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SOIL STRUCTURE INTERACTION EFFECT IN FOUNDATIONS

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Abstract

A foundation transfers a portion of a structure's weight to the earth. The traditional method of isolated and eccentric footing has been replaced by mat foundation in recent trends. Nevertheless, the concept of soil structure interaction (SSI), which refers to the qualities of the soil in contact with the foundation, has not been implemented in detail in reality. Research has shown that integrating soil structure interaction (SSI) has a major impact on a structure's performance. Winkler's approach was employed in our work to mimic the spring-like foundation soil. This study details how several foundation types, including combined footing, strap footing, and eccentric isolated footing, affect the RC-frame structure's dynamic properties, including base shear, roof displacement, and natural time period. For all foundation types, the SSI impact revealed an increase in the structure's roof displacement; however, the effect is more pronounced in the case of an eccentric isolated foundation. Roof displacement was used as a performance criterion to assess the constructions' performance. This research analyses changes in base shear, roof displacement, and natural time period as a result of taking SSI into consideration. It ends with a call for SSI to be taken into account in structural analysis and design.

Keywords: Roof displacement; Base shear; Winkler's technique; Foundation; Soil Structure Interaction (SSI)

1. Introduction

Due to land scarcity and the fast pace of urbanisation, multistory structures are being built. The moment-resisting frame, shear walls, core walls, and combinations of these components make form the superstructure of these buildings. But unless we take into account the way that soil and structure behave in response to one another—a phenomenon known as soil structure interaction (SSI)—there is a gap in the efficiency of the foundations (Pradhan, 2002). The motions that are not impacted by structural vibrations or the waves that are scattered at and around the foundation. The three types of soil that are included in the study are soft, medium, and hard soil (Thapa, 2017). It has been demonstrated that adding SSI is contributing to roof displacement (Halkude et al., 2014, "IS 1893 (Part 1): Criteria for Earthquake Resistant Design of Structures", 2002). The importance of our study comes from the application of these findings to the structural design procedure.

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2. Methodology

Fig. 1 as follows provides a conceptual framework for the in-depth investigation of this study:
There are two primary methods for simulating the soil beneath a foundation in the literature that has been consulted; these models are referred to as the Winkler and the Continuum models.

2.1. Winkler Model

The Winkler foundation concept views the soil as a system of springs that move in response to loads applied to them. The method uses a single parameter—the modulus of sub grade reaction, or "K" parameter—to represent the soil and explains it in terms of linear stress strain behaviour. Idealisation of Winkler model is shown in Figure 2.

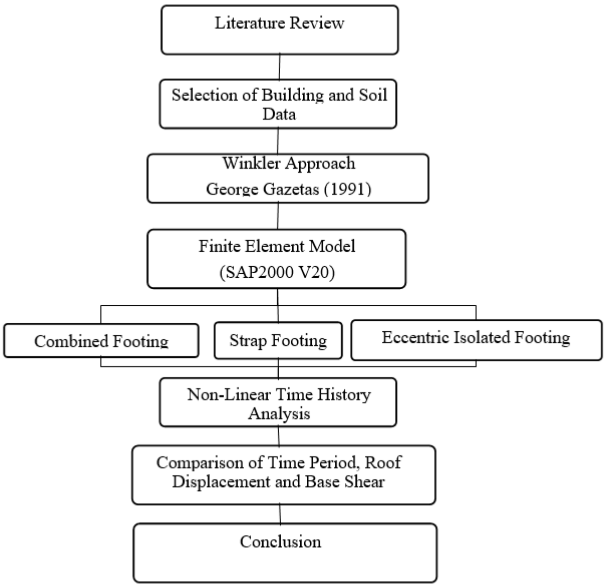

Figure 1. Flowchart for Methodology

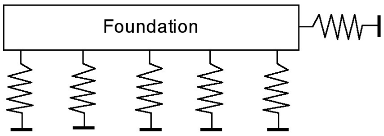

Figure 2. Winkler model

2.2. Finite Element Model

FEM of a building with varying support conditions. Two distinct structures—Twostorey, and Four story—were taken into account during the investigation. Table 1 and Table 2 display their attributes.

