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ENGINEERING-GEOLOGICAL ZONING AS A SCIENTIFIC-METHODICAL BASIS FOR SCHEME'S DEVELOPMENT OF ENGINEERING-CONSTRUCTION ASSESSMENT (ON THE EXAMPLE OF IRPIN TOWN KYIV REGION)

The article is aimed at conducting the engineering-construction assessment of Irpin town of Kyiv region. It is based on the engineering-geological zoning of the settlement, which provides the allocation of different-level taxonomic units with a set of natural and anthropogenic factors of construction conditions from the largest unit (engineering-geological region) to the smallest (sites and subsites). Engineering and geological surveying and mapping became the main research methods. The main result of the study was a comprehensive comparison of data on the geomorphological, geological-genetic structure, hydrogeological conditions, soils' composition and properties of Irpin. It ultimately provided an opportunity to build a large-scale synthetic map of engineeringgeological zoning and engineering-construction assessment of the town. The study identified eleven engineeringgeological sites with appropriate characteristics of natural and anthropogenic factors of construction conditions factors, including have been identified, among which six sites are unfavorable for construction. The scientific novelty of the above research lies in the application of engineering-geological zoning as a basis for engineeringconstruction assessment, which is not limited to the selection of planning restrictions of an engineeringgeological nature. For the first time the novel method of engineering-geological subsites' selection is based on the principle of taking into account natural hazards and morphometric characteristics of the relief. They reflect the degree of erosion dissection, potential for the of modern relief-forming processes' manifestation and soil erosion. The practical aspect of the conducted research consists in creating a high-quality scheme of engineeringconstruction assessment, supplementing the scheme of existing planning restrictions, selecting optimal and economically justified measures for engineering preparation and territories' protection against dangerous geological processes. Engineering-geological zoning allows you to determine safe places for the accomodation of engineering structures, their structural features, choose rational types of foundations, reduce the cost of survey and construction work and generally improve the design's quality.

Key words: engineering-geological zoning; engineering construction assessment; taxonomy units; dangerous geological processes; morphometric characteristics; geological-lithological structure; Irpin.

Introduction

The scheme of engineering-construction assessment is desirable among additional graphic materials of projects of settlements' master plans as determined by the State Building Regulations [SBR B.1.1-14:2021, 2022]. It is created on the basis of engineeringgeological zoning of the town territory, which involves the selection of multilevel taxonomic units that have a certain set of common engineeringgeological conditions. They ultimately determine whether construction sites belong to a certain suitability category. As practice shows, the engineeringconstruction assessment scheme is far from the above standards in most cases. Designers are limited to the mandatory scheme of existing planning restrictions. Along with the allocation of sanitary and protective zones from enterprises, transport, engineering networks and infrastructure objects, they show restrictions of an engineering-geological nature. They include the delineation of areas and development of dangerous natural processes. Other natural and evaluation factors are neglected. This entails an inadequate assessment of the degree of construction sites' suitability, irrational and dangerous placement of structures from the point of view of their construction and operation, inappropriate or incomplete volume of measures for engineering preparation and protection of the territory [Simonov, Kruzhalin, 1993].

Engineering-geological maps with engineering geological conditions form the basis for engineering

construction scheme's development. Geological structure of the territory, lithological composition, hydrogeological conditions and current natural and technogenic geological processes are the most important of these conditions. Engineering geological zoning maps have a particular significance among engineering geological maps for engineering-construction assessment. They are drawn up as a result of identification in the space on the basis of theoretical positions' combination and tutorial methods of objectively existing territorial elements that have common engineering geological features of their delineation from territories that haven't such features, their mapping and description [Trofimov, Krasilova, 2008].

Different order' territorial units are allocated during regional type of engineering geological zoning and each next unit is allocated from previous (larger) by dividing it into separate parts on the basis of specific classification features. Each allocated territorial unit is characterized by bright individuality and gets a unique characteristic and own name..

The principles of engineering-geological zoning were most fully developed by I. V. Popov, who proposed to distinguish engineering-geological regions, oblasts, districts and subdistricts of various orders as independent taxonomic units.

Engineering-geological regions are distinguished by structural and tectonic features. The engineeringgeological region of the first order is the largest taxonomic unit. The second-order region, namely the engineering-geological province, is distinguished by its morphostructure and hydrogeological structure. The region of the third order (subprovince) is distinguished on the basis of the morphogenetic type of the territory of the first order [Popov, 1951].

I. V. Popov proposed to distinguish engineeringgeological areas within one region based on geomorphological features. With this approach, the geomorphological features of the territory are a consequence of the history of its geological development, mainly in recent times. We can say that engineeringgeological regions are territories distinguished by geostructural features as a result of the analysis of the history of the geological development of this territory for the entire time available to us. Engineeringgeological oblasts are parts of regions that have had different development in recent times, which was reflected in their geomorphological features [Popov, 1951]. So, engineering-geological oblasts are distinguished on the basis of the II order's morphogenetic type.

Engineering-geological districts in the engineeringgeological oblasts are distinguished on the territory of which the uniformity of the geological structure is noted. It is expressed in the same sequence of rocks' occurrence, their thickness and petrographic composition. Such relatively small territories can be formed under the conditions that they experienced tectonic movements of the same sign and intensity over their entire area. They wereand were in the same paleoclimatic conditions throughout their development history, which goes beyond the latest stage of the Earth's geological development [Popov, 1951]. Therefore, engineering-geological districts are distinguished on the basis of the common conditions of geological development.

