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Study of geotechnical conditions of the city of Pavlodar

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ABSTRACT: Pavlodar is one of the main industrial regions of Kazakhstan, with a historically formed territorial and production complex, which is an important part of the national wealth of our country. Increasing volumes of construction of all forms of ownership of this city predetermine further increase of engineering design and survey works. However long-term observations show that technogenic impacts of buildings and structures on the geological environment cause changes in it is elements, which are manifested in the development and activation of such engineering and geological processes as erosion and destruction of the coastal slope, gullying, waterlogging and salinization of soil. Therefore, in order to minimize the damage caused by these processes, it is necessary to develop in a timely development scientifically based urban and architectural planning solutions, where the task of generalizing the results of the current engineering and geological surveys with the purpose of typing geotechnical conditions of the city. The presence of the typing will allow to carry out a more rational study, identification of features and assessment of geotechnical conditions for such issues as, reduction of engineering and geological surveys, increase of economic efficiency. The article considers questions of typification of engineering and geological conditions of the city territory, as the main factor is studied geological structure. An analysis of the physical and mechanical properties of the soils with the study of strength and deformation characteristics of the soils located in the territory of the city of Pavlodar was also performed.

1 INTRODUCTION

As it is well known that any construction begins with the construction of the most important part – the base. The reliability of the building in the processes of construction and operation on foundation which perceives external influences and transfers to the foundation, and the reliability of the foundation and base depends on physical and mechanical properties of foundation soils, which are studied and analyzed in detail engineering and geological surveys.

The territory of the Republic of Kazakhstan is characterized by a wide variety engineering and geological conditions. The issues of designing, construction and operation buildings and structures in difficult engineering and geological conditions are becoming increasingly relevant, taking into account the decrease in the area with favourable soils. However engineering and geological data of surveys in the regions of our country are almost not generalized and are most often in paper form. As a rule, companies engaged in engineering research accumulating impressive archives, most often not very open in the exchange of data.

All this complicates the conduct of survey works, it is more difficult for prospectors to predict development engineering and geological processes, and most importantly, there are cases of duplicate works, sometimes full exploration in the same territories [Zhussupbekov et al. 2021].

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Therefore, the timely development of scientifically new urban and architectural planning solutions for the territory of our country on the example of Pavlodar city will be a relevant decision.

2 CHARACTERISTICS OF THE OBJECT OF STUDY

2.1 *Characteristics of the object*

Pavlodar – the largest city of North Kazakhstan located between 41°57′-54°27′ northern latitude and 73°25′-79°20′ eastern longitude from Greenwich and covers an area of 127.5 thousand square kilometers. It is bordered by four regions of the Republic of Kazakhstan (North Kazakhstan, Akmola, Karaganda, East Kazakhstan) and two entities of the Russian Federation (Omsk region, Altai region). The territory of the region, stretching more than 450 km from north to south and over 420 km from west to east, is crossed by the Irtysh River, the main waterway of the region. Currently, there are 10 rural districts, 3 cities of regional subordination, 4 villages, 169 rural districts in the region [Smailov 2015].

Here, in addition to traditional industrial enterprises and the extraction of hydrocarbon raw materials, large-scale industry is developed, with which the Pavlodar city acts as one of the major industrial centers of the Commonwealth of Independent States. The region accounts for 7% of industrial production, 70% of coal production, 3/4 ferroalloys smelting, 40% of electricity generation and oil products processing from the level of the republic [Zhakupov et al. 2014]. Increasing volumes of construction of all forms of ownership of this city predetermine further increase of engineering design and exploration, it is enough to note, renovation and construction of new neighborhoods, such as Saryarka and Dostyk.

2.2 *Characteristics of engineering and geological conditions*

In geological and structural terms, the area of the Pavlodar region is located in the zone of junction of two large geological structures - the Kazakh folded country (Saryarka), which occupies about 25% of the area of the region, and the West Siberian lowland.