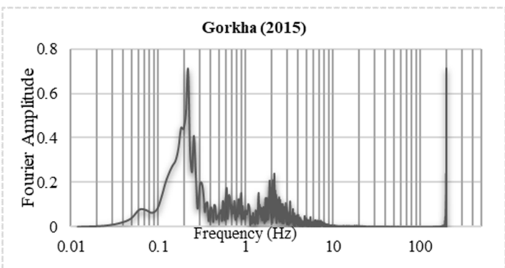

Figure 3. Gorkha earthquake (2015) time history plot

2.3. Non-Linear Time History Analysis

Nonlinear Time History Analysis is used to examine each type of model's dynamic performance. The Gorkha earthquake 2015 is used in the analysis, which had a PGA of 0.16g. Figure 3 displays the earthquake's time history.

Table 1. Description of Two Storey Building

Description	Data (m)
Number of storey	2
Number of bays in X direction	3
Number of bays in Y direction	3
Storey height	2.9
Bay width in X direction	4
Bay width in Y direction	4
Size of beam	0.4×0.23
Size of column	0.35×0.35
Thickness of slab	0.125
Strap footing size (Property Line)	1.69×2
Strap footing size (Middle)	1.52×2
Strap beam size	0.65×0.4
Combined footing size	4.85×1.32
Eccentric footing size	2×2
Depth of footing	0.65

Table 2. Description of four storey building

Description	Data (m)
Number of storey	4
Number of bays in X direction	3
Number of bays in Y direction	3
Storey height	2.9
Bay width in X direction	4
Bay width in Y direction	4
Size of beam	0.4×0.23
Size of column	0.35×0.35
Thickness of slab	0.125
Strap footing size (Property Line)	2.92×2.7
Strap footing size (Middle)	1.65×2.7
Strap beam size	0.7×0.55
Combined footing size	4.88×2.53
Eccentric footing size	2.5×2.5
Depth of footing	0.7

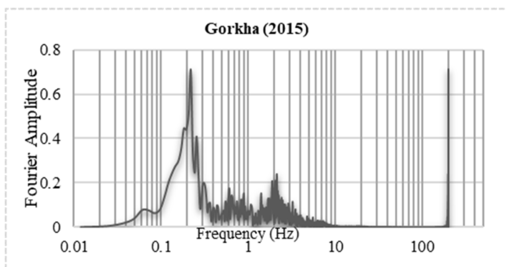

Figure 4. Fourier amplitude spectrum for Gorkha earthquake

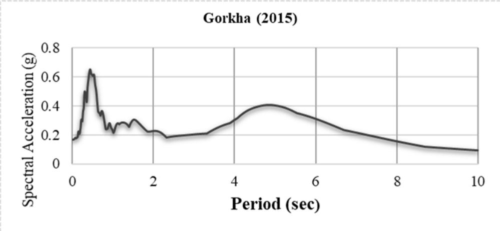

Figure 5. Response spectrum for Gorkha earthquake

3. Results and Discussion

Plotting of the structures' base shear response and roof displacement occurs when the time history is completed for each model. The following section shows the response of structures for soft soil condition.

3.1. Foundations on Soft Soil of Two Storey Building

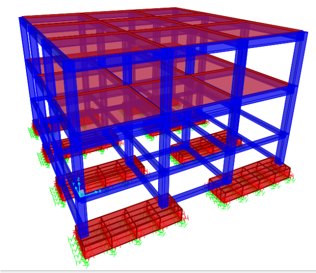

Figure 6. FEM model of two storey building with spring support condition in combined foundation

Base shear and roof displacement response is represented in Figure 7 and 8. Maximum and minimum Roof Displacement were 29.27mm and -45.48mm. Likewise maximum and minimum value of base shear was found to be 1339.58 KN and -1055.13

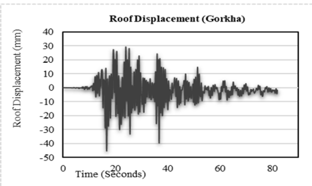

Figure 7. Roof displacement with combined footing under soft soil condition

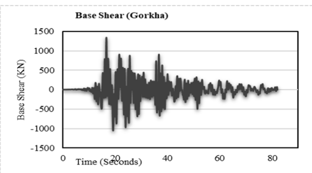

Figure 8. Base shear with combined footing under soft soil Condition

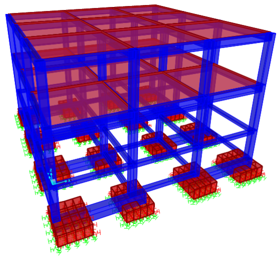

Figure 9. FEM model with strap footing

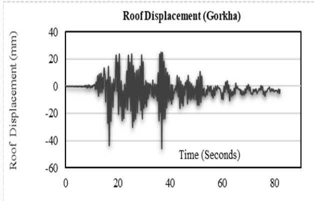

Figure 10. Roof displacement with strap footing under soft soil condition

In strap footing, base Shear and roof displacement response is represented in Figures 10 and 11. . Maximum and minimum roof displacement were 71.13 mm and -51.44 mm. Likewise maximum and minimum value of base shear was found to be 1507.2 KN and -1869.9.

