

ON THE DETERMINATION OF UNDERGROUND AND ABOVE-GROUND PARTS OF BUILDINGS IN TERMS OF STRUCTURAL CALCULATION SCHEME

Zeynalov Latif Majid oğlu- honored engineer, prof., The Ministry of Emergency Situations of the Azerbaijan Republic, State Agency for Control of the Construction Safety, General Administrative Office for State Expertise, z.latif@rambler.ru

Hajiyev Mukhlis Ahmad- doc.tech.sc., prof., AzUAC, hajiyevmuxlis@mail.ru

Polukhov Ilham Khalil- PhD in tech.sc., The Ministry of Emergency Situations of the Azerbaijan Republic, State Agency for Control of the Construction Safety, General Administrative Office for State Expertise, ipolukhov@gmail.com

Asadov Elchin Ziraddin- PhD in tech.sc., The Ministry of Emergency Situations of the Azerbaijan Republic, State Agency for Control of the Construction Safety, General Administrative Office for State Expertise, asadovelcin75@gmail.com

Abstract. The conditions of acceptance of the superstructure and substructure of the building frame from a structural point of view, their mutual structural effect on each other were investigated, and it was proposed to use the results in the improvement of seismic codes in the article.

Keywords: AzDTN 2.3-1, Turkiye seismic codes, superstructure, substructure, building height, base

The correct selection of the load-carrying system of the building and the calculation scheme of this system is one of the basic principles of structural design. Calculation and modeling of the underground and above-ground parts of the building frame separately or together, as well as based on the principle of superstructure-foundation-soil interaction, especially with the consideration of the earthquake effect, becomes even more relevant in the design. Unfortunately, in AzDTN 2.3-1 "Construction in Seismic Areas" code [1], which have been in force since 2010, the issues of structural scheme selection and modeling have almost not been addressed. In "Turkiye Building Earthquake Regulation" [2], published in 2018, this issue has been given considerable attention.

As a rule, building standards in seismic regions limit the height and number of floors depending on the seismicity of the construction site and the load-bearing structures (structural scheme) of the building [1, table 8; 2, table 4.1; 3, table 8]. Designing experience shows that there is a need to clarify the concepts of "building height" and "number of floors" from a seismic point of view.

Below, it was tried to examine the conditions of acceptance of the underground and above-ground parts of the building frame, their mutual structural influence on each other. First of all, let's note that the structural division considered here should be distinguished from the division of the underground and above-ground parts of the building from the point of view of architecture, operation, MEP and other such aspects. We are talking about the frame parts that make up the load-bearing system of the building, their distribution and correct modeling in terms of their work under external influences, especially under the influence of earthquakes. To distinguish between these approaches, the upper and lower parts can be called superstructure and substructure, respectively.

AzDTN 2.3-1 codes contain a note "The height of the building is accepted as the height from the planned surface of the pavement or adjacent land (if there is a slope) to the lower level of the cover of the last floor" [1, change 2, table 8, note 1]. According to СНиП II-7-81* "the height of the building is considered to be the difference between the lower pavement or planning level adjacent to the building and the top of the outer wall" [3]. The clarification provided in both norms is not complete, disputes arise in the determination of the lower and upper levels, as a result of the lower and upper parts from the structural point of view, i.e. the heights of the substructure and superstructure, the total height, as well as the placement of the foundation [5,6,7,8].

First of all, the issue of determining (accepting) the level that separates the building's substructure from its superstructure should be clarified. First, in the seismic codes of the Russian Federation [4] see the following note- "If the basement part of the building is separated from the soil fill or the structure of neighboring buildings (including by deformation seams, from the author), the underground floors are included in the (above ground) floors of the building and the limit height."

By the way, according to another note right there, "The last floor, whose floor mass is less than 50% of the average floor mass of the building, is not included in the (above ground) floors of the building and the limit

height". At first glance, it seems that the issue has been clarified in general. However, when looking at the solution of the issue with specific schemes, it seems that there are problems that need to be specified.