Engineering-geological subdistricts can be allocated within one engineering-geological district according to different states of rocks, as well as manifestation of modern and ancient geological processes., if necessary [Popov, 1951]. For example, within one engineering-geological area there may be different strata of rocks located in a stratigraphic sequence and characterized by similarity or natural variability of engineering-geological characteristics. So, engineeringgeological subdistricts are distinguished on the basis of engineering-geological rock complexes of rocks of a certain age of geological layers of a certain age.

Engineering-geological sites can beare allocated within subdistricts during a large-scale engineeringgeological study of the territory, within which engineering-geological subsites can be allocated. As a rule, theseengineering-geological sites are distinguished according to the construction conditions of construction, i.e.that is, according to the assessment of a complex of natural and anthropogenic factors. There are different approaches to the selection of engineering-geological subsites within their boundaries of the sites. We proposed the selection of subsites according to the geodynamic processes' manifestation as well asand according to the relief's morphometric characteristics.

This approach to the definition of taxonomy units in engineering-geological zoning is shown in Fig. 1 [Popov, 1951; Trofimov, Krasylova, 2008].

Attempts at engineering-geological zoning have been made in Ukraine in such cities as Odesa [Shpakovsky, 1999], Dnipro [Sumatokhina, 2004], Kalush [Mykolaenko, et al., 2019], Reni district of Odesa region [Zhyrnov, 2015], basins of the Prut River [Marchak, 2012] territories along the Small Adzhalyk estuary [Chuiko, 2001], in the Carpathian region [Rudko, Guda, 2013]. Such a procedure was done in other regions of the world: in the Fortaleza region [Zuquette, et al., 2004], Japan [Wakamatsu & Matsuoka, 2013], Albania [Muceku, 2012], in cities Tunis [El May, et al., 2010], Taipei [Huang, et al., 1987], Athens [Koukis & Sabatakakis, 2000], Ostrava [Marschalko, et al., 2012], Mymensingh [Akter, et al., 2018], Almada [Paula da Silva & Rodrigues-Carvalho, 2006], Mecca [Al Solami, et al., 2006], Bendery [Grebenshchikova et al., 2021], Cagul [Bogdevych & Isichko, 2016].



Fig. 1. Taxonomy of engineering-geological zoning

Purpose

The purpose of this article is to carry out the engineering-geological zoning of the territory of Irpin town, Kyiv region, for the qualitative and justified allocation of the town areas with different degrees of favorability for construction development. The geomorphological, geological-lithological structures, hydrogeological conditions of the city were investigated for this purpose. The study researched the composition and properties of the soil, conducted a morphometric analysis of the territory and managed to identify dangerous natural and anthropogenic processes. This allowed us to create appropriate maps and distinguish different-level taxonomic units of engineeringgeological zoning. The final result includes the allocation of engineering-geological sites and subsites based on the construction assessment of the complex of natural and anthropogenic conditions, the course of geodynamic processes and morphometric features of the city. The engineering-construction characteristics are provided for each site and subsite. This helped to form the basis for the creation of a qualitative scheme of engineering-construction assessment of Irpin town.

Materials and methods

The initial data for engineering-geological zoning consist in a topographic survey on Irpin town in scale 1:5000, as well as materials of engineering and

geological investigations conducted between 1990 and 2020 for the construction of residential and public buildings by different design organizations and companies. 154 geotechnical reports were analyzed. Those materials were collected and systematized at SE "Ukrainian Institute of Engineering Technical Exploration for Construction" (UKRIINTR) [Tsybko, 2020]. We also studied a Geological map in scale of 1:50000 on sheets of Kyiv region [Solovytsky, Vozgryn, 1990) and used a project of the master plan for Irpin town [Master plan of Irpin town, 2017].

Field studies and geological surveys of Quaternary deposits were carried out by departments of UKRIINTR. The results of the studies included the following: selection of genetic types of the surface relief of Irpin town, its morphological and age features; the studying of the geological-lithological structure; the creation of geological-lithological sections, as well as the physical-mechanical properties of the soils (engineering-geological elements); research of hydrogeological conditions of Irpin town; recording manifestation of dangerous natural processes .

Specified materials allowed us to create the geomorphological map (1:5000), geological-lithological map (1:5000), hydrogeological map, map of the underground water depth and chemistry of Irpin town (1:5000).

Engineering-geological surveying and mapping became the main research methods. Finally, the complex comparison of the above-mentioned data was transformed into a synthetic large-scale map of engineering-geological zoning and engineeringconstruction assessment of Irpin town (1:5000) (Fig. 2).).



Fig. 2. Data and methodology of the research

Results

Irpin town administratively is situated in the central part of Kyiv region at the distance of 7 km North West from Kyiv, which is the capital of Ukraine.

Geographically, Irpin town is situated in the south-eastern part of the East European Plain, on the north-western slope of the Ukrainian crystalline Shield, within Kyiv Polissia as a part of the Polissia Lowland. According to the map of general geomorphological zoning of Ukraine, the investigated territory corresponds to Makariv moraine waterglacial gentle undulating slightly separated plain between the Irpin, Buchanka, Teteriv and Zdvyzh River valleys [Palienko et al., 2004].