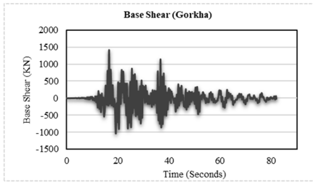

Figure 11. Base shear with strap footing under soft soil condition

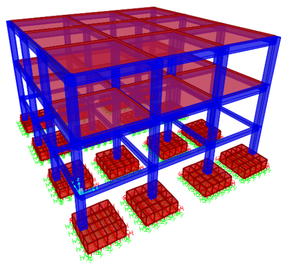

Figure 12. FEM model with eccentric isolated footing

In eccentric isolated footing, Base Shear and Roof Displacement Response is represented in Figure 13 and 14. Maximum and minimum roof displacement were 50.82mm and -64.84mm. Likewise maximum and minimum value of base shear was found to be 907.16 KN and -884.47.

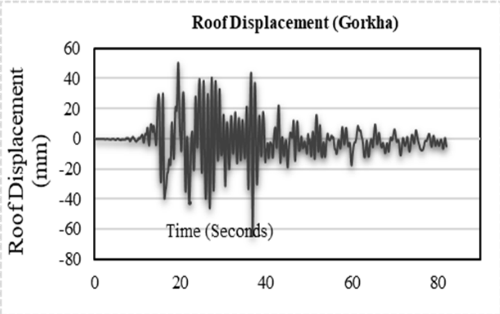

Figure 13. Roof displacement for isolated footing under soft soil condition

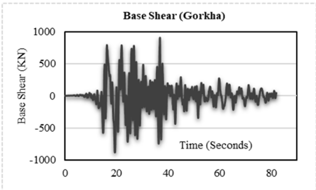

Figure 14. Base shear for isolated footing under soft soil condition

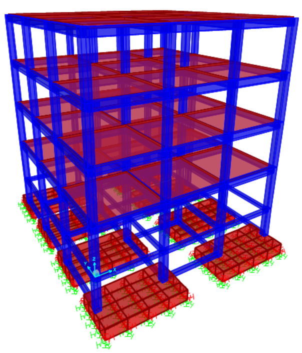

Figure 15. FEM model of four storey building with combined footing

3.2. Foundations on Soft Soil of Four storey building

In combined footing of four storey Base Shear and Roof Displacement Response is represented in Figures 16 and 17. Maximum and Minimum Roof Displacement were 86.19mm and -101.84mm. Likewise maximum and minimum value of base shear was found to be 1889.4 KN and -1860.5 KN.

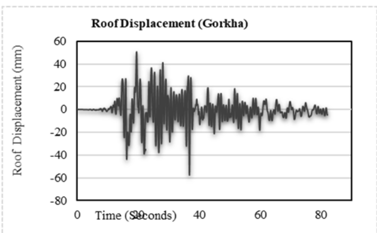

Figure 16. Roof displacement with combined footing under soft soil condition

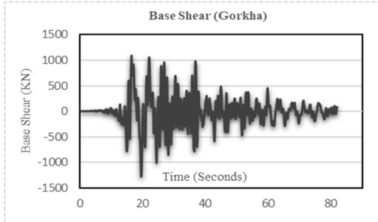

Figure 17. Base shear with combined dooting under oft soil condition

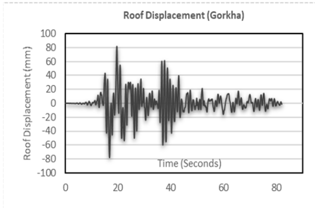

Figure 18. Roof displacement for strap footing under soft soil

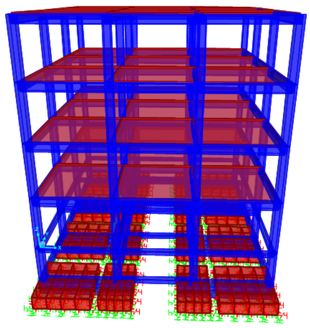

Figure 19. FEM model with strap footing

In Strap footing of Four Storey Base Shear and Roof Displacement Response is represented in Figures 18 and 20. Maximum and Minimum Roof Displacement were 81.32 mm and -77.88mm. Likewise maximum and minimum value of base shear was found to be 1855.71 KN and -1912.29.

