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ZONING OF THE CITY TERRITORY TAKING INTO ACCOUNT THE ENGINEERING AND GEOLOGICAL CONDITIONS

ИНЖЕНЕРЛІК-ГЕОЛОГИЯЛЫҚ ЖАҒДАЙЛАРДЫ ЕСКЕРЕ ОТЫРЫП, ҚАЛА АУМАҒЫН АЙМАҚТАРҒА БӨЛУ

ЗОНИРОВАНИЕ ТЕРРИТОРИИ ГОРОДА С УЧЕТОМ ИНЖЕНЕРНО-ГЕОЛОГИЧЕСКИХ УСЛОВИЙ

Abstract. *The issue of zoning the territory taking into account engineering and geological conditions, including urban ones, continues to be one of the most important in engineering geology. Experience shows that in the practice of surveys and design of quarterly urban development, the type of soil and geological conditions are not taking into account enough. This leads to an irrational use of the natural possibilities of the grounds for the construction of reliable and sustainable buildings and structures. The zoning of the territory, namely the conditional division of soil layers into separate schemes facilitates the process of designing buildings and structures when selecting foundations. Based on the experience of scientists dealing with the problem of zoning territories, the article considers an example of the development of a geoinformation database for the analysis of geotechnical properties of soils and special geotechnical maps. In addition, based on the field description of soils and the results of laboratory tests, the authors studied the engineering and geological features of the soil foundations of the objects of Pavlodar, as a result of which the soils of the city were classified taking into account the determination of their physical and mechanical properties.*
Keywords: *zoning; engineering and geological conditions; soil; foundation; geoinformation database; special geotechnical maps, Pavlodar, physical and mechanical properties.*

Аңдатпа. *Инженерлік-геологиялық жағдайларды, оның ішінде қалалық жағдайларды ескере отырып, аумақты аймақтарға бөлу мәселесі инженерлік геологиядағы маңызды мәселелердің бірі болып қала береді. Тәжірибе көрсеткендей, тоқсандық қалалық құрылысты зерттеу және жобалау тәжірибесінде топырақ түрі мен геологиялық жағдайлар жеткілікті түрде ескерілмейді. Бұл сенімді және тұрақты ғимараттар мен құрылыстарды салу үшін аймақтың табиғи мүмкіндіктерін ұтымсыз пайдалануға әкеледі. Аумақты аймақтарға бөлу, атап айтқанда топырақ қабаттарын жеке схемаларға шартты түрде бөлу іргетастарды таңдау кезінде ғимараттар мен құрылыстарды жобалау процесін жеңілдетеді. Аумақтарды аймақтарға бөлу мәселесімен айналысатын ғалымдардың тәжіри-*

бесіне сүйене отырып, мақалада топырақтың геотехникалық қасиеттерін және арнайы геотехникалық карталарды талдау үшін геоақпараттық мәліметтер базасын әзірлеу мысалы қарастырылады. Сонымен қатар, топырақты далалық сипаттау және зертханалық сынақтардың нәтижелері негізінде авторлар Павлодар объектілерінің топырақ негіздерінің инженерлік-геологиялық ерекшеліктерін зерттеді, нәтижесінде қала топырақтары олардың физика-механикалық қасиеттерін анықтауды ескере отырып жіктелді.

Түйін сөздер: *аймақтарға бөлу; инженерлік-геологиялық жағдайлар; топырақ; іргетас; геоақпараттық мәліметтер базасы; арнайы геотехникалық карталар, Павлодар, физикалық-механикалық қасиеттері.*