Geomorphologically, the location of the territory at the edge of the extensive accumulation of the southern plain of the West Siberian Lowland has led to it is long-term development as a lacustrine, lacustrine-alluvial and alluvial plain since the middle of the Oligocene. The main features of the relief of the territory were created by erosive and accumulative processes of the middle and upper Quaternary time, as well as the modern stage of geological history. The main genetic groups of relief forms are identified: alluvial, lacustrine-alluvial and lacustrine, of various geological ages, from the middle section of the quaternary system to the modern one. The alluvial group includes two terraces above-floodplain and the floodplain of the Irtysh River. Most of the territory is occupied by the second floodplain terrace of the Irtysh river, which is the next oldest relief element. The first terrace above-floodplain of the Irtysh River is covered by a cloak of cover deposits and is characterized by the still quite preserved relief of the former floodplain. It is all indented by numerous lowers, which have the form of a channel bend.

The *geological* structure of the territory of Pavlodar city involves lacustrine-alluvial deposits of the Neogene age (N), which are subdivided into deposits of the Pavlodar suite ($N_{1\text{-}2}$pv), Aral suite (N_1ar) and Kulunda suite (al$N_{1\text{-}2}$kln), overlain from the surface by the upper Quaternary and modern deposits of alluvial-deluvial (ad$Q_{II\text{-}IV}$) and technogenic (tQ_{IV}) genesis.

The *groundwater* of the above-floodplain terraces occurs at a depth of 1 to 17 m (usually 2-5 m). In the last 25-30 years on the territory of Pavlodar city, in particular in the area of the industrial zone of the city, there has been a systematic rise in the level of groundwater. Groundwater depth - 3-5 meters or more.

Physical and geological processes in an urban area are appear processes as erosion and destruction of the coastal slope, gullying, waterlogging and salinization of soil, which in turn cause the changes elements of geological structure. Therefore, in order to minimize the damage, caused by these processes it is necessary to timely development scientifically based urban planning and architectural and planning decisions in order to typify engineering and geological conditions of the city. Engineering and geological typing is one of the practically significant

procedures in the assessment of the conditions building and structures. It allows a more rational study, identification of features and assessment engineering and geological conditions to solve many issues of planning, design and rational use of natural resources [Astvacaturova 2009].

In the course of the study the construction zoning was performed according to the floors and residential buildings and facilities. Three main building areas were identified for residential development in Figure 1:

– building zone of multi-storey residential buildings;
– building zone low-rise residential buildings up to 4 floors;
– building zone with individual residential buildings.

