Foundation Type Influence on the Construction Site Seismicity

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Abstract. The construction site geotechnical conditions are an important factor in the structures seismic resistance estimation. Based on the earthquakes consequences analysis to buildings with the same structural schemes and overall dimensions, the construction site estimated seismicity dependence on the base soil seismic stiffness and the transverse waves speed is fixed in the seismic building design code. In the research, a math modeling experiments for completely identical structures, but with different foundations types on identical soil conditions, were performed. The performed calculations analysis showed a significant discrepancy in the structures response under seismic impact for different foundations types.

Keywords: Seismic Impact · Time History Analysis · Soil Conditions · Microseismic Zoning

1 Introduction

Strong earthquakes consequences analysis showed many examples of various damage to same design schemes buildings and structures, but located in different geotechnical conditions [1–4]. Seismic building design code links the seismic impact intensity with the soil density and its water saturation. This dependence was obtained on the long-term observations' basis of the strong earthquakes' consequences.

For example, some buildings and structures after the earthquake in 1964 in the Niigata city (Japan) withstood the seismic impact, but were significantly damaged as a result of the earth foundation destruction. Due to the sands compaction, about a third of the city's territory suffered sharp subsidence, in some places reaching two meters.

After the earthquake in Alaska in the same 1964, the city of Anchorage, located 130 km from the earthquake epicenter, was badly damaged, and the Valdez and Seward cities were less damaged, although their distance from the epicenter is identical. The reason for the destruction is unstable thixotropic clays significant thickness that form

S. V. Klyuev et al. (eds.), *Innovations and Technologies in Construction*, Lecture Notes in Civil Engineering 307,
https://doi.org/10.1007/978-3-031-20459-3_37

the base in the Anchorage area. These soils are subjected to structural changes under dynamic influences.

Perform the calculation together with the soil base in an explicit form (3D soil model) both in terms of computer capacity and creating such models. As part of the technical documentation audit, it was noted the following approach prevalence in the calculation schemes formation: the structures seismic impact calculation is performed separately from the base, or with soil reaction coefficient usage. These approaches do not allow assessing the soil mass real stress–strain state, that may lead to consequences similar to the earthquakes in Anchorage and Niigata.

Under performing microseismic zoning, the construction site design seismicity is specified depending on the base soil seismic stiffness and the speed transverse waves. According to Table 4.1 SP 14.13330.2014 «Seismic Building Design Code», the design seismicity can be reduced by 1 point for category I soils and vice versa it can be increased for category IV.

This design code desire to provide soft soils design "margin" is quite reasonable, but does this assumption reflect the actual system response during earthquakes? Are the soft soils dissipative properties taken into account during seismic impact? Is it correct to reduce the construction site design seismicity for the category I soils? And does the foundation type choice affect the overall system response under earthquake?

2 Methods and Materials

Seismic impact math modeling by time history method was performed using the Plaxis 2D software package.

The research object is a four-tiered flat equipment structure 10 m wide and 12 m high (floor height—3 m). Foundation thickness—600 mm, slabs and column thickness—300 mm. Structures material—concrete B25. The calculation is performed in the elastic formulation. Damping in the structures is taken into account using the Rayleigh equation [5, 6].

The structure foundation is composed of three engineering-geological elements (see Fig. 1):

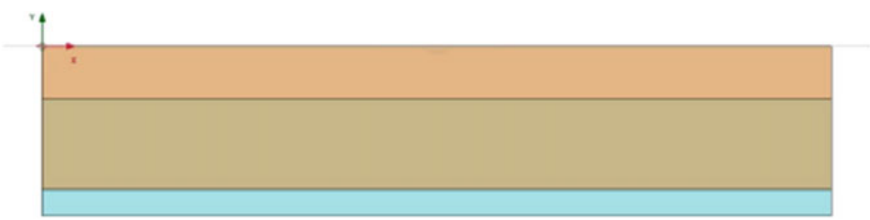

Fig. 1 Structure base

- Upper layer—silty gray loams, indistinctly layered, with plant remains, fluid-plastic;

- Middle layer—silty gray sandy loam with gravel, pebbles, with interlayers of loam, plastic;
- Bottom layer—granite.