Аннотация. *Вопрос зонирования территории с учетом инженерно-геологических условий, в том числе городских, продолжает оставаться одним из важнейших в инженерной геологии. Опыт показывает, что в практике изысканий и проектирования квартальной городской застройки тип почвы и геологические условия учитываются недостаточно. Это приводит к нерациональному использованию природных возможностей местности для строительства надежных и устойчивых зданий и сооружений. Зонирование территории, а именно условное разделение слоев грунта на отдельные схемы облегчает процесс проектирования зданий и сооружений при выборе фундаментов. Основываясь на опыте ученых, занимающихся проблемой зонирования территорий, в статье рассматривается пример разработки геоинформационной базы данных для анализа геотехнических свойств грунтов и специальных геотехнических карт. Кроме того, на основе полевого описания грунтов и результатов лабораторных испытаний авторами были изучены инженерно-геологические особенности грунтовых оснований объектов Павлодара, в результате чего грунты города были классифицированы с учетом определения их физико-механических свойств.*

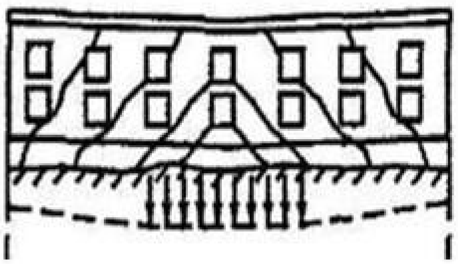
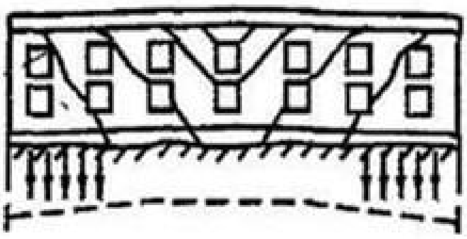
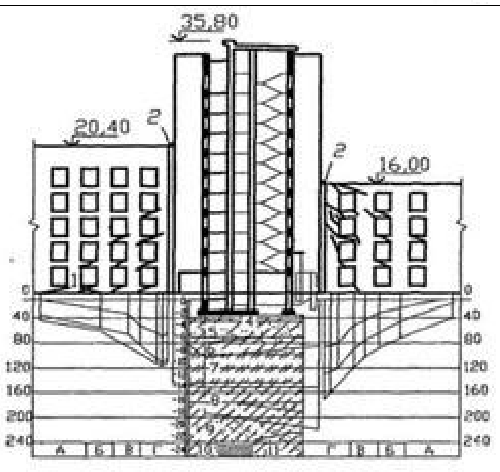
Ключевые слова: *зонирование; инженерно-геологические условия; грунт; фундамент; геоинформационная база данных; специальные геотехнические карты; Павлодар; физико-механические свойства.*

Introduction. The modern construction system is organized in such a way that engineering and geological surveys, development of building projects, design of bases and foundations, work on their arrangement are carried out by organizations that poorly coordinating with each other. Their joint work is regulated by the provisions of normative documents [1], unified throughout the territory of the Republic of Kazakhstan, which are not fully observed. And, despite the large volume of construction, on the territory of cities, full-scale observations of the precipitation of buildings from the moment of their construction are carried out extremely rarely and commonly for a short time.

In general, design engineers return to the design objects only in cases of damage to structures caused by changes in the foundations that lead to deformations of constructions. Examples of some deformations are given in Table 1. In these cases, verification calculations give little, since observations organized after the occurrence of damage do not have sufficient information content. This leads to the fact that in most cases, designers and researchers do not have full-fledged materials on the basis of which it is possible to check and correct the calculations of the bases, to make a reasonable choice of the precipitation forecast method taking into account the specific engineering and geological conditions of the region [2].

One of the main factors taking into account in the design of the foundation is the choice of engineering and geological conditions. Engineering and geological conditions, in turn, are one of the determining factors in the urban zoning of the city territory. They represent a complex of actual geological features, with the help of which it is possible to determine the conditions of engineering surveys, construction and engineering structures. The most significant of them are the nature and conditions of occurrence of soils, their composition, state and properties, morphological and morphometric features of the relief, temperature distribution of frozen, thawed and non-frozen strata, thickness of frozen rocks, depth of seasonal thawing - freezing, types, their cryogenic structure, regularities distribution, water abundance and regime of groundwater, depth of occurrence, their composition and mineralization, aggressiveness in relation to building materials and other innovative geological processes and phenomena [3].