Physical geographic and administrative town location helps to establish the location of Irpin according to the principles of engineering and geological taxonomy. Irpin is situated within the East European platform, the province of the northeastern slope of the Ukrainian crystalline Shield, Kyiv Polissia subprovince, engineering and geological region of the Makariv moraine water-glacial gently undulating, dissected plain [Tsybko, 2020]. Engineering geological districts are provided by general conditions of geological development and by relief morphogenetic types.

Engineering-geological survey of Irpin identified floodplains with swamp massifs and peat depressions of the Holocene age. It also determined the floodplain terrace of the Irpin and Buchanka rivers, the plateau and the elevated part of the moraine-water-glacial plain of the Dnipro period with absolute elevations above 135–160 m. The study established the lowland part of the moraine-aqueous-glacial plain of the Dnipro period with absolute elevations of 120–135 m, bottoms of beams and drift cones of the Holocene age, and areas with artificially modified relief. [Barshchevskyi et al., 1989].

Dangerous natural processes in Irpin town include flooding within the floodplain of the Buchanka and Irpin rivers, inundation within the flood terrace and the first floodplain terrace of the Buchanka and Irpin rivers. It is connected with naturally high levels of groundwater, floodplain flooding processes during spring tide and also unloading of aquifers into permanent and temporary watercourses. Eutrophication occurs within the floodplain of the Buchanka and Irpin Rivers. It is associated with spring floods and unloading of aquifers confined to Middle-Quaternary water-glacial deposits of watershed.

River erosion is relatively underdeveloped along the Irpin and Buchanka Rivers. However, it is distinct in some areas, where the floodplain deposits are eroded during spring floods.

Sand deflation is connected with eolian activity. It is observed in some areas of flood and first floodplain terraces of the Irpin and Buchanka Rivers (north east and north west town outskirts) [Tsybko, 2020].

Significant hydration of Quaternary deposits, high groundwater level, which provokes flooding, waterlogging and eutrophication are the main obstacles for urban development [Rudenko et al., 1971]. A complex morphometric analysis of the territory of the Irpin town was carried out. It established the indicators of slope steepness, horizontal and vertical dissection and exposure of slopes. This index can characterize the degree of erosion dissection, manifestation of current relief-forming processes, and soil erosion in any territory. The final result included ranking the complex morphometric index into 3 categories according to the complexity of the building development [Kravchuk, 1991].

Data comparison of the morphogenetic structure of the territory, aerials of development of dangerous natural processes and complex morphometrical analysis enabled the creation of a geomorphological map of Irpin town (Fig. 3)



Fig. 3. Geomorphological map of Irpin town

The morphogenetic and morphological structure of the relief lays the foundations for the selection of engineering-geological districts and subdistricts. However, it is necessary to distinguish corresponding geological-genetic complexes of Quaternary sediments within the erosion-accumulative alluvial plain and the denudation-accumulative watershed moraine waterglacial plain. In addition, determination of the lithological composition of the mentioned Quaternary deposits allows identifying relief morphological elements.

Therefore, the analysis of the territory geomorphological features and their geological

structure made it possible to distinguish four geologicalgenetic rock complexes on the territory of Irpin town:

1. A complex of modern alluvial sandy-clay deposits (alIV) with a thickness of 10-16 m represented by fine-grained quartz sands of light yellow and gray-yellow color with lenses and interlayers of sandy loams and loams with a thickness of 0.3-0.9 m.

2. A complex of Upper Quaternary alluvial sandyclay deposits (alIII) with a thickness of 8-2 m, represented by quartz medium-grained sands of light gray and yellow-gray color with lenses and layers of sand with a thickness of 0.2-0.5 m.

3. A complex of Upper Quaternary water-glacial sand-clay deposits (fIIdn) with a thickness of 5–20 m represented by granular quartz sands of a light gray

color with lenses and interlayers of sands, loams and clays with a thickness of 0.2–2.7 m with the inclusion of gravel and weakly rolled pebbles of crystalline rocks.

4. A complex of Upper Quaternary moraine deposits (gIIdn) with a thickness of 8–13 m, represented by boulder loams and clays, in places with layers of sand [Tsybko, 2020].

The analysis of the geotechnical properties of the soils made it possible to divide the selected complexes into 12 engineering-geological elements (EGE). The names of engineering-geological elements are shown in Fig. 4, geological-lithological sections are presented in Fig. 5, physical-mechanical properties of engineering-geological elements are described in Fig. 8.



Fig. 4. Geological-genetic map of Irpin town



Fig. 5. Geological-lithological sections I-V on Irpin town's territory along conditional lines





Fig. 5. (Continuation). Geological-lithological sections I-V on Irpin town's territory along conditional lines



Fig. 5. (End). Geological-lithological sections I-V on Irpin town's territory along conditional lines

Engineering-geological districts and subdistricts can be distinguished based on the comparison of geomorphological and geological-lithological maps in accordance with the taxonomy scheme of engineeringgeological zoning. Physical-mechanical properties of engineering-geological elements are the basis for the selection of engineering-geological sites. However, hydrogeological data are needed for this, so the selection of engineering-geological sites is currently impossible [Sedin et al., 2015].

