*Research Inventy: International Journal of Engineering And Science*
*Vol.12, Issue 5 (May 2022), PP 01-08*
*Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com*

# Studying the Influence of Soils under the Foundation on the Structural System When Subjected To Seismic Loads

Ha Thanh Tu[1]
[1] *Faculty of Civil and Environment, Thai Nguyen University of Technology, Thai Nguyen, Vietnam*

***Abstract:*** *Big earthquakes with the intensity of earth-quaking from VII degrees to IX degrees were forecasted to be able to occur in Viet Nam. Therefore, studying to calculate the impacts of earthquakes on building structures in Viet Nam is very necessary. This paper studies the influence of different types of soil on the structural system of high-rise buildings when the building is subjected to earthquakes. After analyzing the model in Etabs software, the authors found that different types of ground for displacement, internal force difference up to 167%. At the same time, the authors also proposed a procedure to calculate the earthquake load-bearing structures using the response spectrum of many types of copper vibrations. It helps design engineers to easily apply structural calculations*

***Keywords:*** *Mortality. Earthquake, high-rise building, response spectrum, displacement, internal force.*

---

Date of Submission: 04-05-2022 Date of Acceptance: 18-05-2022

---

## I. INTRODUCTION

Earthquakes are extremely terrible natural disasters because in just a few seconds a large city can completely collapse. Entire areas can be subject to subsidence and sometimes rivers are changed as a result of strong earthquakes. To this day, contemporary scientists and technicians have not been able to accurately predict when and where earthquakes will occur. Therefore, humans do not have active prevention measures for each earthquake. And as an inevitable consequence, when an earthquake occurs, it causes great damage to people and property. However with earthquake disasters that have occurred in the world and Vietnam, it has been shown that, to minimize the loss of life and property caused by earthquakes, the construction itself must be designed properly. earthquake resistant. Each country must take appropriate measures in this regard.

In recent times, earthquakes have occurred frequently with increasing magnitude. The occurrence of earthquakes causes a lot of damage to buildings. In Thai Nguyen, there have been more tremors in recent years. Although it has not caused much damage to the works, but the works are also affected. Due to climate change, human impact on the stratigraphic structure, the risk of increasing the vibrations causing earthquakes is increasing. Planning and investing in earthquake mitigation strategies is becoming a topical issue. It is very urgent in many countries around the world, including Vietnam. If you do not want to pay the cost of many times greater costs for earthquake response operations or earthquake reconstruction and recovery activities, it is necessary to have planning and done before the earthquake has happened. Recognize the importance of earthquake prevention and mitigation. Since 2000, Vietnam has started a new research direction on urban earthquake risk assessment, structural behavior research when subjected to earthquake loads.

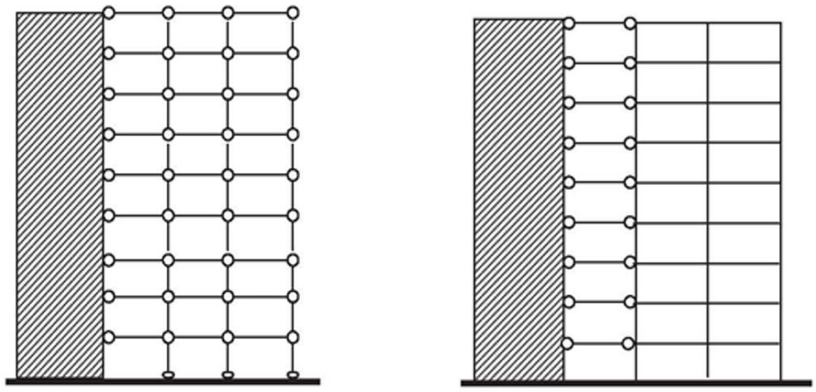
Earthquake calculation methods are interested in research by scientists around the world and are becoming more and more complete with increasing accuracy. Along with that trend, Vietnam has issued the standard TCVN 9386:2012 - design standard for earthquake-resistant buildings. This standard is based on EUROCODE - Design of structure for earthquake resistance standard. It has added and replaced some content to suit Vietnamese conditions. However, the guidance for design staff who can calculate the impact of earthquake loads is limited, especially earthquakes depend on seismic properties of each region.