Table 1. Types and causes of deformation of structures of buildings and structures

Deformation diagram constructions	Type and reasons deformation
	Building deflection *Possible causes of damage:* - incorrect structural solution of foundations on heterogeneous soils; - softening of soils in the middle of the building; - frosty heaving of soils under the ends of the building.
	Building bend *Possible causes of damage:* - incorrect constructive solution of foundations on heterogeneous soils; - softening of soils under the ends of the building; - frosty heaving of soils in the middle of the building.
	Distortion of old buildings due to the construction of a new building - inserts *Possible causes of da.mage:* - incorrect structural solution of the foundations in the place where the new building adjoins the old ones

More detailed information about the properties of soils, of course, can be obtained on the basis of a comprehensive field and laboratory study of them during engineering and geological surveys. It is very important to systematically describe and study individual lithological types and soil complexes as a natural-historical formation, which are simultaneously characterized by regional features. If the patterns of changes in the composition and properties of individual lithological-genetic types and soil complexes are not revealed, the description of the study may be difficult [1].

The engineering and geological conditions of many cities of Kazakhstan are well studied, however, after the collapse of the large state organization Kazakh Geotechnical Research Institute, which had own regional expeditions, departments, and branches in all regions of the country, it was revealed that most of the materials are not available for general use, since the state archives created by the trust of this company do not exist, or are in private property, which in turn do not want to share information [4].

In this regard, for an objective assessment of the territory of urban development, taking into account various engineering and geological conditions, it is necessary to analyze the regional soil conditions before a detailed study based on reports of engineering and geological surveys, for further development of special geotechnical maps for zoning the territory of the city, taking into account the engineering and geological characteristics of soils and their strata.

Experience of territory zoning using GIS technology. Today, the study and use of natural resources, rational economic development, environmental protection, and monitoring, making practical decisions related to the geological environment are impossible without reliable information support [5]. Since 2007, N.T. Alibekova, under the supervision of A.Zh. Zhussupbekov, began to collect together all the data on engineering and geological survey for the city of Astana [6]. Based on the collected materials of earlier engineering and geological surveys, for the first time developed the program "Geoinformation database of Astana" (fig.1) taking into account dynamic and static tests of pile foundations, which includes data from 2500 boreholes, 1500 points of cone penetration testing (CPT) and 575 points of standard dynamic penetration (SPT) [7].