So, the first district is represented by Upper- and Holocene Quaternary QIII-QIV erosion and accumulation alluvial plain with absolute marks of 107-118 m. Alluvial deposits with a thickness of 8-16 m lie on the Kyiv suite marls, which include a water-resistant layer for this area. Two engineering-geological subdistricts are allocated in the first district: 1) Alluvial floodplain inundated flat terrace with marsh massifs and peaty downgrade of Holocene age that composed modern alluvial deposits alQIV with capacity of 10-16 m, covered by modern organogenic formations (silt, peat) bQIV with capacity of 0.3–5.0 m. Alluvial deposits are represented by quartz finegrained sands of light yellow and gray yellow colors with a layer of sandy loams and loams with capacity of 0.3-0.9 m. The alluvial complex lies on the

washed-out surface of the Kyiv suite marls P2kv; 2) Alluvial Upper Holocene slightly separated first floodplain terrace that composed by alluvial sandy and clayey deposits alQIII with capacity of 8–12 m, that represented by alluvial quartz fine-grained sands of light gray and yellow-gray colors with lens and layers of sandy loams with capacity of 0.2–0.5 m. The alluvial complex lies on the washed-out surface of the Kyiv suite marls P2kv.

The second district is represented by Middle Quaternary QII denudation and accumulative watershed moraine water-glacial plain with absolute marks of 120-160 m. Water-glacial and glacial deposits with a thickness of 5 to 23 m lie on the marls of the Kyiv suite, which is a regional water-resistance layer for this area. Four engineering-geological subdistricts are allocated in the II district: 1) the lowland part of the moraine-water-glacial plain of the Dnipro period with absolute elevations of 120-135 m. Subdistrict is composed of a complex of middle Quaternary fluvialglacial sandy-clayey deposits (flQIIdn3) with capacity of 5-20 m at 10 m medium capacity. The complex is represented by medium-grained light gray quartz sands with lenses and interlayers of sands, loams and clays with a thickness of 0.5-2.7 m with the inclusion of gravel and weakly rolled pebbles of

crystalline rocks. Sometimes the gravel-pebble material is collected in the form of lenses and layers; 2) the elevated part and plateau of the moraine-waterglacial plain of the Dnipro period has absolute elevations of 135-160 m. Subdistrict is composed of moraine complexes (glQIIdn2) with a thickness of 8-13 m. They are covered and underlain by fluvioglacial sand-clay deposits of the advance and retreat of the Dnipro glacier (flQIIdn1 and flQIIdn3). Moraine deposits are represented by loams and clays with the inclusion of pebbles and boulders. Fluvial-glacial deposits are represented by average-grained quartz sands with layers of sandy loams and loams including gravel and pebbles; 3) the bottoms of the beams and cones of Holocene age are composed of modern proluvial-deluvial deposits of QIVpr-dl, which are represented by medium-grained quartz sands, interlayering of sandy and loamy soils with a thickness of 0.5-2.5 m; 4) Sites with artificially modified relief presented by recent technogenic deposits tOIV are mounds with structural sorted medium-grained light gray, gray-yellow sands and interlayering of marls and clay with a thickness of 1–2 m [Tsybko, 2020].

Five aquifer complexes are distinguished within the Irpin town territory in accordance with the geological structure and geostructural features of the district:

1) aquifer complex confined to Modern and Upper Quaternary alluvial deposits;

2) an aquifer complex confined to Mid-Quaternary water-glacial and glacial deposits;

3) aquifer complex in Bucha-Kaniv sediments;

4) aquifer complex in Cenomanian sediments;

5) aquifer complex of the fractured zone of Precambrian crystalline rocks [Alekseev, 2005].

The depth of the groundwater table varies widely: from 0–2 m in river valleys to 20–25 m in the watershed. According to the composition, water is mainly sulfate-hydrocarbonate, sulfate-chloride calciumsodium-magnesium, and fresh. There are three types and degrees of groundwater aggressiveness: weak total acid aggressiveness (type I), medium alkaline aggressiveness (type II) and strong sulfate aggressiveness (type III) (Fig. 6) [Tsybko, 2020].

Engineering-geological sites within the subdistricts can be distinguished by assessing the complex of natural and anthropogenic conditions, analyzing the geomorphological, geological-lithological structure, hydrogeological conditions, composition and properties of the soils of Irpin town. It is necessary to provide them with the appropriate engineering-construction characteristics, which will finally compose the engineering-construction assessment of the Irpin territory.



Fig. 6. Groundwater's depth and chemistry of Irpin town

We selected eleven engineering-geological sites with the corresponding characteristics of natural and anthropogenic factors of construction conditions according to the principles of engineering-geological zoning (Fig. 7, 8).

I-1-a. The site is represented by floodplains of the Buchanka and Irpin rivers. The site is unfavorable for construction development according to hydrogeological and lithological conditions. The maximum marks of the groundwater level are higher than the marks of the foundations. There are weak soils (mud, peat) in the geological section at various depths. Flooding and waterlogging are widespread here. Development of the site contradicts the articles 80, 81, 88 of the Ukrainian Water Code. Conditions for construction are unfavorable. Currently, the floodplains are drained, reclaimed and widely used for agricultural land.

I-2-a. The site is unfavorable for construction according to hydrogeological conditions: the maximum groundwater levels are higher than the foundations. Groundwater has weak and medium aggressiveness to concrete. The soil is sandy, impermeable. The conditions for construction are unfavorable. The close proximity of groundwater levels (0–2) m) which have weak alkaline (type I) and strong sulfate (type III corrosion) aggressiveness, requires waterproofing and lowering the level of groundwater, as well as the implementation of anti-erosion measures. The soils have a high bearing capacity, so the construction on a natural basis is possible.

