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GEOTECHNICAL MONITORING

GEOTECHNICAL GEO-INFORMATION SYSTEM OF ASTANA

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A. Zh. Zhussupbekov, N. T. Alibekova, S. B. Akhazhanov, N. U. Shakirova*, and A. B. Alpyssova
Gumilyov Eurasian National University (Astana, Kazakhstan),
*Corresponding author, E-mail: nur_shakirova77@mail.ru.

The article considers the Geotechnical Geo-Information System (GGIS) of Astana, Kazakhstan. The GGIS was developed by methods of geoinformatics applied to engineering survey and geotechnical monitoring technologies. A special database program and set of geotechnical zoning maps were created for differentiation by ground bases type, showing the quaternary sediments and bedrock soils distribution, allowing for more efficient field investigations and engineering geological surveys, thus optimizing the length of piles foundations. The GGIS enables engineers to better justify the selection of particular designs, and significantly reduces the time and costs of field investigations and foundation design and construction.

Introduction

One of the most prevalent challenges of engineering and geological research is forecasting possible changes in the interaction between a proposed facility and a geological environment [1]. For rational forecasting of the changes in geological environment in the construction industry, it is expedient to use GGIS, taking into account the long-term experience of construction in Astana. This system allows for the use of maps and various fields of properties for a thorough evaluation of the available data, for modeling of geological fields in time and space, and for obtaining new information [2, 3].

Engineering-geological conditions of large cities in Kazakhstan have been sufficiently studied to make reasonable design decisions. However, most engineering-geological literature in Kazakhstan is available only in printed form and, even then, not always accessible. There is practically no data storage system in Kazakhstan [4].

Japan, USA, Finland, Sweden, Czech Republic, Germany, Russia, and many other countries have been conducting research for the creation of a Geo-information database since the 20th century.

Since the 1950s during the design process in Japan, special attention was paid to specific geological engineering maps created on the basis of systematized data collection. For example, the GIS database of the Kansai area, developed in 1966, consists of data on more than 40,000 wells [5].

Geo-information databanks have similarly already been created for many large cities in Russia. For example, the "Information systems in geotechnical investigations for urban development" program was created for the city of Perm (Russia) in 2010-2012. The goal of the program was to create an integrated information system to provide reliable data necessary for minimization of construction cost [6].

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In this regard, the Astana GGIS was developed for an objective assessment of a construction site of diverse soil strata. Its program makes possible the rapid qualitative assessments of construction sites and reduce the cost of design, surveying, and setting of foundations and building construction.

Geo-Information Database Creation Algorithm

The main objectives of this assessment are:

1) to learn the characteristics of geographical, geological, geomorphological, lithological and facial conditions;

2) to obtain a qualitative and quantitative characteristics of the structure, composition, conditions, age, and petrographic makeup of soil, to map these characteristics, and to determine their spatial variability;

3) to identify the age, occurrence, and distribution of various soil types;

4) to understand the nature and intensity of development of modern geological processes and phenomena, and its influence on engineering practice.

The development of the "Geo-Information database" program (DIG-system) provides data collection on geotechnical surveys in its inherent format, thereby expanding the concept of database connectivity.

The basic control system of the "Geoinformation database" program has a hierarchical structure, consisting of two levels and including the following main functions:

1) general management; 2) input data management; 3) data extraction and processing; and 4) data supplement.

The general management comprises the first level of the hierarchical structure. The second level consists of the other three functions that are meant to assure preliminary processing of initial information and provide graphic representations of data.

Initial information used in the program is subdivided into basic sections:

1. The constant data set (local database) included directly in the program (for example, a city map, coordinates, and characteristics for reception of graphic images).

2. The initial data prepared directly by the user based on the results of engineering geological investigations and entered into the program.

The initial database of the second section consists of stages:

– firstly, to determine the study area on the city map and refine spatial coordinates;

– secondly, to create complex tables for entering information on each borehole and sensing point reflected in geological and lithological tables and the penetration passport (including the depth, age, and conditions of the soil layers); passport data are entered for the points of penetration.

GGIS Research of the Geotechnical Environment of Astana

The first "Geo-Information database of Astana" program to be created was based on the materials of previously carried out engineering geological surveys, taking into account dynamic and static tests of pile foundations, including data on 2500 boreholes, 1500 points of static penetration, and 575 points of dynamic penetration.

The program makes it possible to analyze soil conditions and systematize data from survey reports through the construction of a digital model of a engineering geological structure of the territory.

For example, in order to get information on the geotechnical structure and properties of the soils of the studied area using the "Geo-Information database of Astana," one could perform the following operations.

1. Determine the approximate location of the study area using the coordinates indicated on the program desktop;

2. Zoom into the selected area for a more detailed study (Fig. 1);

3. If there are drilled boreholes in this area, then select a borehole or a set of boreholes to create an engineering geological section of the area.