With the continuous progress of science and technology, construction works in the world in general and Vietnam, in particular, is developing with radical heights and complexity. The main characteristics of high-rise buildings are the number of floors, their heavyweight, and the impact of horizontal loads. As the height of the building increases, the complexity of design calculations also increases. In particular, they are determining the response of the building to the impact factors of external conditions such as loads due to wind, earthquakes. The study and Calculation of high-rise buildings taking into account earthquake loads is still limited and has not been focused on research.

# II. METHODOLOGY

## 2.1 Design basis of high-rise buildings subjected to earthquake loads

When designing high-rise buildings, it is necessary to consider whether the building is located in an area prone to strong earthquakes to apply the corresponding regulations. A structure without an earthquake-resistant design is called a conventional structure. Special attention should be paid to structural requirements when designing earthquake-resistant structures. Structures of high-rise buildings need to calculate and design with combinations of vertical loads, horizontal loads (wind: static and dynamic), earthquake loads according to TCVN 2737:1995 “Loads and impacts”; TCVN 9386:2012 Design of earthquake-resistant works; TCXDVN 198 – 1999 High-rise buildings. Structural high-rise buildings need to calculate and check for strength, deformation, stiffness, stability and vibration. Internal force and deformation of high-rise buildings are calculated by the elastic method. For beams, it is possible to adjust the internal force due to plastic deformation. In mixed structures, depending on how the frameworks, it is divided into two diagrams: bracing diagram and frame-brace diagram.



(a) Bracing diagram b) Frame-bracing diagram

***Figure 1***. Working diagram of high-rise building

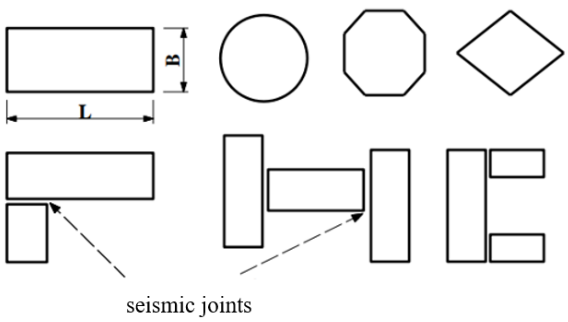



***Figure 2.*** Types of high-rise dental plan

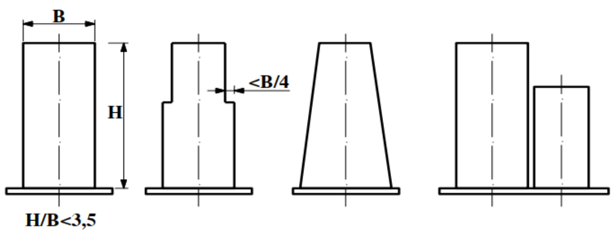



***Figure 3***. Shape by height

## 2.2 Calculation methods of structures subjected to earthquake loads

***Equivalent static method:*** The static equivalent calculation method (also known as the equivalent horizontal force method) is the simplest of the methods used to determine the response of structures subjected to earthquakes. This method assumes that the working structure is elastic linearly, while the geometric nonlinearity is considered indirectly. The horizontal loads acting on the building height are considered equivalent to the seismic action and are combined with the vertical loads (gravity forces). This method is often used to design relatively regular works with a basic period of about 1.5 - 2s. For structures with irregular shapes or long periods, dynamic methods should be used. It is more accurate than form analysis or inelastic reaction history analysis.