I-2-b. The site is considered favorable for construction according to the hydrogeological conditions. The maximum levels of groundwater are at the depth of foundation lying or at a depth of 1-2 m. The soils are sandy, impermeable. There are no geological processes that negatively affect construction. The territory is conditionally favorable for

construction. Groundwater lies at depths of 2–5 m and has a weak alkaline (I type) of corrosion and strong sulfate (III type of corrosion) aggressiveness. Measures to reduce groundwater, waterproofing are needed. The soils are characterized by high bearing capacity. Therefore, the construction on a natural basis is possible.



Fig. 7. Engineering-geological zoning and engineering-construction assessment of Irpin town

PROVINCE	SUBPRO	OBLAST	DISTRICT	SUBDISTRICT	SITE	TYPICAL	SOILS?	SITES'
MORPHOSTRUCTURE	JUDIKO		GENERAL	(QUATERNARY		GEOLOGIC.	GEOTECH.	ENGINEEDING
HYDROGEOLOGICAL	VINCE	GENETIC TYPE)	CONDITIONS OF	ROCKS'	CONDITIONS -	GEOLOGIC-	GEOTECH-	
STRUCTURE)	(I ORDER MORPHO-		GEOLOGICAL	ENGINEERING-	ASSESSMENT OF	LITHOLOGIC	NICAL	GEOLOGICAL
	GENETIC TYPE)		DEVELOPMENT)	GEOLOGICAL	NATURAL AND	COLUMN	PROPERTIES	ASSESSMENT
				COMPLEXES)	ANTHROPOGENIC			
NORTHERN SLOPE	KYIV POLESIA	MAKARIV GENTLE	L EROSIVE-	1-1	I-1-a			Development of the site
OF UKRAINIAN	ON THE BLURRED	UNDULITING	ACCUMULATIVE	The subdistrict is	The site is represented by		1. FINELY DECOMPOSED	contradicts articles 80, 81 of
CRYSTALLINE	PALEOGENE-	SLIGHTLY	with absolute	floodplains of the Irpin	and Irpin rivers. The site is		<u></u>	the Ukrainian Water Code Conditions for construction are
SHIELD	NEOGENE BASIS	MORAINE-SANDR	surface marks of	and Buchanka rivers and is composed of a	unfavorable for construction development according to		vv-22% vo-1,97 gf/cm ³	unfavorable. Currently, the
Composed of a		PLAIN.	Alluvial deposits	complex of alluvial	hydrogeological and	++++	yc-1,6 gf/cm ³	reclaimed and widely used for
layer of Paleozoic,	It represents	A weakly hilly	with a thickness	(aIV) with a thickness	maximum marks of the	2	T-0,07 MPa	agricultural land.
Mesozoic and	giacial, moraine	absolute marks on	the marks of the	everywhere covered	than the marks of the	4	EO=2,0MPa	
sedimentary rocks	moraine-sandr	the surface from	Kyiv suite, which	by modern organic formations (bIV) with	foundations. There are weak soils (mud. peat) in the			
the section of the	lowland plains	100 to 190 m. The	is a water barrier	a thickness of 0.3-5.0	geological section at various	62		
sedimentary layer	dissected by wide,	roof deposits are	Groundwater in	deposits are	and waterlogging.	8	2. QUARTZ	
ends with deposits	shallowly incised	represented by the	Quaternary	quartz fine-grained			FINE-GRAINED SAND	
of glacial and	terrigenous (floodplain and	tollowing	pressureless,	sands of light yellow and gray-yellow color		10	Ch-1,7	
formations with a	two	rock complexes	fresh (up to 1 g/l).	with a thickness of		12	γο-2,02gf/cm ³	
thickness of	suprafloodplain	water-glacial	practically no	complex lies on the			yc-1,60-1,75 gf/cm ³ Natural slope's angle under	
400-600 m,	terraces) river	(various-grained	connection	blurred surface of marls of the Kviv		14	water - 25°	
represented by	valleys. The	sands), alluvial,	(P2bc) and	suite (P2kv).		16 P2kv	29-35°	
alluviogiaciai,	moraine plains are	(fine-grained	underground			+ peat sand clay	φ-34° C-0,03 kgf/cm ²	
lake-swamp and	characterized by	sands), glacial	waters in this area The main			loam loam	Eo-240 kgf/cm ²	
loess-loam	unconsolidated	(ciays, ioanis, sandy loams) and	aquifer for	1-2	I-2-a.			The conditions for construction
lithological-genetic	areas of terraced	biogenic (peats).	centralized water	Covers the first	The site is unfavorable for			are unfavorable, the close
complexes.	and sandr massifs	The sediment	Bucha aduifer	the Irpin and	construction according to		FINE-GRAINE SAND	proximity of groundwater levels (0-2) m) which have weak
Cretaceous system	are characterized	capacity of the	lying at a depth of	Buchanka rivers Composed of a	the maximum groundwater		Ch-2.1	alkaline (type I) and strong
(K2), Paleogene	by eolian forms.	most widespread	20-30 m.	complex of Upper	levels are higher than the		Cc-8-12%	aggressiveness requires
system (P2kn,	Significant areas	water-glacier		sandy-clay deposits	has weak and medium		¥c-1,70 gf/cm ³	waterproofing and lowering the
P2bc, P2kv, P2ch)	swamped A	from 70 to 200 m		of 8-12 m. The alluvia	aggressiveness to concrete.		φ-37° C-0,01 kgf/cm ²	the implementation of
Quaternary system	moraine complex	Groundwater lies		deposits are represented by quartz	The soil is sandy, impermeable		Eo-280 kgf/cm ² Natural internal friction-32°	anti-erosion measures. The
(Q) take part in the	of Quaternary	at a depth of 0-25		fine-grained sands of			Under water-25°	capacity - construction on a
geological structure	sediments is	m and confines to		lenses and interlayers	ŝ			hatural basis is possible.