For the upper and middle layers, a Hardening Soil with Small Strain Stiffness (HSS) material model was adopted. In fact, to describe the change in stiffness with the amount of deformation, only two additional parameters are needed:

- Initial shear modulus or shear modulus for ultra-small strains G_0;
- Shear deformation level $\gamma_{0,7}$, at which the secant shear modulus G_S decreases to about 70% of the value G_0.

Depending on the type of foundation, three calculation models are modeled:

- Direct foundation (see Fig. 2);

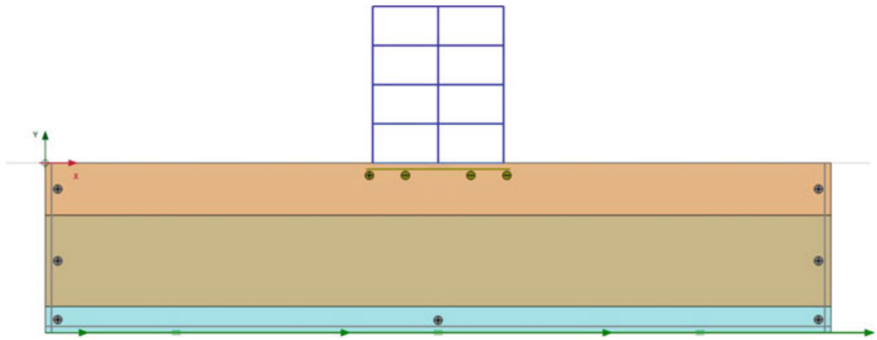

Fig. 2 Calculation model with direct foundation

- Pile foundation: compression piles with a cross-section of 400 × 400 mm (see Fig. 3);

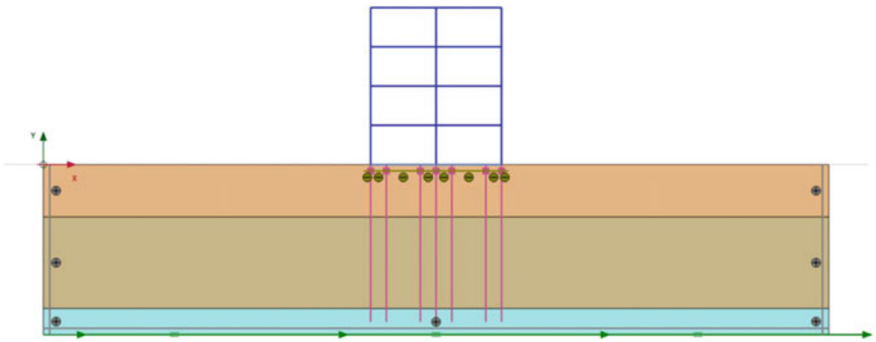

Fig. 3 Calculation model with compression piles

- Pile foundation: friction piles with a cross-section of 400 × 400 mm (see Fig. 4).

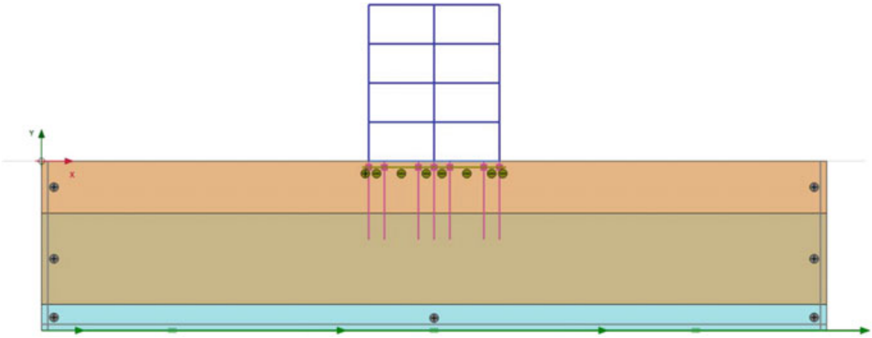

Fig. 4 Calculation model with friction piles

The boundary conditions choice depends on the vibration source location:

- The source is located inside the model. The generated and reflected waves go beyond the model boundaries;
- The source is outside the model. The generated waves remain inside the model, while the reflected waves must go beyond it.

The boundaries were assigned according to the second variant: the earthquake source is located outside the model at significant depth.

At the lower boundary, Compliant base (special boundary condition) was used. The left and right boundaries are set using the Free field boundary conditions.

Seismic impact is modeled by applying a seismogram (Line Displacement) at the lower boundary. Earthquake intensity—8 points [4, 7–10] (Fig. 5).

