile foundation, the analysis of three storeyed building frame having two bays are reported in the present study. The effect of diameter of piles is evaluated on the displacement of the frame.

II. MODELING OF THE SUPER- AND SUB-STRUCTURES

The elements of the superstructure (beam, column and slab) and that of the substructure (pile and soil) are modeled using simplified modeling approach, as the one suggested by Desai et al [19]. The slab in the frame is idealized as the two- dimensional plate element and beams and columns of the frame along with the pile are idealized as one dimensional beam element. The soil is modeled as the discrete independent linear springs. The finite element formulation employed in the analyses is presented elsewhere (Chore *et al*. [16], a).

III. NUMERICAL PROBLEM

A three storeyed (G+2) space frame resting on pile foundation as shown in Fig. 1 is considered for the purpose of the parametric study. The frame, 9 m high, is 10 m × 10 m in plan with each bay of dimensions 5m × 5m. The height of each storey is 3 m. The slab, 200 mm thick, is provided at the top as well as at the floor level. The slab at the top is supported by beams, 300 mm wide and 400 mm deep, which in turn rest on columns of size 300 mm × 300 mm. While dead load is considered according to unit weight of the materials of which the structural components of the frame are made up for the parametric study presented here, a lateral load of 1000 kN is assumed to act at the three points of the frame, as shown in the Fig. 1.

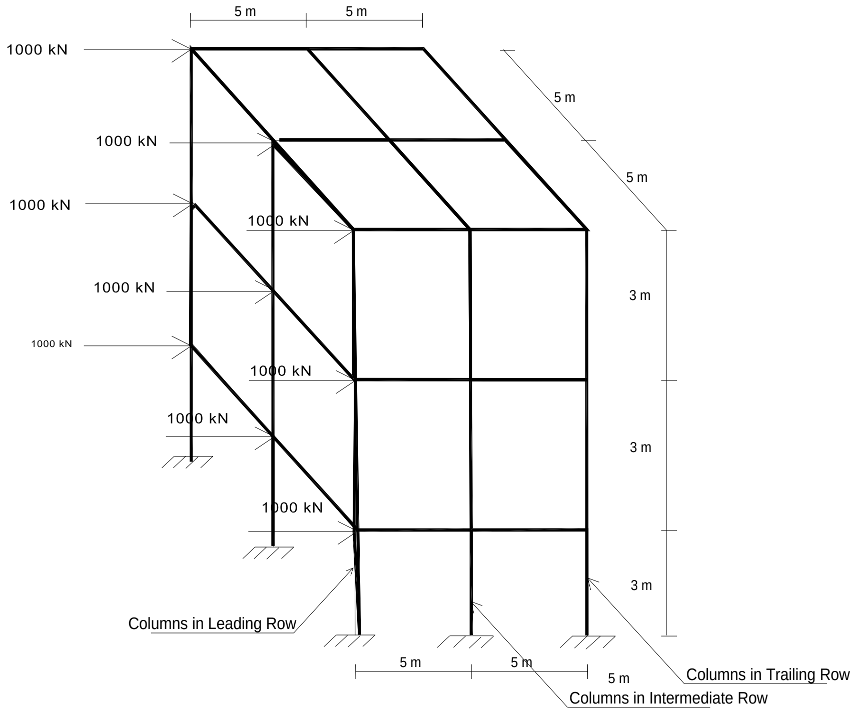

Fig.1: Typical building frame considered in the present investigation

The diameters of piles are considered as 300 mm, 400 mm, 500 mm and 600 mm. The embedment depth ratio (L/D) is kept constant as 10. The properties of the concrete for the superstructure elements and sub-structure element (according to Indian specification) are given in Table 1. The corresponding Young's modulus of elasticity and Poisson's ratio are also given in Table 1. A soft cohesive soil is considered in the analysis.

Table 1: Material Properties

Properties	**Corresponding Values**
Grade of Concrete used for the Frame Elements	M-20 (Characteristic Comp Strength: 20 MPa)
Young's Modulus of Elasticity for Frame Elements ($E_{c\ Frame}$)	0.25491×10^8 kPa
Grade of Concrete Grade used for Pile	M-40 (Characteristic Comp Strength: 40 MPa)
Young's Modulus of Elasticity for Foundation Elements ($E_{c\ Foundation}$)	0.3605×10^8 kPa
Poisson's Ratio (μ_c)	0.15
Young's modulus of elasticity (E_s)	4267 kN/m^2
Poisson's ratio (μ_s)	0.45
Modulus of subgrade reaction (K_h)	6667 kN/m^3.