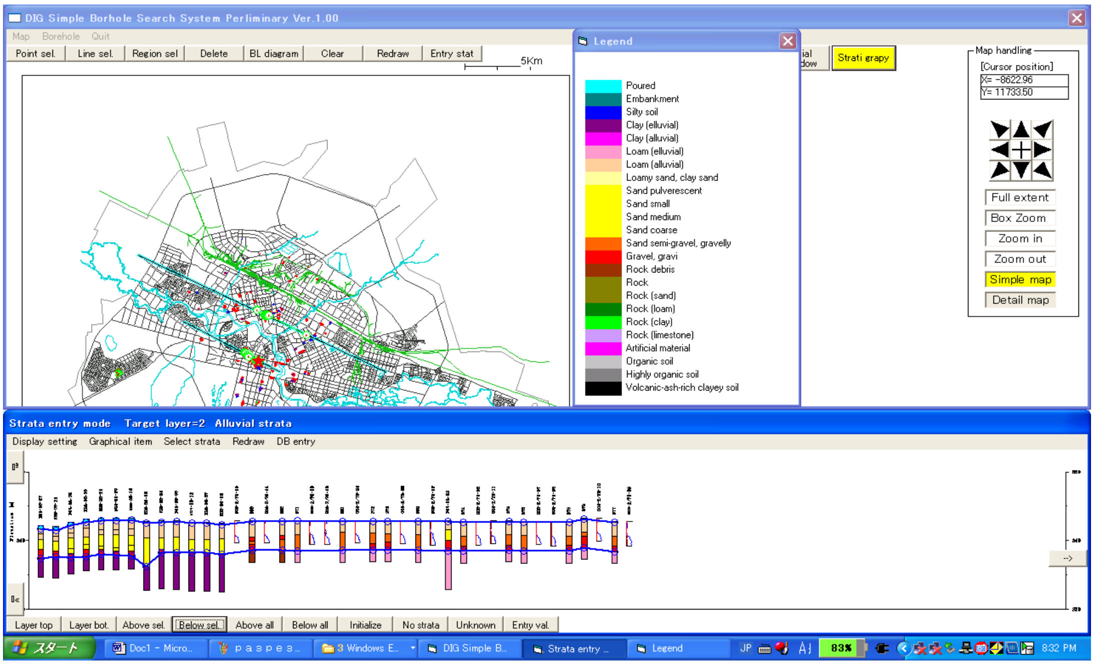


Figure 1. Geoinformation database of the city of Astana

The program allows to analyze the conditions of soil occurrence and systematize data from survey reports with the construction of a digital model of the engineering and geological structure of the territory [8].

In addition, with the help of the program "Geoinformation database of Astana" for the rational use of the geological environment, special geotechnical maps of the occurrence of quaternary deposits and bedrock soils, map was built for the driven piles, and the optimal variations in the pile length for each zone (fig. 2) were determined, finally on the basis of a graphical analysis of engineering-geological sections, a map of the zoning of the territory by type of foundation (fig. 3) was built.

