Structural Analysis of Pile Raft Foundation in Soft Soil for High Rise Building

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Abstract – Present study focus on the behavior of reinforced concrete frames considering Pile Raft Soil Structure interaction by performing linear static and dynamic analysis. A reinforced concrete frame having G+10 storey is considered for different foundation. The investigation on the behavior of Reinforced Concrete (RC) frame is carried out by using equivalent static method (ESM) and Response Spectrum method (RSM). The modeling of RC frame is carried out using finite element-based computer program i.e., STAAD.Pro. The investigation will be carryout by considering variation in structural models such as Model with Pile Foundation supported on soft, Model with Raft Foundation supported on soft and Model with Pile Raft foundation supported on soft. By considering all these parameter total 3 models each for Static and Dynamic Conditions were created, all models were analyzed for the Seismic zone V. The Response of each RC frame with respect to others will be checked for axial force, Shear Force, twisting moment, Bending Moment, Lateral displacement, Base Shear, Structural Frequency, Seismic Time Period and Mass Participation factors. The behaviour of each RC frame with respect to others is describes with the help of graphs.

Key Words: RC frame, Soil Structure Interaction, Pile Foundation, Raft Foundation, ESM RSM, Soil Properties.

1. INTRODUCTION

In conventional analysis of any frame structure the super structure is usually analyzed by treating it as independent from foundation and soil medium on the assumption that no interaction takes place. This usually means that by providing fixity at the support structural analysis simplifies soil behaviour, while geotechnical engineer neglects structural behavior by considering only the foundation while designing. When a structure is built on soil some of the elements of the structure are in direct contact with the soil. When the loads are applied on the structure, internal forces are developed in both the structure and as well as in soil. This results in deformations of both the components (structure and soil) which need to be compatible at the interface as they cannot be independent of each other.

Several investigations have worked on the problem of soil structure interaction in frame building. Some of the important works are described below.

Priyanka Bhartiya et al. [1] carried out study on piled raft foundations (PRFs) resting on sandy soils using Abaqus software. Four different types of sand with three different states (loose, medium and dense) and twenty different configurations of PRFs with rectangular, square, and strip rafts are considered in this study. Rajib Saha et al. [2] present a paper to see whether DSSI have an adverse effect on elastic as well as inelastic behaviour in superstructure and foundation. Nonlinear seismic response of the whole structure with emphasis on consideration of material nonlinearity in both pile and soil which may contribute in salient design inputs towards performance based design of the whole structural system. Study reveals that consideration of DSSI condition results in inelastic deformation of superstructure and it exhibits marginal increase at higher stories.Chao Zhang et al. [3] Investigates the seismic performance of bridge pile foundation, Finite model of the bridge pile foundation is developed different types of ground motions on the bridge pier fragilities are studied and discussed. Sahar A. Ismail et al. [4] studied the behavior of a 15 storey midrise concrete seismic frame structure rested on raft foundation and founded on silty sandy soil block, 3D nonlinear time history finite element simulations using Abaqus were performed.

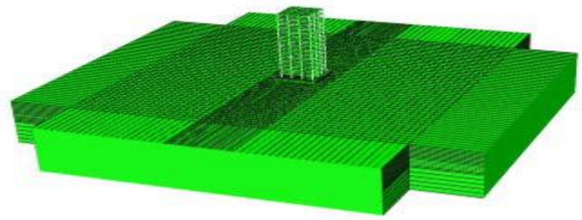

Figure-1.1: Geometry and model mesh distribution

Lei Sua et al. [5] studied Seismic fragility assessment of large-scale pile-supported structures considering soil-pile interaction. A collection of ground motions with low and high moment magnitudes as well as small and large fault distances are selected for nonlinear time history analysis. Shivanand Mali and Baleshwar Singh [6] studied behavior of large piled-raft foundation on clay soil supporting the offshore structures. The objective is to investigate the effect of pile spacing, pile length, pile diameter and raft-soil stiffness ratio on the settlement, bending moments, and shear force behavior of large piled-raft foundation.