***Nonlinear static calculation method:*** In this method, the assumed distribution of horizontal inertia forces is based on the assumption that the response of the structure is controlled by a single vibration pattern. The shape of this oscillation remains constant throughout the reaction time. Usually, the chosen fundamental vibrational form is the dominant response form of the dynamic multiple degrees of freedom system. The effects of other types of oscillations are considered to be small and ignored. The nonlinear static calculation method with such a horizontal load distribution is called the conventional incremental calculation method. It is often used to calculate the response of low and medium-height buildings. The method is simple and deterministic with acceptable accuracy. The deformation process of the structural system and its components does not require complicated modeling and elaborate calculations like other dynamic calculations. Therefore, the incremental calculation method is considered an effective and convenient method in dynamic computation.

***Vibration analysis method and response spectrum:*** The response of structures with many degrees of freedom to earthquake action can be calculated by analyzing the structural system into multiple structural systems with one equivalent degree of freedom. Calculate the response of each equivalent system in time and then algebraically add the reactions to get the response of the original structure. If the calculation is only to determine the maximum response quantities, the seismic action will be given as a response spectrum. Calculation results according to the vibration integral method will be the largest response of the structural system. The vibrational integral method, as well as the response spectrum method, has the following disadvantages:

- Depends on the artificial separation of vibrational patterns.
- It is necessary to combine the calculation results in the forms of vibration according to the principle of cooperation, so it is limited to the linear elastic working stage of the material.
- Not applicable to some structural systems that cannot use form analysis techniques.
- Does not give precise instructions on the formation of plastic joints in some members.

***The method of direct integration of the equation of motion:*** The response of structural systems subjected to any action or earthquake can be determined by directly integrating the equation of motion for time. This method does not need to change or transform the equations of motion to a system with one or more degrees of freedom as in the oscillatory integral method. The direct time integral method determines the approximate values of the solution for a selected set of time values $\Delta T$.

The principle of this method can be summarized as follows: (i) assume functions describing the variation of displacement, velocity and acceleration over a period of time and (ii) the equations of motion are not satisfied at all

times DT but only for a constant time $\Delta t$.

This time interval is called the time step. This also means that the static equilibrium condition of the inertial, drag and elastic forces with the applied load will occur at many time steps $\Delta t$, $2\Delta t$, …, $n\Delta t$. At each time step, the equation of motion is solved with the initial conditions of displacement and velocity determined in the previous step. The method of direct time integration can be applied to both static and nonlinear structural systems. This method can be considered as the only general method for calculating the dynamic response of structural systems under any load.

**2.3 Research model of high-rise buildings**

Research on reinforced concrete structures for 15-story buildings in Thai Nguyen City; has a typical floor plan as shown in Figure 4