of the studied area	widespread in the	fluvioglacial,		of sandy loam with a thickness of 0.2-0.5	l-2-b	2_		The territory is conditionally
The upper	Kviv Polesia	moraine denosits		m. The alluvia	Site is considered favorable			favorable for construction Groupdwater line at depths of
laver is composed	There is a small	Mainly fresh		eroded surface of	for construction according to the hydrogeological	4-1		2-5 m and has a weak alkaline
of Quaternary and	area of peat	water,		(P2kv).	conditions. The maximum	6-	4. QUARTZ	I type of corrosion) and strong
Paleogene	complex in the	hydrocarbonate,			levels of groundwater are at the depth of foundation		MULTI-GRAINED SAND	aggressiveness. Measures to
sediments.	north-eastern part,	sulfate and mixed			aying or at a depth of 1-2 m		Ch-3,4	reduce groundwater waterproofing are needed. The
	on the rest of the	types, possessing			below. The soils are sandy,	10	yo-2,00 gf/cm ³	soils are characterized by high
	fluvioglacial sandy	addressiveness			geological processes that		γc-1,72 gt/cm ³ φ-27°	bearing capacity - construction on a natural basis is possible.
	complex.	towards concrete.			negatively affect		C-0,02 kgf/cm ² Eo-320 kgf/cm ²	
		There are such			construction. I-2-c	14	Natural internal friction	Conditions for construction are
		geological			The site is quite favorable		under water-29°.	quite favorable. Groundwater
		processes:			for construction according to the complex of conditions.	Pilor		aggressiveness, (III type of
		flooding and sand			The maximum groundwater	F2NV		corrosion) lies at depths of more than 5 m. Soils have a
		deflation.			levels are more than 30 m below the foundations. The			high bearing capacity
					soils are sandy and		5 000DV/ 000	Measures for engineering preparation of the territory are
					impermeable. There are no		5. SANDY LOAM	not required.
					negatively affect		W-16% W-22%	
					construction.		Jp- 1-7(4)	
							yc-1,69 gf/cm ³	
			II. DENUDATION-	<u>II-1.</u>	<u>II-1-a</u>		φ_27°	The conditions for construction
			WATERSHED	of the watershed plain	construction according to		C-0,160 kgf/cm ² Eo-300 kgf/cm ²	of groundwater levels (0-2 m)
			MORAINE-SANDR	between the Irpin and Buchanka rivers with	hydrogeological conditions.			with average overall acid
			PLAIN mid Oustamany	absolute surface	The maximum marks of the groundwater level above the			corrosion) requires
			with absolute mark	m. The subdistrict is	foundations. Groundwater	4		waterproofing and lowering of the groundwater level, as well
			of 120-160 m	complex of middle	has medium and strong	2	6. LIGHT LOAM	as the implementation of
			with a thickness of 5	squarters of Ofluvioglacial sand-clav	concrete. There is a flooding	4	Jp-10	anti-corrosion measures. It is necessary to arrange artificia
			to 230 m lie on the	deposits (flldn3) with	of the territory.		W–13% WI–26%	bases and foundations.
			maris of the Kylv suite which is a regiona	20.0 m with an		6_	γo-2,14 gf/cm ³	
			water barrier for thi	10.0 m. The complex		8-0-fidn3	e-0,43	The territory is conditionally
			area. Groundwater in Quaternary denosite in	nis represented by slight-gray	Site is conditionally favorable		C-0,265 kgf/cm ²	favorable for construction
			pressureless, mostly	multi-grained, mainly medium-grained	for construction according to		Eo-460 kgf/cm ²	Groundwater lies at a depth of 2-5 m and has average overall
			fresh, (up to 1 g/l) and	quartz sands with	The maximum marks of the	12		acid aggressiveness (II type of
			(up to 2.5 g/l) in	sands, loams and	groundwater level are at the	P2kv		corrosion). The soils have a high bearing capacity
			places. There is	sciays with a thickness of 0.2-2.7 m.	depth of the foundations or 1-2 m below. There are no	пісок пісок+галька	7. CLAY	construction on a natural basis
			connection betwee	Inclusions of gravel	geological processes that	супісок	Jp-22	IS POSSIDIE. A SMAIL amount of planning work is required.
			pressure (P2bc) an	pebbles of crystalline	hegatively affect	Пина	WI-44%	
			The main aquifer for	Fluvioglacial	moderately aggressive		yo-1,99 gf/cm ³	
			centralized wate	washed-out surface of	towards concrete. Soils are	1	γc−1,03 gr/cm ² e−0,67	
			supply is the Buch	amarls of the Kyiv suite #P2ky).	ванау-скау, ппрегтнеарне.		φ-18° C-0.500 kaf/cm²	
			denths of 30-60 m	1	1	1	Eo-350 kgf/cm ²	

Fig. 8. Legend to the engineering-geological zoning map of Irpin town

I-2-c. The site is quite favorable for construction according to the complex of conditions. The maximum groundwater levels are more than 30 m below the foundations. The soils are sandy and impermeable. There are no geological processes that negatively affect construction. Conditions for construction are quite favorable. Groundwater has strong sulfate aggressiveness, (III type of corrosion) lies at depths of more than 5 m. Soils have a high bearing capacity. Measures for engineering preparation of the territory are not required.