IV. RESULTS AND DISCUSSION

In the parametric study conducted for the specific frame presented here, the response of the superstructure considered for the comparison include the horizontal displacement of the frame at the storey level, for both fixed base and soil-structure interaction (SSI) cases. The displacements of frame evaluated in respect of various pile diameters and the fixed base condition is shown in Table 2.

Table 2: Values of displacements for various pile diameters (D)

Storey Height in m	Fixed base	D= 0.3 m		D = 0.4 m		D = 0.5 m		D = 0.6 m	
	Displacement	Displacement	% increase	Displacement	% increase	Displacement	% increase	Displacement	% increase
9	9.76	26.63	172.71	24.52	151.04	23.99	145.70	23.92	145.01

6	8.33	25.14	201.65	23.03	176.37	22.51	170.15	22.44	169.36
3	4.68	20.74	342.99	18.73	299.96	18.23	289.28	18.16	287.89
0	0.0	7.043	100	6.130	100	5.84	100	5.79	100

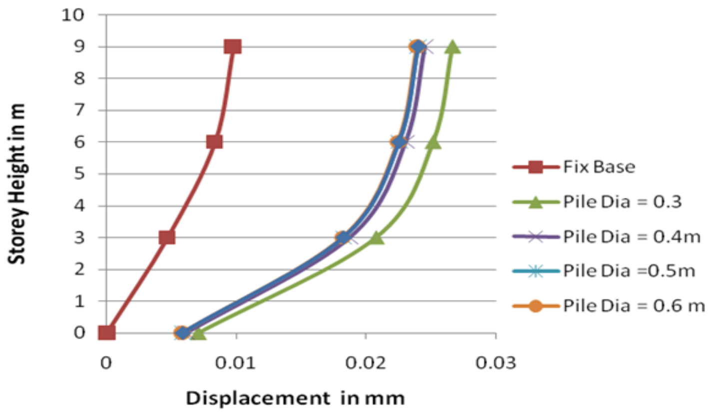

Fig.2. Effect of pile diameter on displacement

The general trend observed for all the pile diameters considered in this investigation is that horizontal displacement is on higher side when the effect of soil structure interaction (SSI) is considered (Fig.2). For 300 mm pile diameter, at top of the subsequent storeyes, the percentage increase in displacement is found to be 343, 200 and 172% due to incorporation of the effect of SSI. The increase in the storey displacement is observed to be 300%, 176% and 151% for 400 mm pile diameter; and 289%, 170% and 145.7% for 500 mm pile diameter. In respect of 600 mm pile diameter, the corresponding increase is found to be 288%, 169% and 145%.

With increase in pile diameter, it is observed that the displacement at each storey decreases. However, the difference between the displacements at corresponding storey obtained in respect of a pile diameter of 400 mm is marginal when compared with the displacement obtained for the higher pile diameters such as 500 mm and 600 mm. The increase in diameter of the pile increases the stiffness of the sub-structure (i.e., foundation) and therefore, the displacement decreases.

Moreover, with increase in storeyes, the displacement is found to decrease when the effect of SSI is considered. The displacements obtained at the second storey are found to decrease by 70% on an average as compared to that obtained at the first storey in respect of all the pile diameters. Similarly, the displacements obtained at the third (top) storey is observed to be less by 17% when compared with the displacements obtained at the second storey.

V. CONCLUSIONS

Based on the interaction analysis presented in this paper, following broad conclusions can be deduced.

i. Soil- Structure interaction effect increases the displacement in each storey of the frame.
ii. With increase in pile diameter, the displacement decreases at the corresponding storeyes.
iii. With increase in number of storeyes, the displacement decreases.

REFERENCES

[1] Chameski, C. *Structural Rigidity in Calculating Settlements, Journal of Soil Mechanics and Foundation Engineering, ASCE, 82 (1)*, 1956, 1-9.