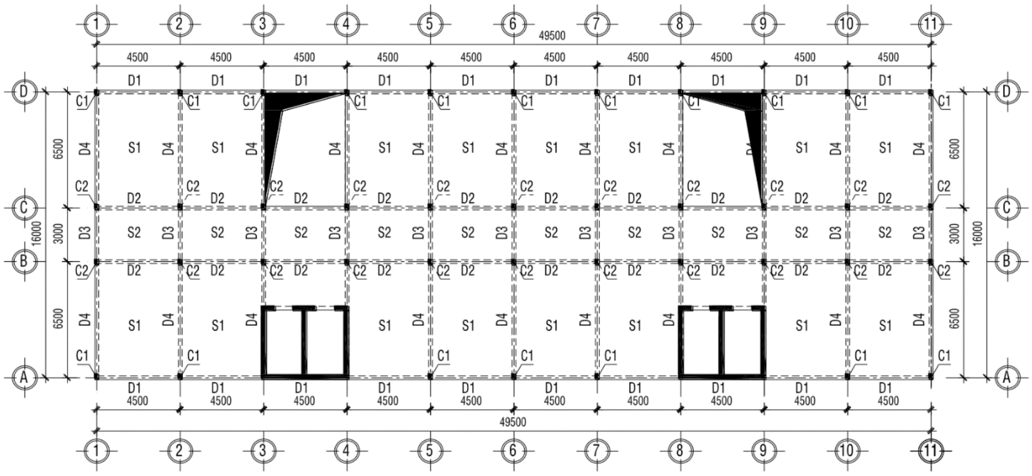



***Figure 4.*** Typical floor plan of floors 1-15

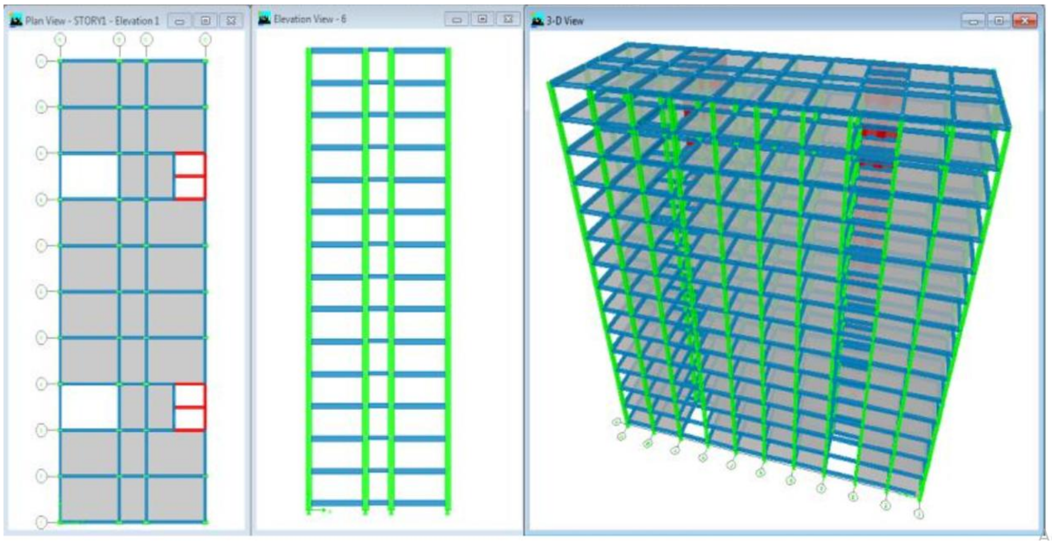



***Figure 5.*** Building structure model in ETABS

**Materials:** Reinforced Concrete; Using durable grade concrete B25. Height of each floor: $h_t$= 3.3 (m); distance from foundation beam to foundation surface 1.5 (m).

**Section:** Floor S1 (120 mm), S2 (100 mm); Core thickness δ= 250 mm; Beams D1,2,3 (250x400) mm, D4 (250x550) mm; Column C1 (300x600) mm, Column C2 (300x700) mm.

**Calculated load:**

- Static loads due to the weight of the structure itself: Floors, beams, columns, walls, declared for ETABS v9.2 software to calculate automatically.
- Static load of floor structural layers: $g_{tt}$ = 1.1 (kN/m2).
- Static load due to walls built on beams: $g_t$ = 11.48 (kN/m).
- Floor live load: S1 ($p_{tt}$= 2,4 kN/m2); S2 ($p_{tt}$= 3,6 kN/m2)
- Earthquake load: importance factor γ = 1; behavior coefficient q= 3.9.

## III. EXPERIMENTAL RESULTS

### 3.1. Research results

Analysis of earthquakes by the method of response spectrum of many vibrations to evaluate the influence of different types of ground on the structure of the building when subjected to earthquakes.