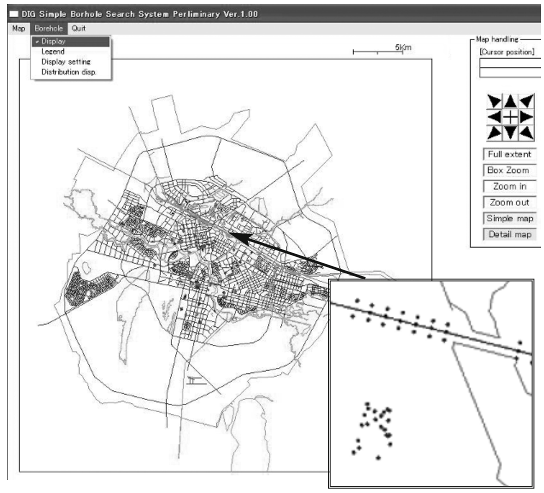

Fig. 1. The location of the study area and a magnified fragment

TABLE 1

Soil code	Description of the soil
EGE-1	anthropogenic deposits are presented by soil-vegetable stratum (EGE-1a) and filled soil (EGE-1b)
EGE-2	alluvial medium-quaternary recent deposits are presented by clay soils. It is formed mostly by loams (EGE-2a) with alternation of loamy sands (EGE-2b), clays (EGE-2c) and silts (EGE-2d), there are lenses and sand bands of different size up to 1-3 cm thick (with this figure sometimes as high as 10 cm)
EGE-3	alluvial medium-quaternary recent deposits are presented by so-called sand-gravel formations, which consist mostly of sands of different size (EGE-3a), gravel sands (EGE-3b), and gravel soils (EGE-3c)
EGE-4	eluvial formations of residual soil are presented by loams and lentil clays with interlayers of loamy sands soils. The eluvial clay soils are found immediately below alluvial formation
EGE-5	eluvial formations of residual soil are presented by breakstone soils
EGE-6	the siltage of lower carbon are presented mostly by sandstones, which interleave with siltstones and mudstones (argillites) of the same age throughout its thickness

Based on such studies and on analyses of the physical-mechanical properties of soils in Astana, six main engineering geological elements (EGE) were identified (Table 1).

In addition, using the "Geoinformation database of Astana" program for the rational use of the geological environment special geotechnical maps that take into account long-term experience of construction in the city could be created.

The sequence of mapping is the following:

1. The graphic module of the "Geoinformation database" program displays available exploration boreholes and points of penetration.

2. The line of the engineering geological section (with the automatic inclusion of the necessary boreholes) is set. The user can change the set of boreholes, adding or removing them in dialogue mode, as well as redefine the cut line and recreate a new set of boreholes.

3. Stratigraphic boundaries of soils and EGE are determined.

4. Information on all EGE boundaries is recorded in the appropriate folder. Both the coordinates of the EGE and their boundaries are saved to disk. You can edit the EGE boundaries or add new ones at any time.

5. On the basis of the processed information, maps of quaternary deposits and bedrocks are constructed.

Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8
EGE-1 EGE-2a EGE-4	EGE-1 EGE-2d EGE-2a EGE-4	EGE-1 EGE-2a EGE-3a EGE-4	EGE-1 EGE-2a EGE-3a EGE-3b EGE-3c EGE-4	EGE-1 EGE-2a EGE-3b EGE-3c EGE-5	EGE-1 EGE-2a EGE-2b EGE-4	EGE-1 EGE-2a EGE-2b EGE-3a EGE-3b EGE-3c EGE-4	EGE-1 EGE-2d EGE-2a EGE-3a EGE-3b EGE-3c EGE-4

Fig 2. Geotechnical map of zoning by type of soil base.

TABLE 2

Type of work	The proposed GGIS	Alternative EGE (collection and analysis of the "paper" archive data)
Drilling of the boreholes	–	–
Field tests	–	–
Laboratory works	–	–
Technical report	+	+
Period of execution, day	1	10

6. The zoning map of base types are created based on the graphic analysis of geotechnical sections (Fig. 2).

Practical Significance and Perspective for the Use of GGIS Astana

The Geo-Information database of Astana" program and special geotechnical maps are programmed to prevent the duplication of work in the same geographic areas so as to optimize construction and enable specialists to promptly receive all the necessary technical and economic background information for construction and assure the city's efficient development (see Table 2) [8, 9].

Conclusion

The GGIS of Astana is a modern computer program that relies on digital technology to map and analyze engineering geological data of the built-up territory of Astana. The technology combines traditional database operations, such as querying and statistical analysis, with the advantages of full-fledged visualization and geographical (spatial) analysis provided by the map. The capabilities GGIS of Astana differ from the capabilities of other information systems in that this system provides unique opportunities for solving a wide range of tasks related to the analysis and forecasting of changes in the geotechnical conditions of Astana and provides explanations for these changes by highlighting the main contributing factors and causes, as well as the possible consequences that may arise from specific design, construction, and operation decisions related to buildings and structures.

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