[2] Morris, D. "Interaction of Continuous Frames and Soil Media", *Journal of Structural Engineering Division, ASCE*, 5, 1966, 13-43.

[3] Lee, I.K. and Harrison, H.B. "Structures and Foundation Interaction Theory", *In: Proc. ASCE, 96 (ST 2)*, 1970, 177-198.

[4] Lee, I.K. and Brown, P.T. "Structures and Foundation Interaction Analysis", *Journal of Structural Engineering Division, ASCE, 11*, 1972, 2413-2431.

[5] King, G.J.W. and Chandrasekaran, V.S. "Interactive Analysis of a Rafted Multistoreyed Space Frame Resting on an Inhomogeneous Clay Stratum", *Proceedings International Conference on Finite Element Methods, Australia*, 1974, 493-509.

[6] Buragohain, D.N., Raghavan, N. and Chandrasekaran, V.S. "Interaction of Frames with Pile Foundation", *In: Proc. Int. Symposium on Soil- Structure Interaction, Roorkee (India)*, 1977, 109-115.

[7] Subbarao, K.S., Shrada Bai, H. and Raghunatham, B.V. "Interaction Analysis of Frames with Beam Footing", *In: Proc. Indian Geotechnical Conference, Roorkee (IGC-1985), India, 1*, 1985, 389-395.

[8] Deshmukh, A.M. and Karmarkar, S.R. "Interaction of Plane Frames with Soil, In: Proc. Indian Geotechnical Conference", *(IGC-1991), Surat, India, 1*, 1991, 323-326.

[9] Dasgupta, S., Dutta, S.C. and Bhattacharya, G. "Effect of Soil- Structure Interaction on Building Frames on Isolated Footings", *Journal of Structural Engineering, SERC, Chennai (India), 26(2)*, 1998, 129-134.

[10] Ingle, R.K. and Chore, H.S. “Soil- Structure Interaction Analysis of Building Frames- An Overview”, *Journal of Structural Engineering, SERC, Chennai (India)*, 34 (5), 2007, 201-209.
[11] Chore H.S and R.K.Ingle, ‘Interactive Analysis of Building Frame Supported on Pile Foundation Using Simplified Finite Element Analysis’ *Journal of Structural Engineering (JoSE)*, SERC Chennai, 34 (6), 2008, 460-464.
[12] Chore H.S and R.K.Ingle, ‘Effect of Soil-Structure Interaction on Response of Building Frame’, *Journal of Structural Engineering (JoSE)*, SERC Chennai, 35 (3), 2008, 147-155.
[13] Chore H.S and R.K.Ingle, ‘Soil Structure Interaction Analysis of Building Frame Supported on Pile Group’, *Asian Journal of Science and Technology for Development (AJSTD)*, Thailand, 25 (2), 2008, 457-467.
[14] Chore H.S, R.K.Ingle and V.A.Sawant, , ‘Building Frame-Pile Foundation-Soil Interactive Analysis’, *Interaction and Multiscale and Mechanics (IMM), An International Journal,* Techno Press Group, 2 (4), 2009, 397-411.
[15] Chore H.S, R.K.Ingle and V.A. Sawant: ‘Building Frame- Pile Foundation- Soil Interaction Analysis: A Parametric Study’, *Interaction and Multiscale Mechanics: An International Journal,* Techno Press Group, 3 (1), 2010, 49-73.
[16] Chore H.S and R.K.Ingle, “F. E. Analysis of Building Frame Supported on Pile Foundation Using Simplified Models”, Proceedings of the National Conference on Infrastructure Development in Civil Engineering (IDCE-2008), NIT Hamirpur, 179-182, 2008.
[17] Chore H.S and V.A. Sawant, “Effect of Soil- Structure Interaction on Response of Building Frame”, Proceedings of the National Conference on Urban Infrastructure Development- Issues and Challenges (NCUID-2008), M.V.S.R. College of Engineering, Hyderabad,
[18] Desai, C.S. and Abel, J.F. “Introduction to Finite Element Method”, CBS *Publishers, New Delhi*, 1974.
[19] Desai, C.S., Kuppusamy, T., and Allameddine, A.R. “Pile Cap- Pile Group- Soil Interaction, Journal of Structural Engineering Division”, *ASCE, 107 (ST 5)*, 1981, 817-834.