Combination of frame displacement K6 (in the X direction)

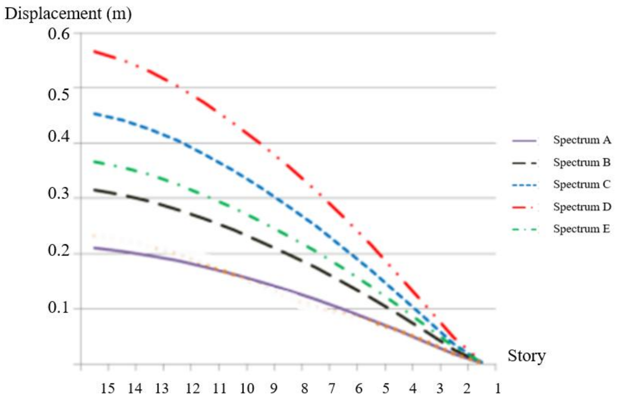
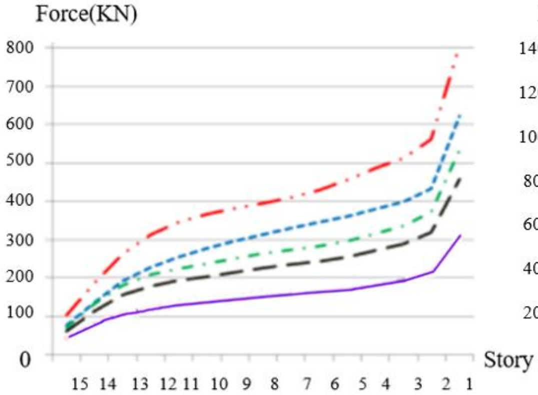



***Figure 6.*** K6 frame displacement when analyzing earthquakes with different types of ground

Combination of internal forces of frame column K6 (in the X direction)



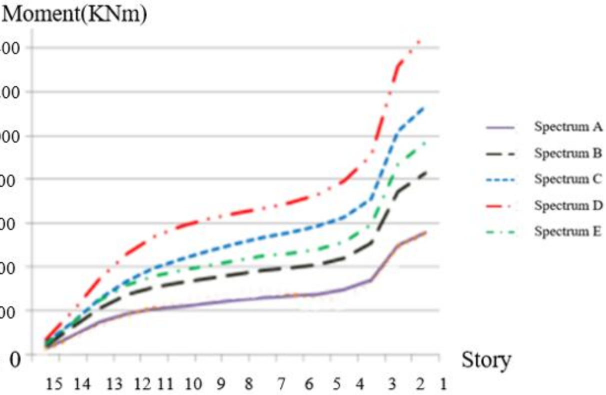




***Figure 7.*** The shear force of column A of K6 frame when analyzing earthquakes with different types of *ground*

***Figure 8.*** Moment of column A of K6 frame when analyzing earthquakes with different types of ground

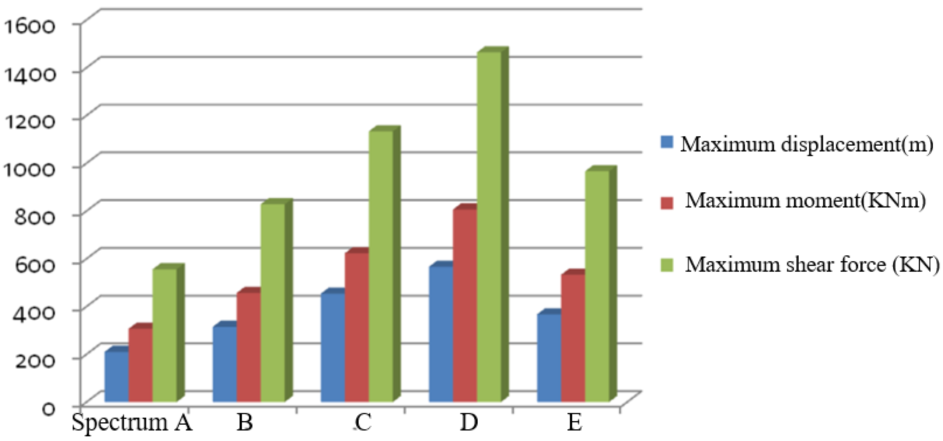



***Figure 9.*** The largest earthquake consequences when analyzing with soil types

The results of earthquake analysis according to the time-history method and the multi-form response spectrum method on the ground type A according to TCVN 9386:2012 have the largest difference of 15%.