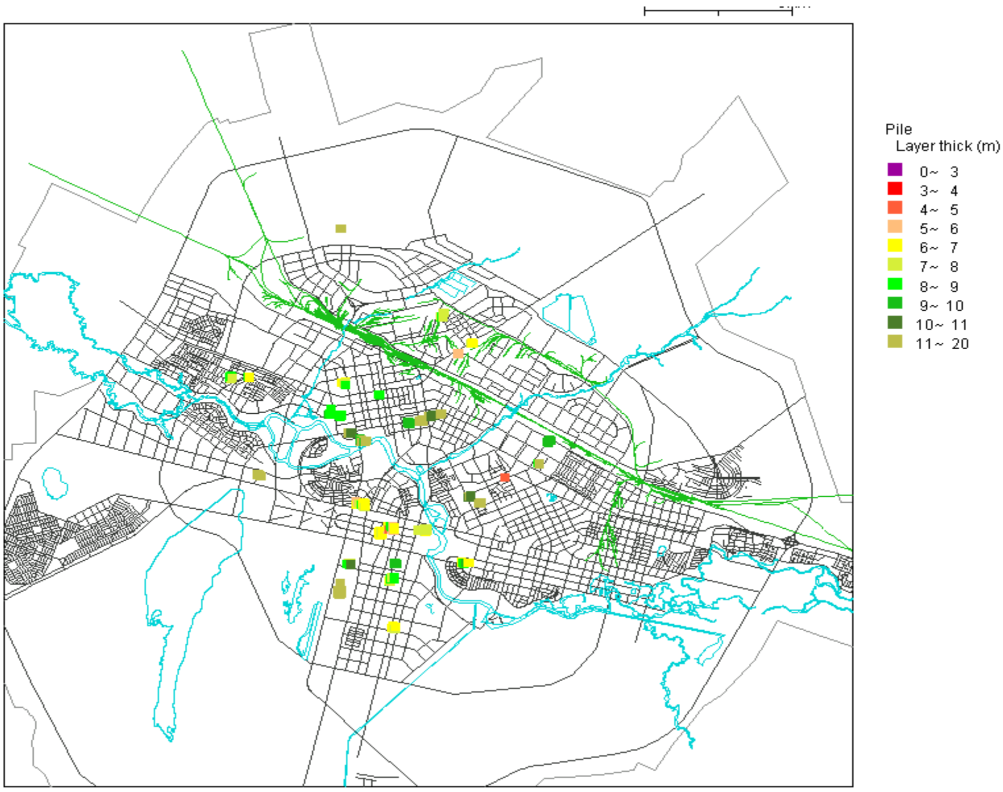
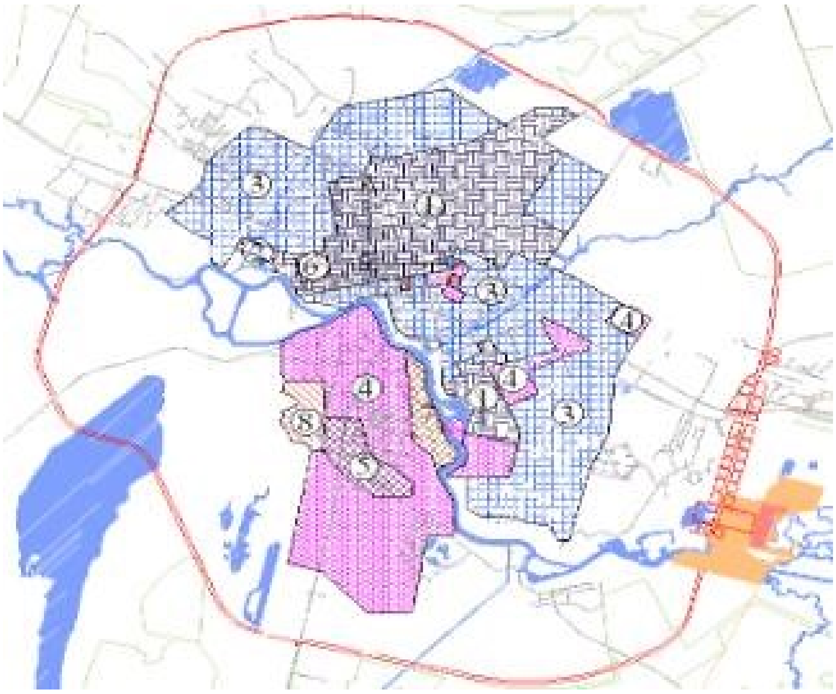
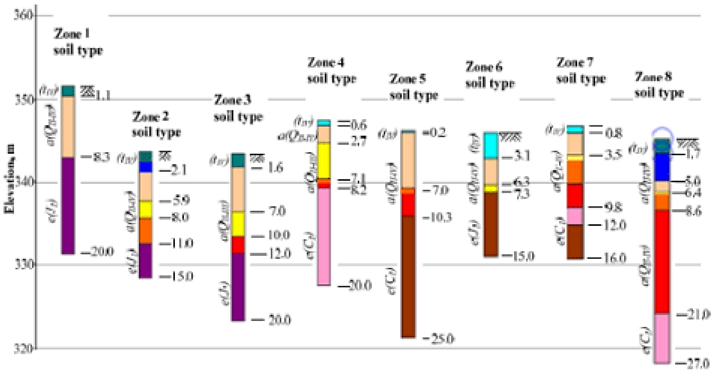


Figure 2. Zoning of the territory of Astana for optimization length of driving piles



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



(a)

(b)

Figure 3. Zoning of the territory of Astana by types of the soil bases: (a) city map with differentiation by soil type zones, (b) vertical profiles of boreholes for each type of soil zones with decoding

Methods and materials. When developing the "Geoinformation database program", it is planned to collect data from engineering and geological surveys with its own format, which expands the concept of database connection.

The main control system of the program "Geoinformation database" (DIG-system) has a hierarchical structure, consisting of two levels and including the main functions:

1) General management function;
2) Input control data function;
3) Function of data extraction and processing;
4) Data augmentation function.

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 functions that perform preliminary processing of the initial information and ensure the organization of the graphic process. The initial information used in the program is divided into main sections:

1. Fixed datasets that form a local program database, included directly in the program text (for example, a city map, coordinates and characteristics for obtaining graphic files).

2. Initial data prepared directly by the user based on the materials of engineering and geological surveys and entered during the execution of the program [1,9].