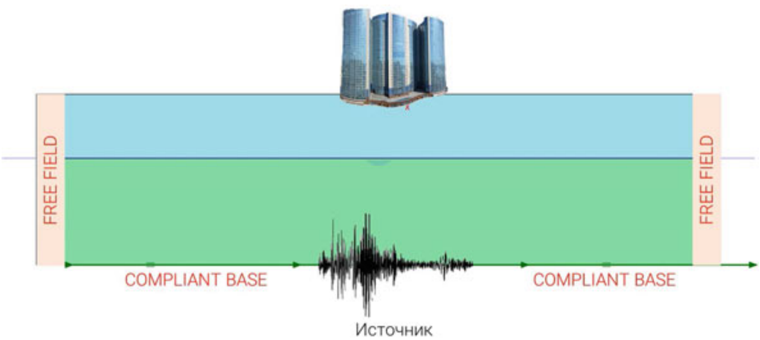

Fig. 5 Calculation model boundary conditions

3 Results and Discussion

According to the calculation results, dynamic models' responses were obtained.

Structure natural vibrations periods with foundations on a natural foundation, with pile foundations (compression and friction piles) are respectively equal to 0.9, 0.75, 0.725 s (see Fig. 6). The difference between the maximum and minimum periods is 19.4% (Figs. 7, 8, 9, 10).

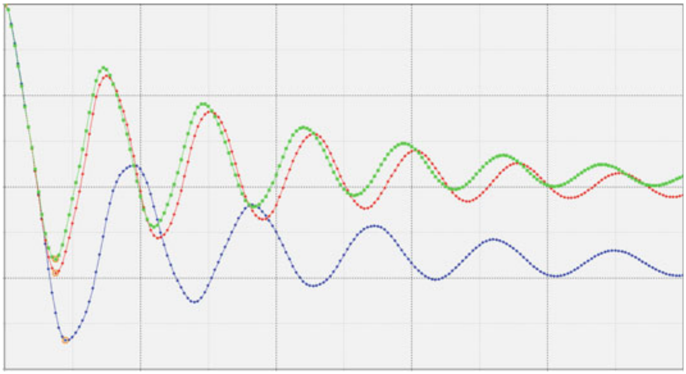

Fig. 6 Top point displacement graph

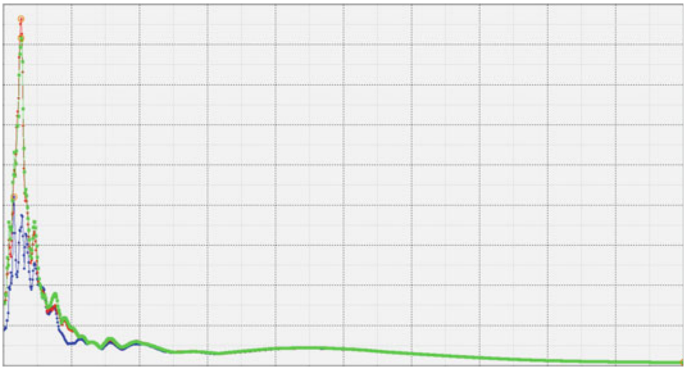

Fig. 7 The response spectrum at foundation level

Under analyzing the structures response, significant discrepancies were obtained in the results for pile foundations and direct foundation (Table 1):

- The natural period difference is 19.5%;
- Peak accelerations differ by more than 2 times.