The ground at the bottom of the structure has a great influence on the earthquake impact on the structure. Earthquake consequences: displacement, internal force of the structure when considering different types of ground soil A, B, C, D, E according to TCVN 9386:2012, the results differ by 167%.

### 3.2 Proposing the calculation procedure according to the response spectrum method

The vibration response spectrum analysis method is a dynamic structural method that uses an emotional response spectrum of all types of vibrations. The response spectrum of the vibration patterns is determined based on the coordinates of the response spectrum curves suitable for the respective natural periods of oscillation.

**Step 1:** Determine applicable conditions: applicable to all types of construction works..

**Step 2:** Determine the ratio value $a_{gR}/g$

Based on the zoning map of the background acceleration with a repeating cycle of 500 years for type A foundation, or based on the partitioning of the ground acceleration according to administrative locations to determine the value of the ratio $a_{gR}/g$ (where: $a_{gR}$ - is the peak of the reference ground acceleration at the construction site, g - the acceleration due to gravity). The $a_{gR}/g$ ratio can also be obtained from data provided by the competent professional body.

Note: The values given in the ground acceleration partition map and the ground acceleration partition table according to administrative locations (of the TCVN 9386:2012 standard) are the ratio $a_{gR}/g$. In addition, the design spectral coordinate parameter $S_d(T)$ of TCXDVN TCVN 9386:2012 does not say anything about the dimension of $S_d(T)$. So in this calculation procedure, to avoid dimensional confusion, the value $S_d(T)$ is replaced by $S_d(T) = S_d(T\,)/g$, which is a dimensionless quantity.

**Step 3:** Level and importance factor.

The significance level is characterized by the importance coefficient $\gamma_l$ . The value of γl is determined according to Article 4.2.5 and Table 4.3 of TCVN 9386:2012 ($\gamma_l$ = 1.25, 1.00 and 0.75 respectively for works I, II and III).

**Step 4:** Determine the design ground topsoil acceleration value.

Acceleration of the design ground topsoil ag corresponding to the ultimate limit state is determined as follows (through g): $a_g/g = a_g/g^* \gamma_l$

Note: TCVN 9386:2012 stipulates:

- Strong earthquake $a_g/g \geq 0.08$, seismic resistance must be calculated and constructed.
- Earthquake is weak $0.04 \leq a_g/g < 0.08$, apply seismic mitigation solutions that have been mitigated.
- Very weak earthquake $a_g/g < 0.04$, no need for seismic design.

**Step 5:** Identify ground conditions according to earthquake impact.

According to soil classification, there are seven types of soil, including A, B, C, D, E, S1, and S2. Based on the stratigraphic cross-section, geotechnical engineering survey data at the construction site and ground conditions according to the seismic impact specified in Article 3.1.2 and Table 3.1 of the standard to identify the foundation soil for the Calculation of seismic resistance.

**Step 6:** Determine the response coefficient q of the structure. Depending on the type of structure, there are different behavior coefficients according to TCVN 9386:2012.

**Step 7:** Determine the number of vibrational forms to consider in the response spectrum method.

Suppose the above condition is not satisfied (such as houses and buildings where the torsional vibration contributes significantly). In that case, the minimum number of vibration types k that need to be considered in the Calculation must satisfy the following two conditions:

$$k \geq 3 \cdot \sqrt{n} \text{ và } T_k \leq 0,2s \tag{1}$$

k: number of oscillations to be considered in the Calculation.

n: number of floors above the foundation or top of the hardware below.

$T_K$: the natural period of oscillation corresponding to the kth form of oscillation.