The database of the initial data of the second section is compiled in stages:

– the purpose of the map is determined, i.e. the construction event for which the map is being compiled is indicated (engineering training, engineering network design, foundation and foundation design, zero-cycle work, etc.);

– the main construction factors related to soils and which are the main ones for the justification of this construction are established;

– archival materials of engineering and geological surveys on the territory of the development are studied and selected, which are useful for drawing up a map;

– the identification of soils by their age, origin, composition, condition is performed;
separate varieties of sediments (for example, quaternary) are distinguished;

– complexes of combining soils are formed; sections of soil strata are drawn up; soil arrays of one or another type of addition are outlined in area;

– a soil map and its symbols are compiled; tables of generalized soil properties are given; recommended construction measures are noted.

Result and dicussion. 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 [10]. 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 [11].

The basis of industrial production of the region is formed by enterprises of the mining and metallurgical complex and energy, in connection with which the structure of industrial production is characterized by the predominance of industries that produce an intermediate product (coal, alumina, ferroalloys, electricity).

Geologically, Kazakhstan is divided into regions that have their own structural and geomorphological features. The geological structure of the Pavlodar region is represented by denudation-accumulative plains in the south of the West Siberian lowland and denudation plateaus of the Kazakh folded system (fig. 4).

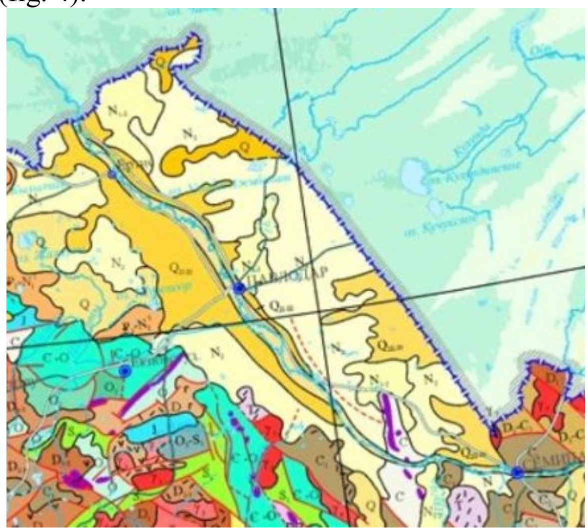


Figure 4. Fragment of the geological map of Kazakhstan, Pavlodar (Geological map of Kazakhstan) [12]

Investigating the engineering and geological features of the soil foundations of many objects in Pavlodar, based on the field description of the soils and the results of laboratory tests of archival reports of engineering and geological surveys performed on the territory of Pavlodar from 2014 to 2021 (fig. 5), an assessment was made on the built-up territory of the city [13].

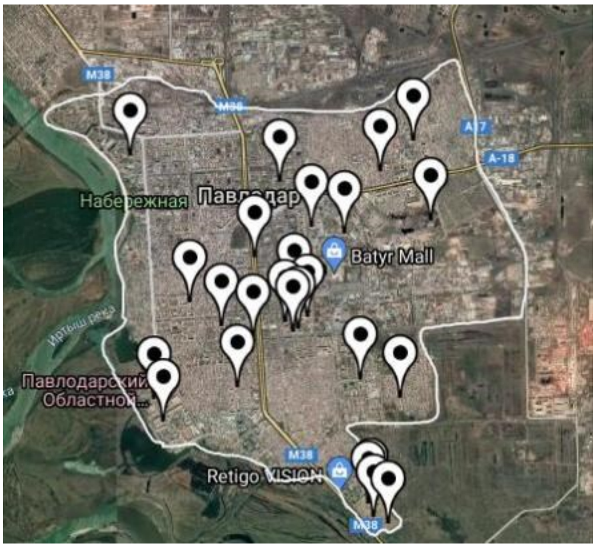


Figure 5. Schematic map of the city of Pavlodar
(with objects of engineering and geological surveys)

Lacustrine-alluvial deposits of Neogene age (*N*) take part in the geological structure of the territory of Pavlodar, which are divided into deposits of the Pavlodar suite (*N1-2pv*), the Aral suite (*N1ar*), the Kulunda suite (*alN1-2kln*), overlain from the surface by upper quaternary and modern deposits of alluvial-deluvial (*adQII-IV*) and technogenic (*tQIV*) genesis.

