Rating assessment of an urbanized area for insurance purposes

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Abstract. A rating assessment of the engineering-geological and geomorphological features of the territory has been carried out in the work. An area of 5 km x 4 km was allocated on the territory of Tbilisi. The area was divided into the squares with the size 100x100m. The minimum size of the plots was determined by the maps scale 1: 10,000. On the basis of these maps, each plot was assigned a rating according to the appropriate factor (soil type, layer thickness, groundwater level, relief, hazardous geological processes - landslide, avalanche, rockfall). Each factor was assigned a corresponding rating index (0-4). The best sites had the lowest index. Final maps of individual site ratings were compiled for various factors (soil type, thickness, etc.). On their basis, a summary rating map has been drawn up. All maps were made in GIS technology. The paper shows that the influence of these conditions can be significant in the absence of seismic impact. The results of the work can serve as a basis for assessments of any level, including for assessing seismic risk, as well as for insurance of buildings and structures located in the relevant territories.

1. Introduction

The list of studies, in which instrumental measurements are very actively used in various, very different fields of geophysics, has significantly expanded in recent years. This undoubtedly raised the quality of the results obtained as well as their reliability [1-5]. There is currently a concentration of population and basic means of production in the world in urbanized areas. From an economic, social and political point of view, this phenomenon is characterized by a high feasibility as it facilitates the management, organization, protection and communication of a concentrated population and industry. However, upon careful analysis of the situation, this fact turns out to be completely inappropriate in the conditions of a high earthquake probability, since this creates additional problems, especially if earthquakes occur in very large urban areas. This problem is very relevant for many cities in the world. Therefore, urbanized areas should be investigated in detail to establish all possible consequences of earthquakes or any other disasters.

2. Allocation of zones with different rating levels

One of the ways of a detailed study of an urbanized territory is a rating assessment of its engineering-geological and geomorphological features. For this purpose, a sufficiently large area was allocated on the territory of Tbilisi for relevant research. The allocated territory was 5 km long and 4 km wide, i.e., the total area of the study area was 20 km²[6]. The region covers the western part of Tbilisi and completely includes
the Vake region and most of the Saburtalo region. The choice of the indicated territory was based on the following considerations. Individual development occupies almost half of the territory here, and it is very concentrated. Industrial buildings take up a much smaller area. The population of the allocated area exceeds 200,000 people (this is more than 1/5 of the total population of the city). The allocated territory is one of the most important parts of the Tbilisi territory. Most of the offices and shops of Georgian and international firms and organizations are located here (Universities, UN and UNESCO representative offices, the International Eurasia Foundation, Soros Foundation, etc.). At the same time, the Vake and Saburtalo districts (especially Vake) are considered prestigious districts of the city, and the new buildings are rapidly developing here. Most of the houses were built in the second half of the twentieth century. From an engineering-geological point of view, the area is very interesting, because a wide variety of soil types and variations in their thickness, groundwater levels and difficult terrain are presented here. In addition, there are areas where dangerous geological processes are possible.

The study area was divided into 100x100 m squares. Thus, the entire selected area was divided into 50x40 = 2000 squares. Each of these sites, in order to be able to compare them, was subject to an individual rating assessment. Information about the engineering-geological conditions of the selected area was obtained on the basis of studying the engineering-geological maps of Tbilisi with the scales of 1: 10000 and 1: 25000 [1-3]. The maps scale that determined the minimum size of the square areas was used. Each feature of the geotechnical map (soil type, layer thickness, groundwater levels, slope, etc.) was transferred to the corresponding model of the site in electronic form (into a computer).

The following factors were used to form the site rating:
- Soil types
- The thickness of the soil layers
- Groundwater level
- Relief (topography)
- The existence of hazardous geological processes

Each factor was assessed on a 4-point scale, where 0 corresponded to the least influence of this factor on the site status deterioration and 4 to the biggest. Based on the analysis of engineering-geological maps, the soils of the selected area were divided into several groups:

- Unweathered and weathered rocky soils, conglomerates (A).
- Semi-weathered clayey deposits and pebbles (B).
- Clays and dense sandy loam (C).
- Subsidence clays, loams and sandy loams (D).
- Lacustrine-bog and silty soils (E).

This division was based on the fact that more or less homogeneous soil types behave differently at different degrees of watering or different slopes of the relief. When flooded (almost to the day surface), a relatively dense soil (for example, C soils) can become "weaker" than the initially "weak" but non-watered soil (E soils). The soils were ranked in the order of transition from dense soil to soft soil. At the same time, the soils were rated according to their types as follows: A soils were rated - 0, B - 1, C - 2, D - 3, E - 4 (Table 1 - 2.).