II-1-a. The site is unfavorable for construction according to hydrogeological conditions. The maximum marks of the groundwater level above the foundations. Groundwater has medium and strong aggressiveness towards concrete. There is flooding of the territory. The conditions for construction are unfavorable, the closeness of groundwater levels (0-2 m) with average overall acid aggressiveness (II type of corrosion) requires waterproofing and lowering of the groundwater level, as well as the implementation of anti-corrosion measures. It is necessary to arrange artificial bases and foundations.

II-1-b. The site is conditionally favorable for construction according to hydrogeological conditions. The maximum marks of the groundwater level are at the depth of the foundations or 1–2 m below them. There are no geological processes that negatively affect construction. Groundwater is moderately aggressive towards concrete. Soils are sandy-clay, impermeable. The territory is conditionally favorable for construction. Groundwater lies at a depth of 2–5 m and has average overall acid aggressiveness (II type of corrosion). The soils have a high bearing capacity, so the construction on a natural basis is possible. A small amount of planning work is required.

II-1-c. The site is quite favorable for construction according to the set of natural conditions. The maximum groundwater level is more than 3.0 m below the level of the foundations. Groundwater is moderately aggressive towards concrete. Soils are sandy-clay, impermeable. There are no geological processes that negatively affect construction. Conditions for construction are quite favorable. Groundwater lies at depths of more than 5 m. The soils have a high bearing capacity, so the construction on a natural basis is possible. A small amount of planning work is required. Special measures for engineering preparation are not required.

II-1-d. The site is represented by technogenic landforms: sand embankments and a clay quarry. This

area is unfavorable for construction. The site is not planned for construction. Involvement of undermined territories in construction is impossible.

II-1-e. The site is represented by a gully network with a manifestation of gully erosion and flooding processes. The site is unfavorable for construction due to the complexity of the geomorphological conditions and the presence of dangerous natural processes. The site is unfavorable for construction. The site is characterized by inundation and intensive manifestation of gully erosion. The site serves as a place for discharging groundwater, which makes construction impractical.

II-2-a. The site is quite favorable for construction according to the complex of natural conditions. The maximum groundwater level is more than 3.0 m below the level of foundations. Groundwater is moderately aggressive towards concrete. The soils are sandy and clayey, impermeable. There are no geological processes that negatively affect construction. Conditions for construction are quite favorable. Groundwater lies at depths of more than 5 m. The soils have a high bearing capacity. It is possible to build on a natural basis. A small amount of planning work is required. Special measures for engineering training are unnecessary.

II-2-b. The site is represented by a gully network with a manifestation of gully erosion and flooding processes and by engineering-construction characteristics it is similar to site II-1-e (Figs. 7, 8) [Tsybko, 2020].

We present the engineering-construction characteristics of the engineering-geological subsites of Irpin town according to the geodynamic process manifestation and relief morphometric characteristics (see table, Fig. 7).

Engineering-geological subsites	Engineering-construction assessment		
1	2		
Subsites with manifestation of	The subsites are unfavorable for construction, as the process is typical for the		
flooding line by catastrophic	floodplains of the Buchanka and Irpin Rivers (violation of the requirements of		
inundation with 1 % support level	Articles 80, 81, 88 of the Ukrainian Water Code) with unsatisfactory engineering and construction characteristics. The installation of embankment dams or raising the		
	banks to non-flooding levels with gabion structures is necessary to eliminate		
	flooding [BC B.1.1-25-2009, 2010]		
Subsites with rocky and earthen	Subsites are unfavorable for construction, since construction is impossible on		
cliffs	cliffs. Cliff subsites require complex engineering planning and protection: it is		
	necessary to carry out earth planning works, arrange drainage systems, build		
	retaining walls and as much as possible greening of steep slopes [BC B.1.1-		
	24:2009, 2010]		
Subsites with sand deflation	The subsites are unfavorable for construction, as the process is typical for the		
	floodplains of the Buchanka and Irpin Rivers with unsatisfactory engineering-		
	construction characteristics. The installation of artificial obstacles or the anchoring of		
	sand massifs with vegetation with a branched root system is necessary to eliminate		
	sand deflation		