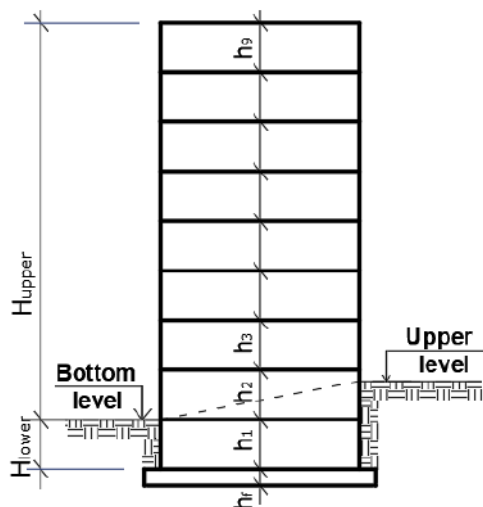


Figure 1. The underground part of the building is connected to the soil from the side [1]

Above, with the notes taken from [1 and 4] it is possible to determine the heights and storeys of the substructure and superstructure parts of a stand-alone building (Fig.1), and with the notes taken from [4] the building with neighboring buildings around it (Fig.2).

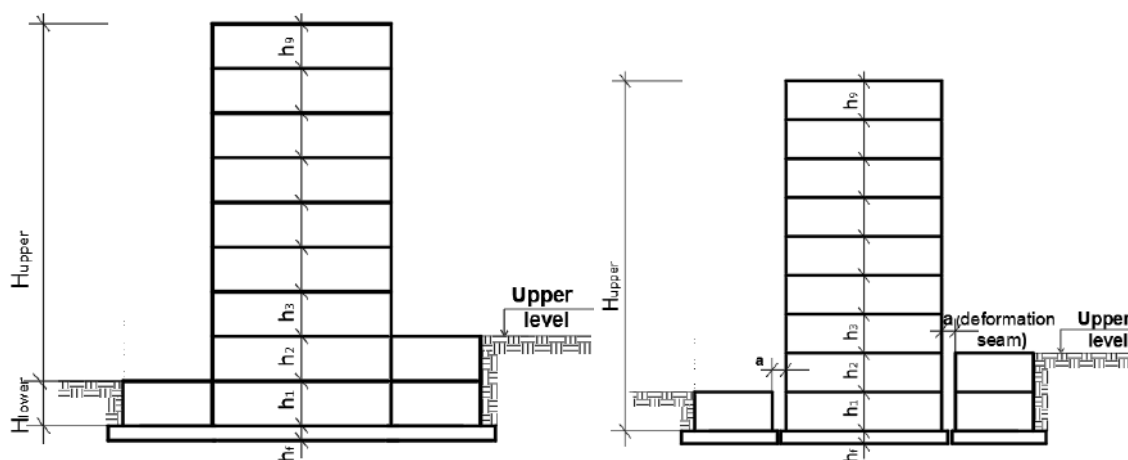


Figure 2. a) Neighboring buildings are in one block with the considered building.

b) Neighboring buildings are separated from the considered building by a deformation seam [4]

Building's substructure 1 floor and superstructure 8 floor will be in figures 1 and 2a and heights of these parts will be following:

$$H_{\text{lower}} = h_1 + h_f \quad \text{and} \quad H_{\text{upper}} = h_2 + \dots + h_9 \quad (1)$$

Since the basement of the building in Figure 2b is separated from the structure of the neighboring buildings, its basement floor is also included in the total structural height of the building (see note taken from 4). That is:

$$H_{\text{lower}} = h_f \quad \text{and} \quad H_{\text{upper}} = h_1 + \dots + h_9 \quad (2)$$

However, upon careful examination, it becomes clear that the structural substructure and superstructure division that is being discussed should not be considered simply as the height distances of building parts and the number of floors. This division has an important place in the resistance of the building frame to earthquake effects, and it should be treated very seriously in the creation and modeling of the calculation scheme of the building frame. The substructure must ensure that all loads and impacts transmitted from the superstructure are

properly transferred to the ground base. When viewed from the point of view of static loads, the working principles of the upper and lower constructions are similar, and in fact they differ in the values of the loads. Under the horizontal dynamic influence of the earthquake, the work of the substructure becomes much more complicated.