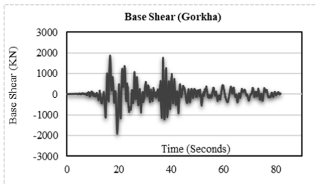

Figure 20. Base shear with strap footing under soft soil

Roof Displacement Response is represented in Figure 22 and 23. Maximum and Minimum Roof Displacement were 153.15mm and -132.9mm. Likewise maximum and minimum value of Base Shear was found to be 1584.28 KN and -1686.18.

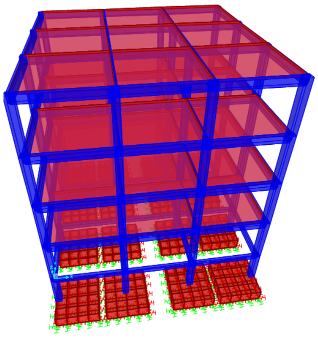

Figure 21. FEM model with eccentric isolated footing

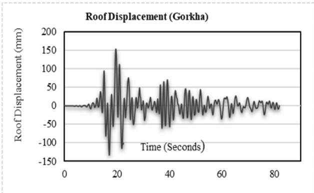

Figure 22. Roof displacement for eccentric footing under soft soil condition

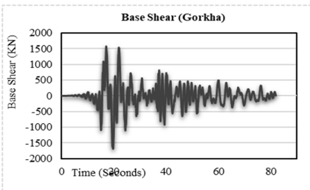

Figure 23. Base shear for eccentric isolated under soft soil condition

3.3. Fixed Base Condition

In Two Storey fixed based condition Base Shear and Roof Displacement Response is represented in Figures 25 and 26. Maximum and Minimum Roof Displacement were 24.50 mm and -43.68 mm. Likewise maximum and minimum value of Base Shear was found to be 1403.743 KN and -1269.76 KN.

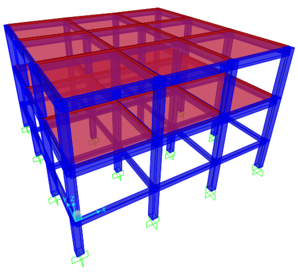

Figure 24. FEM model of two storey with fixed base soft soil condition

In four storey fixed based condtion Base Shear and Roof Displacement Response is represented in Figures 28 and 29. Maximum and Minimum Roof Displacement were 48.69 mm and -55.69mm. Likewise maximum and minimum value of Base Shear was found to be 1433.908 KN and -1502.4.

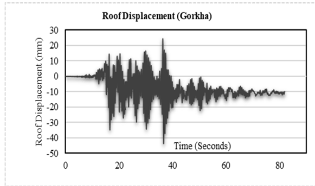

Figure 25. Roof displacement with fixed base under soft soil of two storey building

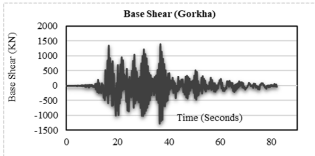

Figure 26. Base shear for two storey fixed base condition

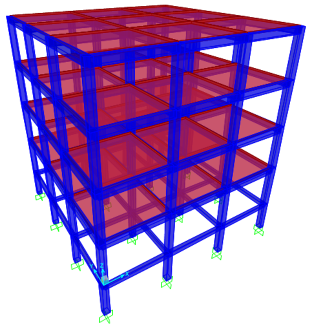

Figure 27. FEM model of four storey building with fixed base

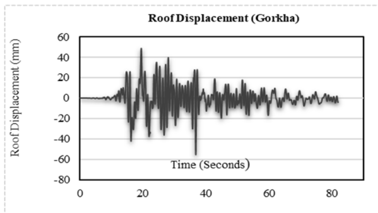

Figure 28. Roof displacement for four storey building with fixed base under soft soil

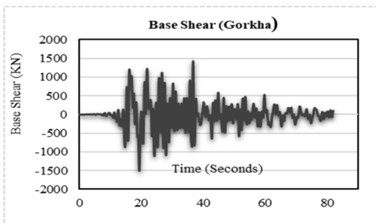

Figure 29. Base shear for four storey building with fixed base under soft soil

3.4. Natural Time Period

Figure 30 and 31 depict how the natural time period varies depending on the kind of support and soil conditions. According to observation, the natural time period of the construction lengthens when SSI is taken into account, and this is especially true in soft soil.