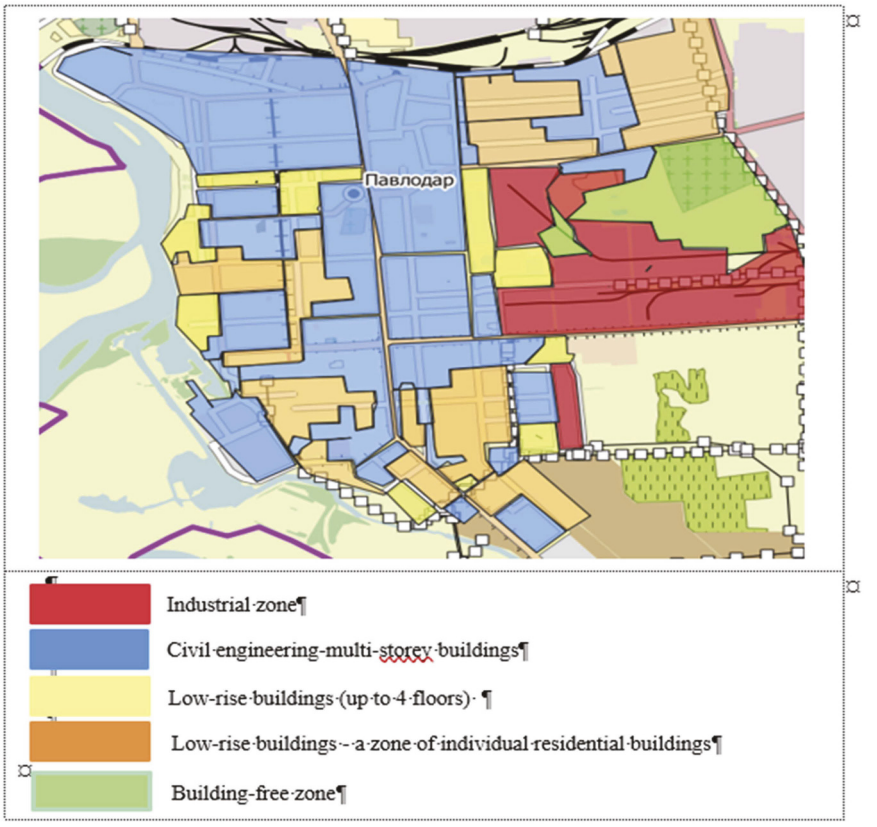


Figure 1. Scheme of construction zoning of the territory of Pavlodar city.

In order to objectively assess of the urban development taking into account various geotechnical conditions geoinformation database program was created, with the help which the regional soil conditions of Pavlodar city were analyzed before a detailed study. In the process of developing Geoinformation Database, the built-up area of multi-storey buildings was investigated.

3 STUDY OF GEOTECHNICAL CONDITIONS OF PAVLODAR CITY USING GEOINFORMATION DATABASE PROGRAM

3.1 *Methodology for the creation geoinformation database*

To create the "Geoinformation Database of Pavlodar city" (Figure 2) published and stock materials of engineering and geological surveys initially were collected and analyzed. Results of boring

of 523 engineering and geological boreholes in 2014-2021 were selected as sources. Composition and physical-mechanical properties studied for 2147 soil samples surface to depth 25 m.

The geoinformation database has a hierarchical structure consisting of two levels and including the following main four functions:

1) General management function (Host DB).
2) Input data management function (Local DB).
3) Data extraction and processing (AP) function.
4) Data augmentation function (Layer DB).

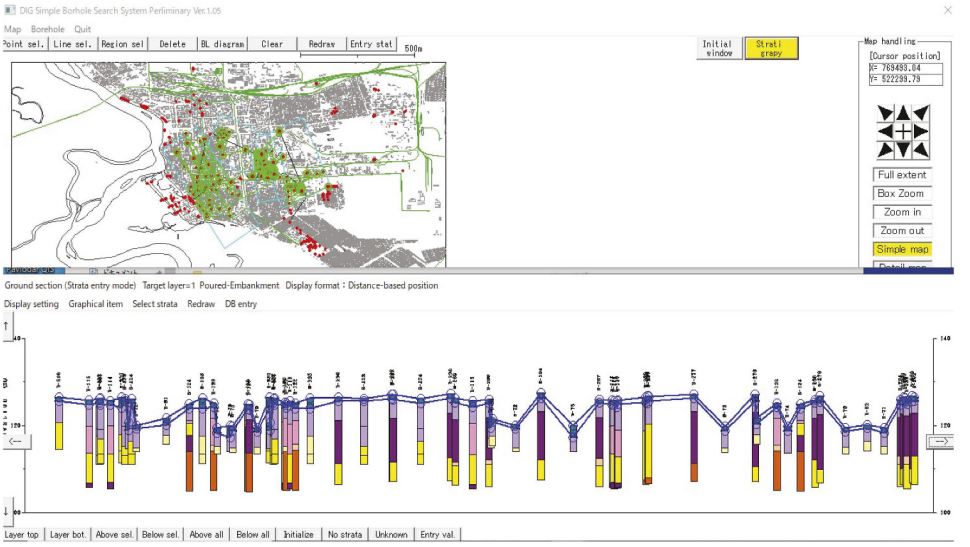


Figure 2. General view of the "Geoinformation Database program of Pavlodar city".

The first level of the hierarchical structure is responsible for the general management function, which provides general management and organization of the graphic process. The second level of the hierarchy includes the remaining three functions that perform preliminary processing of the initial information and ensure the organization of the graphic process [Alibekova 2009].