### Table 1. Indicators of various features of soils on the territory of Tbilisi

| Factor type | Factor type | Soil layer thickness | Groundwater level | Relief slope in degrees | Hazardous geological processes |
|-------------|-------------|----------------------|--------------------|-------------------------|--------------------------------|
| Symbol      | T           | m                    | H                  | W                       | R Gm* Gz*                        |
|             |             |                      |                    |                         |                                |
A Unweathered and weathered rocky soils and conglomerates

| Thickness   | A | B | C | D | E |
|-------------|---|---|---|---|---|
| <5          | 1-3 | 1-10 | - | - | - |
| 5-10        | 4-10 | 10-15 | + | + | + |
| 10-20       | 10-20 | 15-20 | + | + | + |
| 20-30       | >20 | 20-30 | + | + | + |
| 30-40       | >40 | >40 | - | + | + |
| >40         | - | - | - | - | - |

B Semi-rocky weathered clay deposits and pebbles

| Thickness   | A | B | C | D | E |
|-------------|---|---|---|---|---|
| <5          | 1-3 | 1-10 | - | - | - |
| 5-10        | 4-10 | 10-15 | + | + | + |
| 10-20       | 10-20 | 15-20 | + | + | + |
| 20-30       | >20 | 20-30 | + | + | + |
| 30-40       | >40 | >40 | + | + | + |
| >40         | - | - | - | - | - |

C Clays and loams, dense sandy loam

| Thickness   | A | B | C | D | E |
|-------------|---|---|---|---|---|
| <5          | 1-3 | 1-10 | - | - | - |
| 5-10        | 4-10 | 10-15 | + | + | + |
| 10-20       | 10-20 | 15-20 | + | + | + |
| 20-30       | >20 | 20-30 | + | + | + |
| 30-40       | >40 | >40 | + | + | + |
| >40         | - | - | - | - | - |

D Subsidence clays, loams and sandy loams

| Thickness   | A | B | C | D | E |
|-------------|---|---|---|---|---|
| <5          | 1-3 | 1-10 | - | - | - |
| 5-10        | 4-10 | 10-15 | + | + | + |
| 10-20       | 10-20 | 15-20 | + | + | + |
| 20-30       | >20 | 20-30 | + | + | + |
| 30-40       | >40 | >40 | + | + | + |
| >40         | - | - | - | - | - |

E Lacustrine-boggy sediments, silty and loose soils

| Thickness   | A | B | C | D | E |
|-------------|---|---|---|---|---|
| <5          | 1-3 | 1-10 | + | + | + |
| 5-10        | 4-10 | 10-15 | + | + | + |
| 10-20       | 10-20 | 15-20 | + | + | + |
| 20-30       | >20 | 20-30 | + | + | + |
| 30-40       | >40 | >40 | + | + | + |

The soil layers' thickness was divided into 6 groups in the ranges: <5, 5 - 10, 10 - 20, 20 - 30, 30 - 40, >40 (m). For solid soil, power (for the selected area) does not matter. In this regard, the power effect for the corresponding rocky soil A is rated 0 points. For the soils B and C, the rating points were 0, 1, 1, 2, 2, 3. For the soils D and E, the rating was 0, 1, 2, 3, 3, 4, respectively. This indicates a gradual deterioration in the condition for "weak" soils (Table 1 - 2). With an increase in the power of "weak" soil, the number of points or its rating increases, i.e., the conditions worsen.

\( G_m \) - Landslides (soils B, C, D, E)

\( G_r \) - Rockfall or landslide (soils A, B); landslide (soils C, D, E) when the layers slope coincides with the relief slope.

The third factor was represented by the level of groundwater table. The levels are divided into groups 1 - 4, 4 - 10, 10 - 20, >20 (m) from the day surface. The influence of watering on the behavior of A soils is
insignificant and it is 0. For E we have 1, 2, 3, 4, 4. For all other soils, the index was 4, 3, 2 and 0 (Table 1-2).

The next factor is the terrain slope. The influence of the relief was estimated by the inclination angle: 1 - 10, 10 - 15, 15 - 20, 20 - 30, 30 - 40, > 40 (degree). For A soils, the index was 0, 0, 1, 1, 2 and 3. For B, C, D soils had: 0, 1, 1, 2, 3, 4. For E soils: 1, 2, 4, 4, 4, 4. Due to the fact that this type of soils, as a rule, absent on inclined terrain, they become very unstable in conditions of inclination. For "weak soils" this factor becomes very significant (Table 1 - 2).