Based on the assessment, 5 engineering-geological elements (EGE) were identified with their physical and mechanical properties (table 2) [14]:

EGE-1 includes technogenic deposits (*tQIV*) represented by the topsoil (EGE-1a) and backfill (EGE-1b), with a thickness of 0.1 to 4.7 m. Topsoil is represented by humus sandy loam with plant roots, the backfill is composed of sandy loam with sand and construction debris of 20%.

EGE-2 is represented by alluvial-deluvial deposits of Upper Quaternary and modern ages (*adQII-IV*) with a thickness of 0.2 to 10.3 m, consisting of carbonated, subsident loam sand (EGE-2a) from solid to fluid consistency and clay loam (EGE-2b). According to SP RK 1.02–102-2014 [15], the loam sand in this layer is a specific soil, when soaked with water it has subsidence properties under household and additional loads.

EGE-3 is represented by alluvial-deluvial deposits of Upper Quaternary and modern ages (*adQII-IV*) is located at the depth of 2,5 to 8.0 m and consists of sands of different sizes from low-moisture to saturated from dense to medium density. 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 (table 3).

EGE-4 includes 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 is represented by 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.

Table 2. Characteristics of EGE of soils of Pavlodar

Engineering-Geological Element (EGE)	Geological Index (Age)	Average Column of Soils	Soil type	Physical and mechanical characteristics					
				Bulk density ρ, g/cm^3	Moisture w, %	Porosity e	Elastic Modules E, MPa	Angle of internal friction ϕ, °	Cohesion intercept c, KPa
EGE-1	tIV	EGE-1a	Topsoil	1,40	-	-	-	-	-
		EGE-1b	Backfill	1,40	-		13	-	-
EGE-2	ad(QII-IV)	EGE-2a	Loam Sand	1,88	10,0	62,0	12,8	29,0	12,1
		EGE-2b	Loam	2,00	24,0	72,0	18	16,6	28,0
EGE-3		EGE-3	Sand of various size	1,68	9,0	73,0	20	34,0	3,0
EGE-4	N	EGE-4	Sand of various size	2,03	22,0	60,0	35	32,7	2,0
EGE-5		EGE-5a	Clay (Pavlodar suite)	1,97	46,0	73,0	12	17,0	106,0
		EGE-5b	Clay (Aral suite)	1,88	33,0	93,0	15,6	11,0	111,0
		EGE-5c	Clay (Kulunda suite)	2,00	19,0	63,0	7,3	18,0	57,0

Table 3. Granulometric composition of sands

Size terms	Particle size
Fine	Particles larger than 0.25 mm from 32.6 to 52.6 % with an average value of 40.8 %
Medium	Particles larger than 0.25 mm from 62 to 73.2 % with an average value of 67.6 %

Conclusions. The study of the geological structure of the soil foundations of the studied objects, both artificial and under construction, directly affects the quality of the objects under construction, their durability, reliability, strength and stability.

The result of the study is the study of the geological structure of the soil foundations of many objects in Pavlodar for a more complete understanding of the properties of soils, taking into account the "regional characteristics" of soils. Further development of this study will allow to develop special geotechnical maps of the zoning of the city territory, taking into account the engineering and geological characteristics of soils and their strata.

Such maps serve as a basis for solving practical problems, they provide an opportunity to assess the engineering and geological condition of the construction site as a whole and individual sections of the projected structures, as well as to eliminate duplication of work on the same sites, optimize engineering and geological work, promptly obtain the necessary information to justify design work during construction and development planning the territory of the city at the stages of feasibility studies.

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