The horizontal loads collected from the superstructure, seem to have really become a shearing force and try to cut the vertical elements at the junction (interface) of building parts, that is, columns and shearwalls. The direct dynamic effect of seismic waves on substructure elements should not be neglected. Taking these into account, special conditions are provided that ensure that the substructure has a real base function for the upper part of the building. First of all, it is required that the basement (substructure) is surrounded by reinforced concrete shearwalls on at least three external sides along the perimeter, and at the same time, the ratio between the total fundamental period of the building and the fundamental period of the upper section ($T_{p,all} \leq 1.1 T_{p,upper}$) is ensured. If the conditions are not met, basement floors are not included in the base of the building, and in a building with a basement, as in a building without a basement, the base of the building is determined at the upper level of the foundation [3].

Thus, it is clearly seen that the height of the building in earthquake calculations is calculated from the base (heel) of the building. As a base, the upper level of the substructure (basement) should be accepted, if the rigidity of the structural system that makes up the substructure (basement in simplified form) is ensured and a reliable connection of this system with the ground is created, otherwise, the upper level of the foundation should be accepted, regardless of whether or not there is an substructure (basement).

Depending on whether or not the building's substructure is considered as a full-strength load-bearing system, the transmission of earthquake forces (bending moment and shear force) to the sub-unit elements and finally to the foundation and soil foundation is fundamentally different. Therefore, in modern construction standards, a special place is allocated to the construction of the calculation model of the upper and lower structural schemes.

When calculating the buildings with basement surrounded by rigid reinforced concrete walls from the outside by the equivalent seismic load method, the upper part of the building and the lower part with basement are modeled together as a common single load-bearing system. In this case, two load-state calculation methods (Figure 3) can be applied.

In the first loading case, the determined equivalent seismic loads, taking into account the relevant behavior and resistance reduction factors, are applied only to the upper section (Figure 3b), and as a result of the calculation, reduced internal forces are obtained in both the upper section and the lower section.

In the second loading case, again in the single load-bearing system model, only the masses of the basement floors in the substructure and the approximate equivalent seismic loads acting on these floors are calculated by including $T=0$ (Figure 3c). As a result of the calculation using the earthquake load reduction factor $(R_a)_{lower} = D_{lower} = 1.5$ for the substructure, the reduced internal forces in the substructure are obtained [3,4].

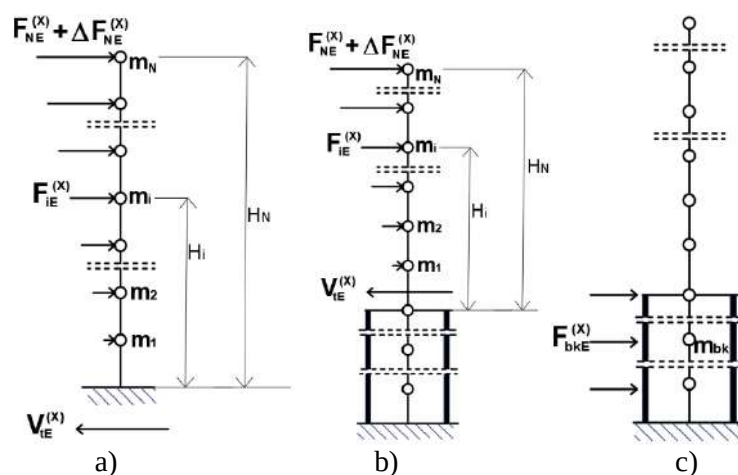


Figure 3. A similar approach can be adopted using these relevant calculation rules and coefficients in modal calculation methods considering earthquake effects. Calculation methods, modeling of load bearing systems [4]

Modeling of building frames without a basement, as well as a lower part (substructure) without the required rigidity, is performed based on the rules for the upper part (superstructure).

The structural scheme of the substructure seriously affects the work of the building foundation under the influence of an earthquake. As it is known, the purpose of designing the building foundation under seismic influence is to ensure that the carrying capacity of the foundation is not exceeded and that the displacements of the soil base are within the permissible limits. The adequacy of the design bearing capacity of the soil base of the foundation can be shown in general as follows

$$E_t \leq R_t \quad (3)$$

Here, E_t represents the design effects that include static and seismic effects and depends on the bearing system of the building frame substructure, and R_t represents the design resistance according to the corresponding collapse mechanism.

The horizontal shear force, which is the basis for earthquake design, is assumed by the passive earth pressure generated on the side of the substructure together with the frictional resistance between the soil base and the foundation [2,4]. For foundations without piles, the following inequality with respect to horizontal displacement is required to be satisfied in each of the loading cases, which include statics and earthquake effects:

$$V_{th} \leq R_{th} + 0.3R_{Pt} \quad (4)$$

Here, V_{th} represents the horizontal design force acting on the foundation base, R_{th} represents the design frictional resistance, and R_{Pt} represents the passive design resistance.

