Features of engineering and geological surveys in the conditions of dense city building

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Abstract. Engineering and geological conditions of the reconstructed territories are the important city-regulating factors in the development of master plans and land use as well as the development rules. They should be taken into account both at the pre-investment stage, and at the stages of the construction projects conceptual and working designs’ development. Data on the exposure degree to hazardous engineering and geological processes make it possible to determine the reconstructed site investment attractiveness degree, choose an effective organizational and technological solution for the urban development reconstruction, and make predictive calculations of changes in the stress-strain state of the buildings and structures depending on changes in soil conditions, such as subsidence and physical and mechanical soil properties.

1. Introduction
The main feature of engineering and geological surveys in a dense urban area is the presence of a huge array of archival materials. Naturally, there is a desire to summarize this material for ease of use and clarity. Earlier, in 1973, in the RostovDonTISIZ trust, under the leadership of K.A. Merkulova, the engineering-geological and hydrogeological maps of the Rostov-on-Don city were compiled [1]. Now, thanks to the information technologies’ development, such maps are created using the GIS technologies [2, 3, 4, 5]. At the beginning of the 2000s, a geoinformation database was created at ArcGis 10.1 software center at the Department of Urban Development and Economics of DSTU [6]. It was created on the spacecraft maps basis by Merkulova [1] and was supplemented by the information from new engineering and geological reports.

2. Results
The creation of electronic maps made it possible to see a number of problems associated with the engineering and geological surveys conduct and the processing of their results. The fact is that when entering information about geological elements into the database, we are faced with the fact that information about the geological structure of the same site from the different sources differs significantly from each other.

There are several reasons, in our opinion. The main reason is the very essence of engineering and geological surveys for construction and reporting. According to GOST 20522-2012 “Soils. Methods of statistical processing of test results” the studied soil thickness is previously divided into EGE “... based on the personal experience of a geological engineer ...” [7]. Further, after analyzing the soils characteristics values, if they differ sharply or are caused by the errors in the experiments, or belong
to another EGE, they are excluded. The final selection of the EGE is carried out on the basis of assessing the nature spatial variability of the soil characteristics and their coefficient of variation or comparative variation coefficient. When determining the boundaries, the newly allocated EGE take into account:
- the presence of a tendency to a regular change in the soil characteristics;
- groundwater level position;
- the presence of the specific soils’ layers (subsidence, swelling, saline, organo-mineral and organic);
- the presence of different consistency soils.

Thus, the boundary of the allocated EGE substantially depends on the subjective factors - personal experience and preferences of the geological engineer [7, 8, 9, 10, 11].

As a result, various geological engineers in the same area of the survey produce various reports on geotechnical surveys. For example, in one geologist, the soil mass is divided into 5-6 EGEs, and in another - 2-3. And both have everything in accordance with GOST!

In addition, the physical and mechanical characteristics of soils in the same areas differ. This is due to the different amount of information received during the research and, again, the different EGE amount.

An important reason for the strikingly different engineering and geological data appearance on the same survey site is unscrupulous performers. Due to high competition and extremely low market prices, the reports on engineering and geological surveys with inaccurate data are quite often found. And here is all hope for the completeness of archival materials, but the city is developing, rebuilding, growing. As a result, such “specialists” have the reports that indicate the geological wells through the underground parking lots or abandoned underground galleries (Old Rostov is rich in them). Such reports use either outdated or incomplete information. In addition, there are also frankly invented reports when the authors do not use the archival data, but compose them completely.

Unfortunately, the state expertise is not able to identify the inaccuracy of the data presented in the report on engineering and geological surveys for objective reasons. The expert takes for granted the data from the field stage of the survey work presented in the report. It is enough that the necessary amount of work is “completed”, the physical and mechanical characteristics of soils are obtained and statistically processed in accordance with regulatory documents, the report contains all the required materials. And how to check whether this report has been completed based on the results of real research, or the rich imagination of the author became its source?

The solution to this problem is possible by implementing the priority national project “Digital Economy” by maintaining a unified urban geo-information database on the new engineering and geological surveys within the framework of the “Smart City” system. Such work should be carried out on the basis of a unified approach, using the information contained in the reports on engineering and geological surveys (a map of the actual material, geological columns, laboratory research data) to independently identify the EGE and statistically process the physical and mechanical characteristics of soils [12]. Then the geographic information base will be constantly updated and supplemented. Updating the information about changes in geotechnical conditions will become much easier. Additional engineering surveys will be less voluminous and less expensive, and, most importantly, more reliable.