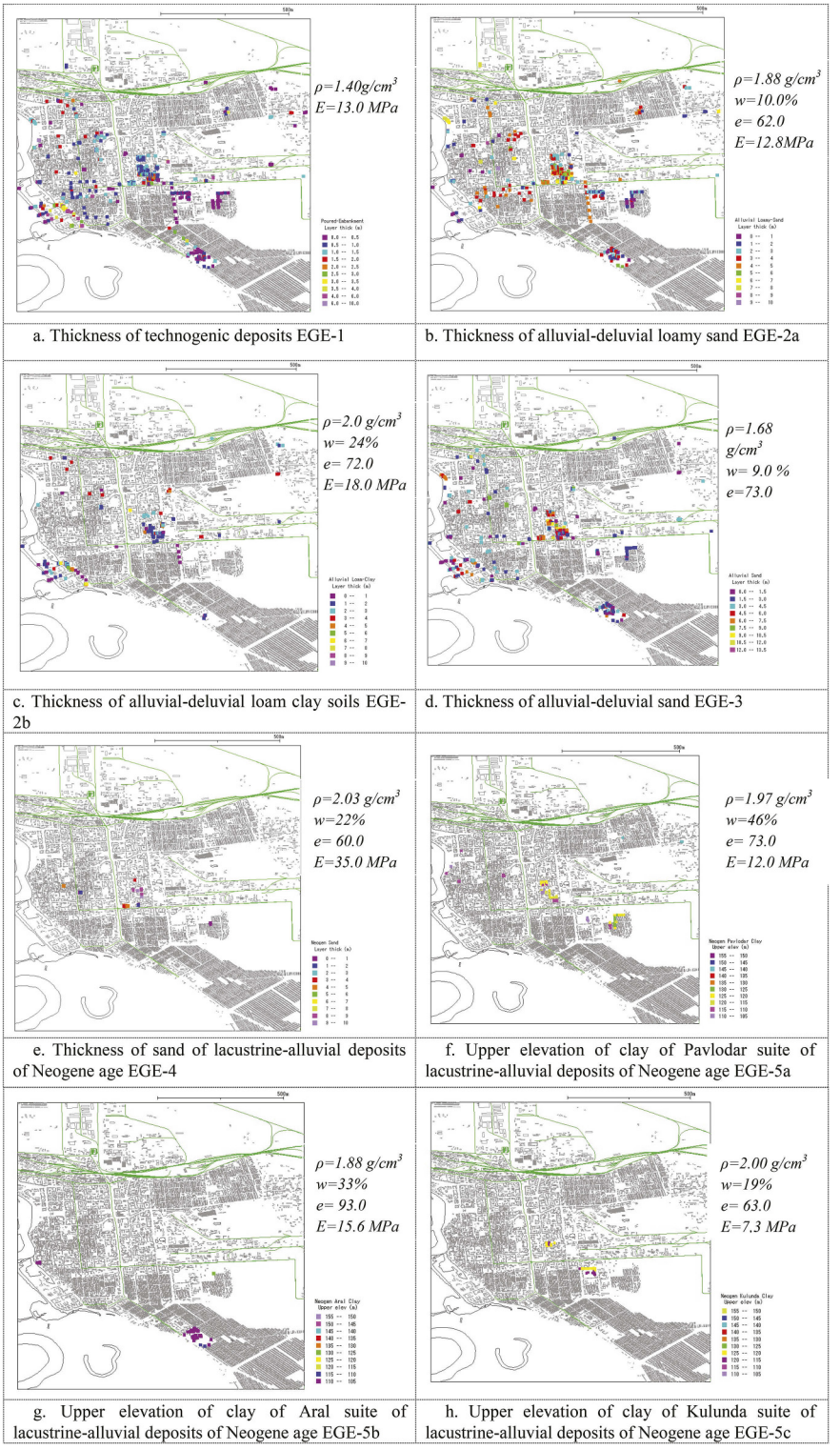
In the process of executing the initial information of the second level, the following stages of work can be distinguished:

1. The survey area was determined, and a map of the survey area is created in CAD program, i.e., AutoCAD.
2. The location of each borehole was indicated and labeled on the survey area map.
3. The exact X and Y coordinates were determined for each borehole.
4. A set of data was collected in the Excel table to log the information about each borehole.
5. Data on all layers, depth of occurrence, age of rocks are indicated [Zhussupbekov et al. 2019].