Frictional resistance in design defined as:

$$R_{th} = \frac{P_{tv} \tan \delta}{\gamma_{Rh}} \quad (5)$$

Here, P_{tv} is the design vertical pressure force acting on the foundation base, and the coefficient of frictional resistance is $\gamma_{Rh} = 1.1$.

δ is the friction angle between the foundation and the soil base, which depends on the soil and concrete of the foundation. As an example, let us show that $\delta = 0,6$ for a monolithic foundation on compacted soil, and $\delta = 0,4$ for precast foundation.

The second term of the above inequality expresses the horizontal force resistance on the side of the substructure. R_{Pt} is called passive design resistance and is calculated by dividing the characteristic passive resistance of the soil by the resistance factor.

Thus, contrary to some misconceptions, it is necessary to increase the lateral passive resistance due to the connection between the soil and the foundation and the connection of the substructure with the soil in order to receive the horizontal forces transmitted from the building frame, especially the forces generated by seismic waves.

Conclusion:

1. Structurally, the heights and number of floors of the lower and upper parts of buildings designed with earthquake effects in mind should be determined not only depending on the location of these parts below or above the ground level, but also depending on the structure, rigidity of the substructure, the connection of the side faces with the ground or neighboring buildings.
2. In order to reliably transfer horizontal impacts from the foundation to the soil base, the cohesion of the foundation to the subsoil and the connection of the substructure to the side soil must be ensured.

References

1. AzDTN 2.3-1. Seysmik rayonlarda tikinti. Layihələndirmə normaları. Dəyişiklik 1.2011, Dəyişiklik 2. Bakı. 2010- 2014
2. Türkiye Bina Deprem Yönetmeliği. Deprem Etkisi Altında Binaların Tasarımı için Esaslar. Ankara. 2018
3. SNiP II-7-81 Stroitel'stvo v seysmicheskikh rajonah. Moskva. 1981
4. Svod pravil SP 13330. Stroitel'stvo v seysmicheskikh rajonah. Moskva. 2013
5. Zeynalov L.M., Poluxov I.X., Asadov E.Z., Rzayev R.A., Asadov S.B., Amrahov A.T. Seysmik nöqteyi-nəzərdən çox mərtəbəli binaların hündür luyunun (mərtəbələrin sayının) təyini haqqında. Az İMETİ, Elmi Praktiki Jurnal 2(13), Bakı. 2017
6. Zeynalov L.M. Yeni yaradılacaq seysmik normaların bezi muddaları haqqında. İnşaatin müasir problemləri mövzusunda AzMIU İnşaat fakultesinin 100 illiyinə həsr olunmuş Onlayn beynəlxalq elmi-praktiki konfrans. Onlayn 18-19. 2020

5. Zeynalov L.M., Hacıyev M.Ə., Polukhov I.X., Asadov E.Z. Seysmik normalarin tekmlleshdirlməsinə dair. Ukrayna- Azərbaycan Onlayn Beynəlxalq Konfrans. Onlayn. 2021
6. Zeynalov L.M., Polukhov I.Kh., Golalmish M.B. Comparison of Azerbaijan and other seismic Codes. Materials of 9th international conference on Earthquake resistant Engineering Structures. A Coruna, Spain. 2013

Məqaləyə istinad: Zeynalov L.M., Hacıyev M.A., Poluxov İ.K., Əsədov E.Z. Struktur hesablama sxemi baxımından binaların yeraltı və yerüstü hissələrinin təyin edilməsi. Elmi Əsərlər jurnalı/ Scientific works. AzMİU, s. 123-127, N2, 2023

For citation: Zeynalov L.M., Hacıyev M.A., Polukhov I.K., Asadov E.Z. On the determination of underground and above-ground parts of buildings in terms of structural calculation scheme. Elmi Əsərlər jurnalı/ Scientific works. AzUAC, p. 123-127, N2, 2023

Məqalə INTERNATIONAL CONGRESS ON ADVANCED EARTHQUAKE RESISTANT STRUCTURES (AERS2023) adlı konfrans materialıdır.