3. Results
In particular, as noted earlier, the beginning of maintaining such a database was laid at the Department of Urban Construction and Economy of the Dagestan Technical University in the early 2000s, where the extensive work was undertaken to create a primary database by the City Administration order [13].

Within the framework of the developed project, the basic information on the geotechnical conditions of urban development is stored in IAS “Geology” in the electronic passport of the well
containing all the necessary information for engineering calculations at the pre-investment design stage.

![Diagram](image)

**Figure 1.** The technology algorithm for mapping the geological risk

Based on the studies, an analysis of the engineering and geological conditions of the territories of the city of Rostov-on-Don was performed (Figures 2-7).

Three categories of geological risk, depending on the engineering and geological conditions, the depth and the rate of rise of the groundwater level are distinguished: 1 - low hazard, 2 - dangerous, 3 - extremely dangerous (Table 1). The developed classification is based on the subdivision of all engineering and geological conditions according to their degree of danger and prevalence in the city.

**Figure 2.** Electronic geomorphological map of Rostov-on-Don

**Figure 3.** Electronic geological map of Rostov-on-Don
Figure 4. An electronic map of Rostov-on-Don with the level of groundwater

Figure 5. An electronic three-dimensional model of the Rostov-on-Don city relief with the level of groundwater in the city of Rostov-on-Don

Figure 6. An electronic map of the groundwater level rise rate in Rostov-on-Don (from 1970 to the present)

Figure 7. Electronic mapping of geological processes in the territory of Rostov-on-Don

Table 1. The geological risk categories’ classification

| Group of engineering and geological conditions | Engineering and geological conditions | Underground water table depth, m | Ground water rise rate, cm / year | Risk categories |
|-----------------------------------------------|-------------------------------------|-------------------------------|----------------------------------|----------------|
| 1                                             | Loess subsidence type II            | >8(10)                        | No lift                         | Low hazard     |
|                                               |                                     |                               | up to 15                         |                |
|                                               |                                     |                               | 15 – 30                          | Dangerous      |
|                                               |                                     |                               | 30 – 50                          |                |
|                                               |                                     |                               | 50 – 60                          | Extremely       |
|                                               |                                     |                               | >60                              | Dangerous      |
| 2                                             | Loess subsidence type I             | 3-8                           | No lift                         | Low hazard     |
|                                               |                                     |                               | up to 15                         |                |
|                                               |                                     |                               | 15 – 30                          | Dangerous      |
|                                               |                                     |                               | 30 – 50                          |                |
|                                               |                                     |                               | 50 – 60                          | Extremely       |
|                                               |                                     |                               | >60                              | Dangerous      |
|   | Floodplain sediments | 0.5-3 | No lift up to 15 | Extremely Dangerous |
|---|----------------------|-------|------------------|---------------------|
| 3 |                      |       | 15 – 30          |                     |
|   | Loess non-stop       | 2.5-4 | No lift up to 15 | Low hazard          |
| 4 |                      |       | 15 – 30          | Dangerous           |
|   |                      |       | 30 – 50          |                     |
|   |                      |       | 50 – 60          | Extremely Dangerous |
|   |                      |       | >60              |                     |
| 5 | Loess non-stop       | 4.1-10| No lift up to 15 | Low hazard          |
|   |                      |       | 15 – 30          |                     |
|   |                      |       | 30 – 50          |                     |
|   |                      |       | 50 – 60          |                     |

In accordance with the proposed classification, an electronic map of the geological risk of the Rostov-on-Don city was built (Figure 8).

![Figure 8. Electronic map of Rostov-on-Don with geological risk zones](image)

The geological risk zone map of the Rostov-on-Don city

The choice of the construction site is based on a comparison of the technical and economic indicators of the proposed options. In the final version, the priority is the solution, which ceteris paribus requires less cost for the implementation of preventive measures and the installation of foundations and allows you to determine the type of foundation depending on the number of storeys of the facility being built.

4. Summary
The studies showed that there was a need to develop and implement a system for monitoring the state of the geological environment of the city, as a part of the priority national project “Digital Economy” implementation. A single digital sub-basis, common formats and data exchange protocols within the framework of the Smart City system will significantly reduce the volume of engineering and geological surveys during the built-up areas development, increase the reliability of organizational and technological decisions in the urban areas’ construction and reconstruction.

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