3.2 *Research of geotechnical environment of the Pavlodar city*

With the help "Geoinformation Database of Pavlodar city" geotechnical conditions were analyzed, in particular, 5 main engineering-geological elements were identified [Abisheva 2021] and special geotechnical maps of the occurrence of soils of Quaternary deposits and deposits of Neogene age with physical-mechanical characteristics were built in Figure 3:

EGE-1 — *technogenic deposits* (tQ_{IV}) represented by the topsoil (EGE-1a) and backfill (EGE-1b). Topsoil is represented by humus sandy loam with plant roots, the backfill is composed of sandy loam with sand and construction debris of 20%.



a. Thickness of technogenic deposits EGE-1

b. Thickness of alluvial-deluvial loamy sand EGE-2a

c. Thickness of alluvial-deluvial loam clay soils EGE-2b

d. Thickness of alluvial-deluvial sand EGE-3

e. Thickness of sand of lacustrine-alluvial deposits of Neogene age EGE-4

f. Upper elevation of clay of Pavlodar suite of lacustrine-alluvial deposits of Neogene age EGE-5a

g. Upper elevation of clay of Aral suite of lacustrine-alluvial deposits of Neogene age EGE-5b

h. Upper elevation of clay of Kulunda suite of lacustrine-alluvial deposits of Neogene age EGE-5c

Figure 3. Special geotechnical maps of Pavlodar city.

EGE-2 — *alluvial-deluvial deposits of Upper Quaternary and modern ages* (adQ_{II-IV}), consisting of carbonated, subsident sandy loam (EGE-2a) from solid to fluid consistency and clay loam (EGE-2b). According to [SP RK 1.02–102-2014], the sandy loam in this layer is a specific soil, when soaked with water it has subsidence properties under household and additional loads. Capacity of this soil is measured from 0.9 up to 10.3 m.

EGE-3 — *alluvial-deluvial deposits of Upper Quaternary and modern ages of sand* (adQ_{II-IV}) is located at the depth of 2,5 to 8.0 m. According to the field description, all sands are similar in color, mostly yellow-brown, dense, saturated with water, with single layers of soft-plastic clay, differ only in the amount of the determining fraction according to the granulometric composition.

EGE-4 — *lacustrine-alluvial deposits of neogene age (N)* represented by sand of various size. According to the granulometric composition, the sands of the deposits are medium-sized, coarse. The thickness of the sands increases from south to north and varies from 0.6 to 9.7 m.

EGE-5 — *lacustrine-alluvial deposits of neogene age* includes clays that are represented by lacustrine-alluvial deposits of the Pavlodar suite (EGE-5a), the Aral suite (EGE-5b), the Kulunda suite (EGE-5c). Lacustrine-alluvial deposits of the Pavlodar suite are represented by brown clay and loam, with a thickness of 1.6 to 5.2 m. Lacustrine-alluvial deposits of the Aral suite represented by clay from light gray to gray green, from hard-plastic to semi-hard, ferruginous, manganese, with inclusions of gypsum up to 10% and marl up to 5%. The thickness of clays varies from 2.5 to 16.2 m. Lacustrine-alluvial deposit of the Kulunda suite are represented brownish-gray, greenish-brown, greenish-gray clays, containing calcareous-marl nodules ranging in size from 0.1 to 0.2 cm and interlayers of sand. Clay thickness varies from 0.5 to 7.6 m.

4 CONCLUSIONS

The assessment of the geotechnical conditions of the territory of Pavlodar city served as the basis for the creation of a geoinformation database program. This geoinformation database system allows the development of engineering and geotechnical maps on geotechnical zoning of the city according to the classification of soils and the criteria of homogeneity formed areas. The economic efficiency of a geoinformation system and developing engineering and geotechnical maps will significantly reduce the time and costs during the survey and design work, as well as in the construction of foundations for buildings and structures in difficult ground conditions. Implementation of geoinformation database ensures sustainable development of megacities, models and approaches in urbanistic development of geo infrastructure megapolises and small cities of the new generation.

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