Hazardous geological processes are associated with the relief and soil type. Three types of possible dangerous geological processes: landslides, rockfalls and landslides were taken into account. Landslides are possible for B, C, D soils. Rockfall or collapse is possible for A, B, C, D soils. Landslides in the absence of watering appear only when the slope of the layers coincides with the relief slope. A collapse is possible for soils C, D, E if the slope of the layers coincides with the slope of the relief. Soils E, as a rule, are free from these processes, because they do not exist on slopes. But if they exist there, then danger increases significantly. For these processes, the soils were assigned the following rating points: A - 0, 0, 1, 2, 3, 4; B - 0, 0, 1, 2, 3, 4; C - 0, 1, 2, 3, 4; D - 0, 1, 2, 3, 4; E - 4, 4, 4, 4, 4, 4, respectively (Table 1-2).

By summing the ratings of individual sites for various factors, the final rating maps of the selected area of the Tbilisi territory were compiled: a map of soil type ratings, a map of ratings by soil capacity, a map of groundwater levels, a map of terrain ratings, a map of hazardous geological processes ratings in GIS technology. This makes it possible to take into account the role of each factor in the formation of the vulnerability on the individual sites in the designated area of Tbilisi. Further, a summary map of the rating assessment of the allocated territory was built (Fig. 1). It is clearly seen that the most dangerous areas are occupied by the areas of dark colors. The areas with a low rating are characterized by a lighter color (up to white).

It should be noted that this study was based on the fact that there was no earthquake. The territory ranking was carried out to assess the impact of exclusively engineering-geological, hydro-geological and geomorphological conditions of the territory and can have the status of their "static" assessment. Taking into account the factor of the earthquake, the rating of the territory will acquire a “dynamic” form. In this case, a number of additional factors will appear, and some of the factors considered will manifest themselves in a different way.

The results obtained are the basis for assessments at any level: in assessing the engineering-geological hazard of urbanized territories, both for non-seismic and seismic regions. This, in turn, can be an important basis for assessing the seismic risk in a territory, as well as for insurance of buildings and structures located in the corresponding territories.

The analysis of the results obtained shows that the use of the considered concept for assessing the rating of one or another section of the soil strata makes it possible to create a very reliable methodology in its reliability. This methodology allows, when formalizing any indicators of the soil layer and its stress-strain state, to use it to assess the expected damage and vulnerability of any real natural and natural-man-made system. This, in turn, becomes the basis for the application of approaches to such a system for assessing risk, including economic and social losses, i.e., the insurance basis.

### Table 2. Rating assessment of soil features in the territory of Tbilisi

| Factor type | Soil layer thickness | Ground water level | Relief (degree) | Hazardous geological processes |
|-------------|---------------------|--------------------|-----------------|--------------------------------|
| u           | m                   | m                  | weight factor   | -                              |


| Symbol | T  | H  | W  | R  | G  |
|--------|----|----|----|----|----|
| A      | 0  | 0  | 0  | 1  | 1  |
|        |    | 1  |    | 2  |    |
|        |    |    | 2  | 3  |    |
|        |    |    |    | 4  |    |
| B      | 1  | 2  | 0  | 2  | 2  |
|        | 2  | 0  | 3  | 3  |    |
|        | 3  | 0  | 4  |    |    |
|        | 0  | 4  | 0  | 0  |    |
|        | 1  | 3  | 1  | 1  |    |
| C      | 2  | 1  | 2  | 1  | 2  |
|        | 2  | 0  | 2  | 2  |    |
|        | 3  | 0  | 3  | 3  |    |
|        |    | 4  | 4  | 4  |    |
| D      | 3  | 2  | 1  | 2  |    |
|        | 0  | 2  | 3  | 3  |    |
|        |    | 4  |    | 4  |    |
|        |    |    |    |    |    |
| E      | 4  | 3  | 2  | 4  | 4  |
|        | 3  | 0  | 4  | 4  |    |
|        | 4  | 4  | 4  | 4  |    |
|        | 4  | 4  |    |    |    |
3. Summary
The rating assessment is the basis for assessments at any level: when assessing the engineering-geological hazard of urbanized territories, both for non-seismic and seismic regions. The analysis of the results obtained shows that the use of the considered concept for assessing the rating of one or another section of the soil strata makes it possible to create a very reliable methodology in its reliability. This methodology allows, when formalizing any indicators of the soil layer and its stress-strain state, to use it to assess the expected damage and vulnerability of any real natural and natural-man-made system. This, in turn, becomes the basis for the application of approaches to such system for assessing risk, including economic and social losses, i.e., the most important insurance basis both for the buildings and structures located in the relevant territories and for their residents.

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