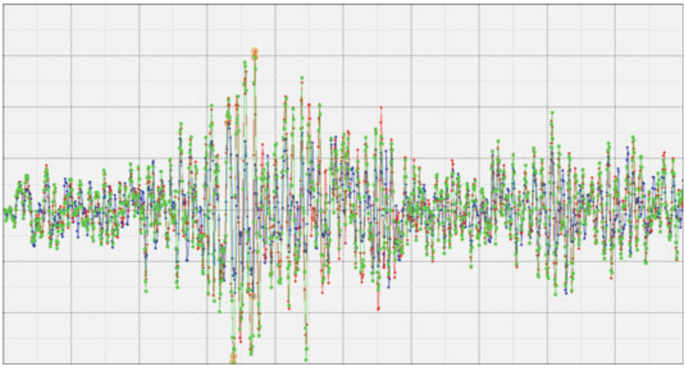

Fig. 8 Accelerogram at foundation level

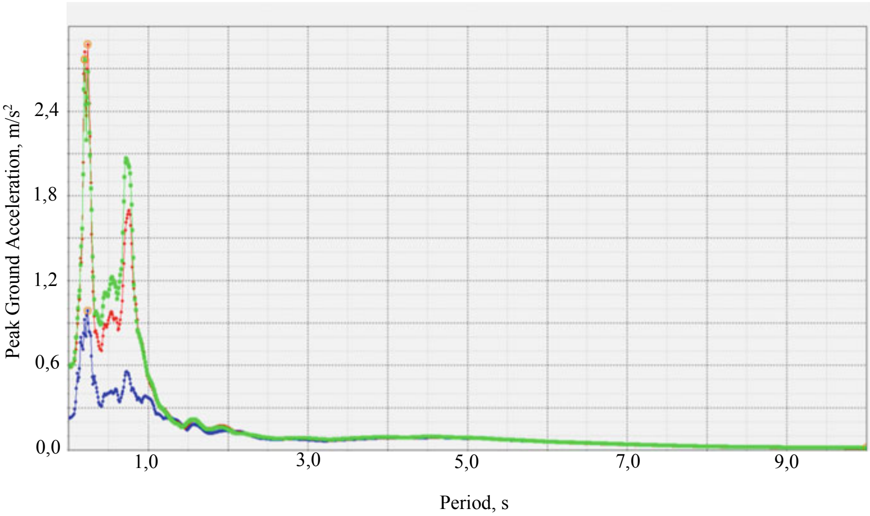

Fig. 9 Response spectrum at top point level: -•-Natural Base, -•-Friction Piles, -•-Piles Racks

4 Conclusion

In the process of research, number of calculations were performed by time history analysis using acceleration records, top point displacement graphs, response spectrum at the foundation and top point level were plotted. The resulting discrepancies are explained by the soil dissipative properties that lead to the seismic impact reduce.

The structures seismic resistance estimation should be carried with the "structure-foundation-base" system usage. This approach makes it possible to make cost-effective decisions, taking into account the soils damping properties. Accelerations graphs of the top point and in the foundations level show significant differences depending on the foundations type. Thus, the foundations design features affect the overall response

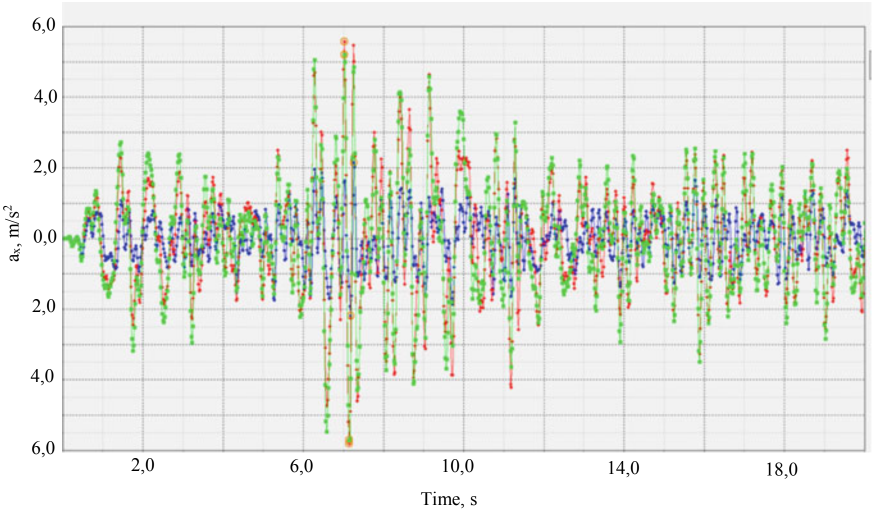

Fig. 10 Accelerogram at top point level: -•-Natural Base, -•-Friction Piles, -•-Piles Racks

Table 1 Results comparison table

Comparison parameter	Foundation type		
	Direct foundation	Compression piles	Friction piles
Natural period, s	0.9	0.725	0.75
Top point displacement, mm	36.5	27.3	29.6
Peak acceleration at foundation level, m/s^2	1.63	3.02	2.98
Peak acceleration at top point level, m/s^2	2.26	5.64	5.51

during earthquakes. To clarify the seismic impact intensity, it is necessary to develop a system for taking into account the foundation type influence during engineering surveys.

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