2. PROBLEM DESCRIPTION

A reinforced concrete (G+10) Storey Frame Structures are considered for the present study with Pile and Raft Foundations. A set of total 3 frames were model for Pile foundation, Raft Foundation and Pile Raft Foundation, using structural analysis and design computer program i.e., STAAD.Pro. All the Structures were model for Seismic Zone-V. The details of geometric properties, design parameters and sectional properties of Frame Structures are given in Table-01, Table-02 and Table-03.

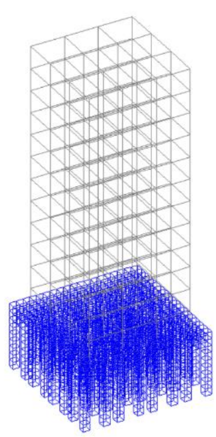

Figure-2.1: Models with Pile Foundation.

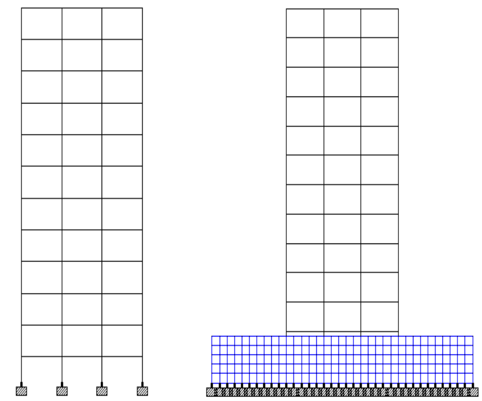

Figure-2.2: Models with Raft Foundation.

Table-01: Design Seismic Parameters

Sr. No	Design Parameter	Value
1	Seismic Zone	V
2	Zone Factor	0.36
3	Response Reduction Factor	3
4	Importance Factor	1.5
5	Soil Type	I
6	Frame Type	OMRF

Table-02: Design Material Properties

Sr No.	Design Parameter	Value
1	Unit weight of concrete	23.56 kN/m^3
2	Unit weight of walls	20 kN/m^3
3	Strength of Concrete	20 N/mm^2
4	Strength of Steel	500 MPA
5	Damping ratio	5 %

Table-03: Design Structural Parameters

Sr No.	Design Parameter	Value (mm)
1	Beam	300 x 450
2	Column	600 x 600
3	Slab thickness	200
4	Wall thickness	230
5	Raft Thickness	1250
6	Pile Size	1000 X 1000

3. OBSERVATION THROUGH GRAPHS

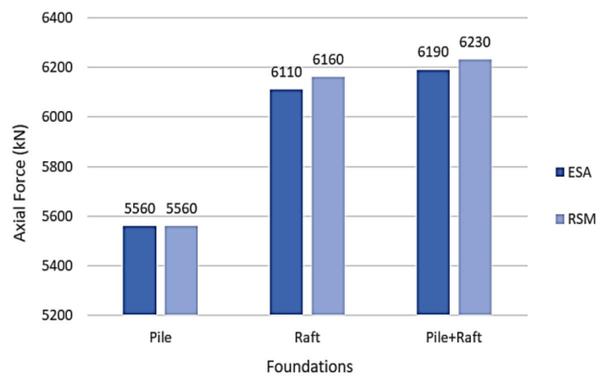

Figure 3.1: Maximum Axial Forces (Fx) in Columns.