**Step 8:** Determine the dimensionless design spectrum $S_d\,(T_i)$ corresponding to each type of vibration.

i: i-th individual vibration pattern in the X-direction on the plane.

$$\begin{cases} 0 \le T \le T_B : \overline{S}_d(T) = \dfrac{a_g}{g} \cdot S \cdot \left[ \dfrac{2}{3} + \dfrac{T}{T_B}\left( \dfrac{2.5}{q} - \dfrac{2}{3} \right) \right] \\ T_B < T \le T_C : \overline{S}_d(T) = \dfrac{a_g}{g} S \dfrac{2.5}{q} \\ T_C < T \le T_D : \overline{S}_d(T) \begin{cases} = \dfrac{a_g}{g} \cdot S \cdot \dfrac{2.5}{q} \dfrac{T_C}{T} \\ \ge \beta \dfrac{a_g}{g} \end{cases} \\ T_D < T \ : \overline{S}_d(T) \begin{cases} = \dfrac{a_g}{g} S \dfrac{2.5}{q} \dfrac{T_C T_D}{T^2} \\ \ge \beta \dfrac{a_g}{g} \end{cases} \end{cases} \qquad (2)$$

In there:

S, $T_B$, $T_C$, $T_D$, determined according to Table 3.2 of TCVN 9386:2012.

T – Period of oscillation of the system (1 degree of freedom);

β – 0.2 (coefficient corresponding to the lower bound of the horizontal design spectrum)

**Step 9:** Determine the bottom shear force at the foot of the structure corresponding to the ith vibration pattern in the X direction by the following formula:

$$F_{X,i} = \overline{S}_d(T_i) W_{X,i} \qquad (3)$$

$W_{X,i}$ : effective weight (in the X-direction on the plane) corresponding to the i-th form of vibration.

$$W_{X,i} = \frac{\left( \sum_{j=1}^{n} X_{i,j} \cdot W_j \right)^2}{\sum_{j=1}^{n} X_{i,j}^2 \cdot W_j} \qquad (4)$$

n: total number of degrees of freedom (number of floors) in the X-direction.

$X_{i,j}$ : displacement value in the X direction on the plane at the jth weighting point of the ith vibration pattern.

$W_j$: weight concentrated on the jth floor of the building.

**Step 10**: Distribute the bottom shear force to the story**.**

$$F_i = F_b \cdot \frac{z_i W_i}{\sum z_j W_j} \qquad (5)$$

**Step 11:** Combination of vibration patterns. For simplicity, consider the oscillations linearly independent by combining the vibration patterns according to the square root principle of the sum of squares.

## IV. CONCLUSION

The ground at the bottom of the foundation has a great influence on the impact of earthquakes on the structure. The soil type of rock, loose soil in the compact state, and clay in the hard state with great thickness will be less affected by earthquakes than the soil in the porous state (medium compaction) or cohesive soil in the soft state. (medium tight). Consequences of earthquakes: displacement, internal force of the structure when analyzed with different types of ground, the difference is up to 167%. Proposing a calculation procedure using the response spectrum of many types of vibrations for high-rise buildings.

**Conflict of interest**

There is no conflict to disclose.

## ACKNOWLEDGEMENT

This work was supported by Thai Nguyen University of Technology, Vietnam.

## REFERENCES


[1]. Nguyen Le Linh (2011), Theoretical basis for earthquake-resistant construction. Science and Technology Publishing House, Hanoi.

[2]. Nguyen Le Linh (2007), Earthquake and earthquake-resistant construction design, Construction Publishing House, Hanoi.

[3]. Nguyen Tat Tam (2010), Calculation of reinforced concrete high-rise buildings with hard floors under the impact of earthquakes according to TCXDVN 375-2006, Master thesis, Hanoi University of Architecture.

[4]. Le Thanh Huan (2007), Structural design of high-rise buildings, Construction publishing house, Hanoi.

[5]. TCVN 9386:2012. Design of earthquake-resistant structures, Construction Publishing House, Hanoi, 2006.


Ha Thanh Tu. " Studying the Influence of Soils under the Foundation on the Structural System When Subjected To Seismic Loads." *International Journal of Engineering and Science*, vol. 12, no. 5, 2022, pp. 01-08.