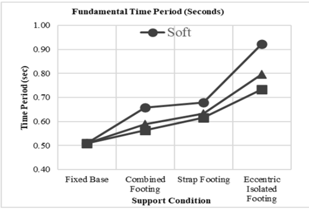

Figure 30. Variation of time period for two building with different soil

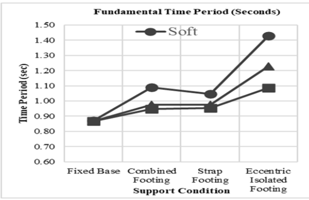

Figure 31. Variation of time period for four storey different soil condition

3.5. Roof Displacement

Figure 32 and 33 illustrate how roof displacement varies depending on the kind of support and soil conditions. Taking into account the effects of SSI has raised the structure's roof displacement and demonstrated a good link with soil flexibility.

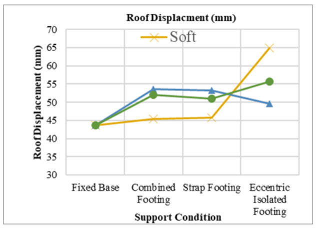

Figure 32. Variation of roof displacement for building for two-storey for Gorkha earthquake

3.6. Base Shear

Figure 34 and 35 illustrate the fluctuation of base shear for different types of support and soil conditions. Base flexibility is seen to increase with base shear.

4. Result Validation

For validation of the result firstly a sample work was carried out according to research paper presented by

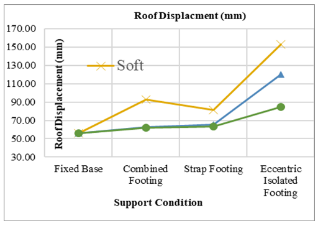

Figure 33. Variation of roof displacement for building for four storey for Gorkha earthquake

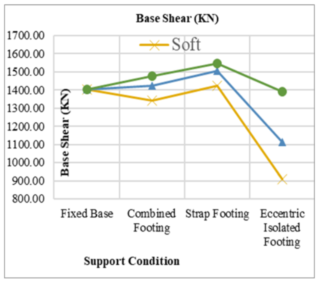

Figure 34. Variation of base shear for building for two storey for Gorkha earthquake

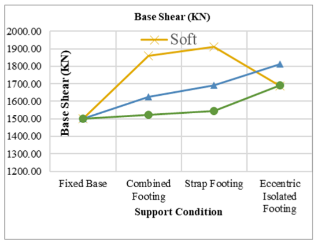

Figure 35. Variation of base shear for building for four storey for Gorkha earthquake

Halkude et al. (2014). A five storey building was modelled as per the properties provided by the author in the research paper. Calculation and analysis procedures were carried out as explained in the research paper The FEM model for five storey building with mat foundation is shown below.

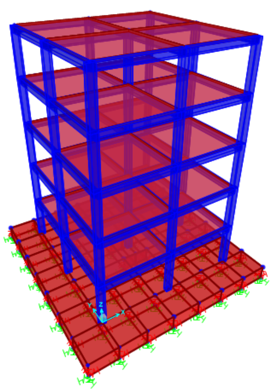

Figure 36. FEM model for five storey building with mat foundation

The results obtained after modal analysis and response spectrum analysis and the comparison with results from research paper is shown in table below.

Table 3. Comparison of five storey building for mat foundation

Source	Time Period (s)	Roof Disp. (mm)
From Research Paper	1.36	20
From Modelling	1.34	24.5

5. Conclusion

Different types of foundation conditions for soft, medium, and hard soil conditions are evaluated for two and four storey buildings. The seismic response of each form of foundation is examined with respect to base shear, roof displacement, and natural time period. The main metric used to assess the structure's performance is roof displacement. Also, the results obtained from the time history analysis of Gorkha earthquake 2015 is primarily taken into account.

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