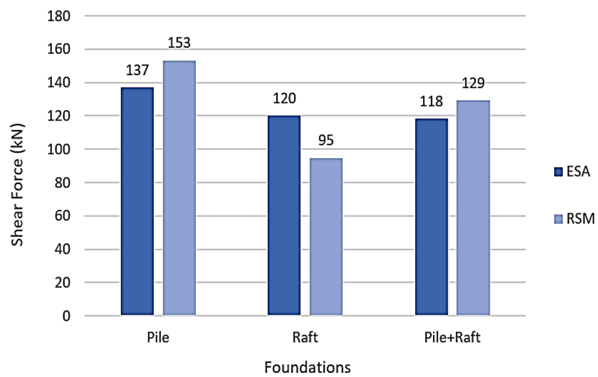

Figure 3.2: Maximum Shear Forces (Fy) in Columns.

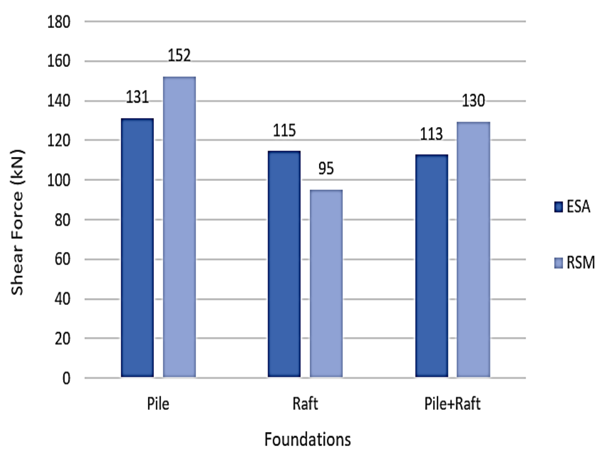

Figure 3.3: Maximum Shear Forces (Fz) in Columns.

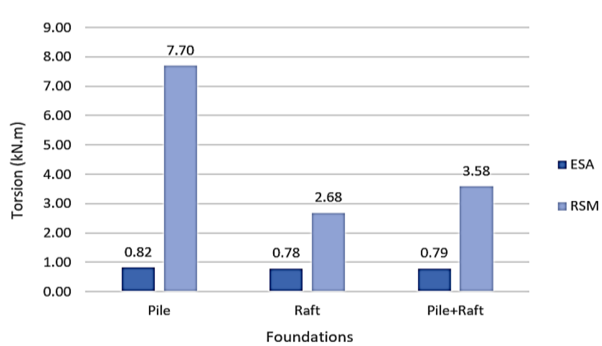

Figure 3.4: Maximum Twisting Moment (Mx) in Columns.

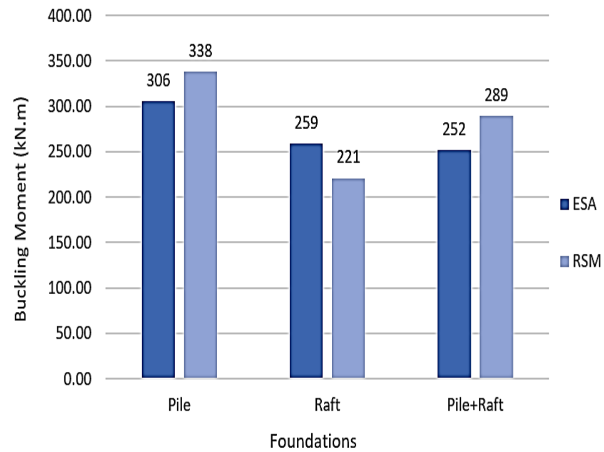

Figure 3.5: Maximum Buckling Moment (My) in Columns.

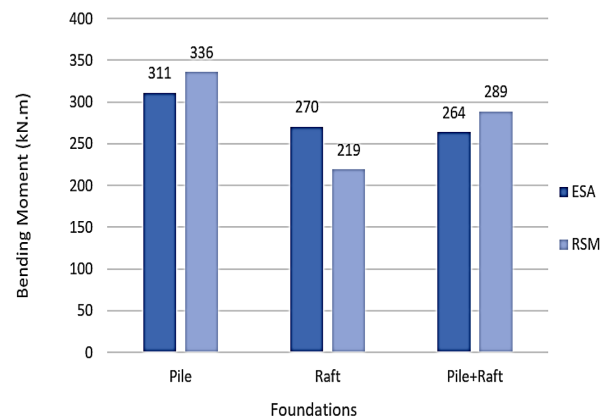

Figure 3.6: Maximum Bending Moment (Mz) in Columns.

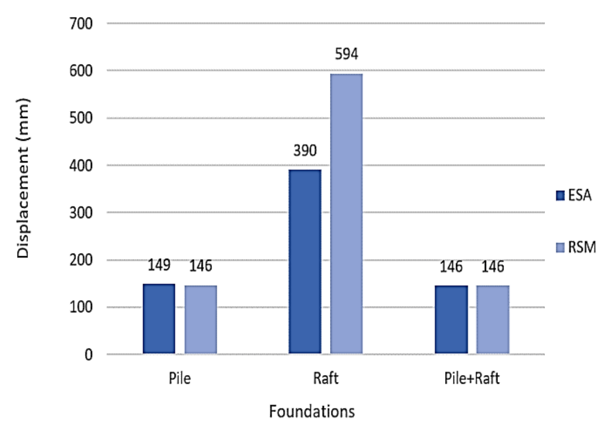

Figure 3.7: Maximum Resultant Displacement in Columns.

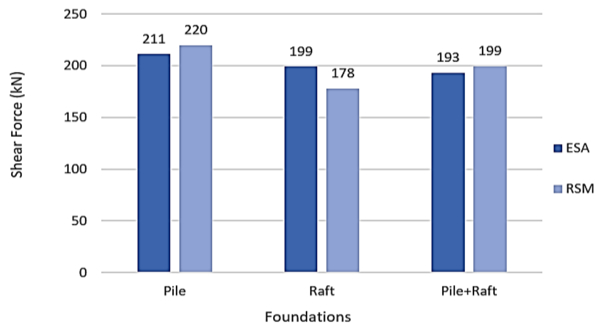

Figure 3.8: Maximum Shear Forces (Fy) in Beams.

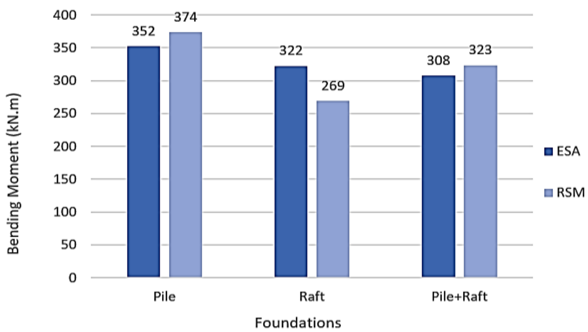

Figure 3.9: Maximum Bending Moment (Mz) in Beams.

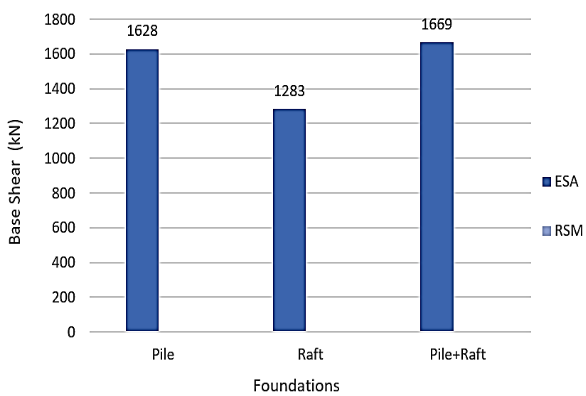

Figure 3.10: Maximum Base Shear Values for Model.

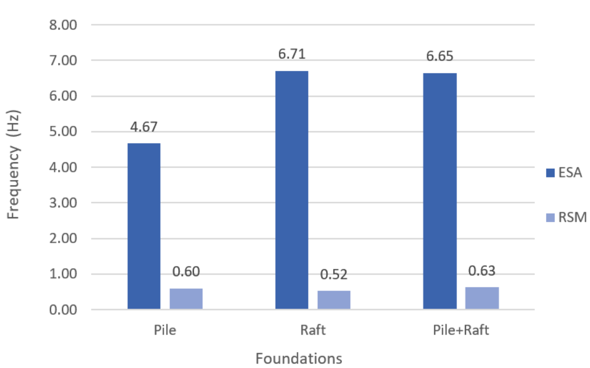

Figure 3.11: Critical Calculated Frequency.

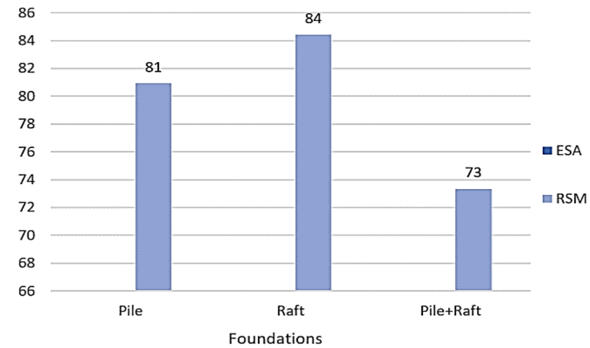

Figure 3.12: Mass Participation Factors in Percentage.

4. DISCUSSION AND CONCLUSION

The G+10 storey RC frame structure is analyzed for equivalent static method and Response Spectrum method for Pile Foundation, Raft Foundation and Pile-Raft Foundation were shown in above figures, it can be concluded that many research studies and building codes have addressed this issue of foundation Soil Structure Interaction. Seismic codes provide criteria to classify soil as soft, medium, and hard. Most of the studies have focused on investigating the structure by considering the soil either soft, medium, hard but in this case the structure is analyzed by selecting specific soft soil properties. It can be concluded that,

- The maximum value of axial force (Fx) shown in figure 3.1, is obtained for Model with Pile Raft Foundation (Model-III) while minimum axial force (Fx) is obtained for Model with Pile Foundation (Model-I). The percentage increase in axial force for Response Spectrum Method is 0.65 %.
- The maximum value of shear force shown in figure 3.2, 3.3, is obtained for model with Pile Foundation (Model-I) while minimum values is obtained for model with raft foundation (Model-II). The percentage increase in shear force for Response Spectrum Method is 11.68 %.
- The maximum value of Torsion (Mx) is shown in figure 3.4, is obtained for Model with Pile Foundation (Model-I) while minimum value is obtained for model with raft foundation (Model-II).
- The maximum value of buckling moment (My) and bending moments (Mz) shown in figure 3.5 and 3.6, is obtained for Model with Pile Foundation (Model-I) while minimum value is obtained for model with raft foundation (Model-II). The percentage increase

in buckling moment and bending moments is 10.45 % and 8.04%.

- The maximum value of displacements shown in figure 3.7, is obtained for model with raft foundation (Model-II) while minimum is obtained for Model with Pile Foundation (Model-I). The percentage increase in displacements is 52.30%.
- The maximum value of shear force in (FY) shown in figure 3.8, in Beams is obtained for model with Pile Foundation (Model-I) while minimum values is obtained for model with Pile raft foundation (Model-III). The percentage increase in shear force in (FY) and is 4.26 %
- The maximum value of bending moment (Mz) shown in figure 3.9, in beams is obtained for Model with pile foundation (Model-I) while minimum value is obtained for model with raft foundation (Model-II). The percentage increase in bending moment (Mz) is 6.25%.
- The maximum value of base shear shown in figure 3.10, is obtained for Model with pile raft foundation (Model-III) while minimum value is obtained for model with raft foundation (Model-II).
- Critical frequency and Time period is obtained for model with raft foundation (Model-II) for Response Spectrum Method.

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