Engineering-geological subsites of Irpin town

1	2
Subsites with underflooding	Underflooding subsites refer to both unfavorable and conditionally favorable areas
	for construction depending on their location within specific areas and the
	expressiveness of the process. The floodplains of the Irpin and Buchanka Rivers
	belong to underflooding areas. Underflooding also covers local subsites and above-
	flood terraces and bottoms of gully network. Local subsites of the lowered part of the
	moraine water-glacial plain with groundwater levels up to 3.0 m from the day surface
	belong to underflooded areas. Shore fortification with gabions using waterproof
	geomembranes up to non-flooded marks, backfilling with mineral soil is
	recommended to eliminate underflooding. Installation of horizontal closed drainage
	is proposed for local areas of underflooding. Clearing water areas and flooding of
	reservoirs, rivers, canais and ditches is an important measure to reduce the area of
	under flooded subsites. It is necessary to organize a network of closed storm sewers
	and establish coastal protective strips of the riphi and Buchanka Rivers. Carrying out
	hydrotechnical structures is desirable within coastal protective strips. Elimination of
	cesspools and water-absorbing wells within the town is necessary as they contribute
	to the process of underflooding [SSU-H & B.1.1-XX:201X, 201X]
Subsites with morphometrical	The subsites belong to favorable areas for construction. There is no need for special
characteristics:	engineering training and protection measures. Installation of networks of closed
$K_{hd} - 0 - 150$ m/ha;	storm sewers is necessary
$K_{vd} - 0-5$ m/ha;	
$i - 0 - 15^{\circ};$	
dominant South, East exposures,	
Flat	
Subsites with morphometrical	The subsites belong to conditionally favorable territories for construction. Certain
characteristics:	measures of engineering preparation are necessary: carrying out land works for
$K_{hd} - 150.1 - 300$ m/ha;	vertical and horizontal planning, in certain subsites it is necessary to install anti-
$K_{vd} - 5.1 - 10$ m/ha;	erosion hydrotechnical structures. The terrace location of buildings and structures,
$i - 15.1 - 30^{\circ};$	the arrangement of drainage systems or storm sewer networks and the maximum
dominant North, West exposures	possible greening of the territory with the planting of moisture-loving tree species
	with a branched root system is necessary on subsites with a relief slope of 20 to 30°.
	Improvement of microclimatic characteristics through the use of appropriate climatic
Subsites with membernetrical	The subsition belong to unforce the group for construction Significant materially.
subsities with morphometrical	The subsities belong to unravorable areas for construction. Significant materially
$V \ge 300.1 \text{ m/ha}$	Mandetory installation of closed horizontal drains and closed storm servers
$K_{hd} \ge 500, 1 \text{ m/ha},$ $K_{hd} \ge 10.1 \text{ m/ha}.$	Terracing and fastening with retaining walls is necessary when developing slopes
$i > 30.1^{\circ}$:	The development of gravitational geological processes is possible. These subsites are
different exposures	not recommended to be involved in construction, the organization of green zones and
	afforestation of the territory is considered the optimal option
	· · · · · · · · · · · · · · · · · · ·

Discussion

The conducted research allows determining two topics for discussion:

• disadvantages of engineering-geological zoning of Irpin town;

• practical significance of engineeringgeological zoning of Irpin town;.

1. Disadvantages of engineering-geological zoning of Irpin town.

The major disadvantage of engineering-geological zoning is absence of information about neotectonic movements, structural forms, whose activity is displayed in relief and Quaternary deposits' structure. The information about a number of factors is of engineering significance. Such factors include summary amplitude of neotectonic movements, neotectonic active discontinuous disturbances, recent violations, selection of neotectonic structures, faults of different orders. As those factors can affect the stability of structures and their trouble-free operation, this information is valuable for the definition of suitability of building sites. There is no information about selection of morphostructures of the first, second and third orders and tectonic lineaments [Barshchevsky et al., 1989].

Irpin has a favorable seismic profile according to the general seismic zoning map [BC V.1.1-12:2014, 2014]. However, if the microseismic zoning of the town were carried out, increased seismic activity would be possible within the areas with the development of dangerous natural processes, increased morphometric indicators, and neotectonic movements. This requires special measures for laying foundations and construction of building frames.

The development of dangerous natural processes has been studied; however, there is no data on anthropogenic morphogenesis within the town. This is primarily manifested in changes in the relief, soil cover, vegetation, and hydrogeological conditions. Taking into account the close location of Irpin town to Kyiv, the capital city, and the pace of construction development for residential and public development, it is worth considering first of all the general equation of the relief, the erosion of geomorphological faces on the surface, the gradual disappearance of the natural microrelief, the appearance of anthropogenic microrelief (quarries, earthworks embankments, dams, berms, road ditches) [Shnyukov et al., 1993].

The main disadvantages in determination of geotechnical properties of soils (engineering-geological elements) within the town of Irpin are the absence of the following studies: a) determination of chemical properties of soils, in particular, missing data on solubility, acid-base properties and soils' chemical aggressiveness; b) determination of physical properties of soils, in particular, missing information on thermophysical (thermal capacity, frost resistance of soils) and electrical properties (electrical conductivity, corrosive activity of soils); c) determination of biotic properties of soils (biological activity, bioaggressiveness and biocorrosion in soils); d) determination of certain physical-mechanical properties of soils (rheological properties: creep, relaxation of stresses in soils, soils' long-term strength; dynamic properties: soils' behavior under vibration and impulsive effects, soils' liquefaction) [Trofimov et al., 2005].

It is worth noting that the construction of geological-lithological sections and the determination of geotechnical properties of soils took place only in the high-density area and most developed northern, northeastern and northwestern parts of the town, while the rest of the Irpin territory has not been explored. This is a significant disadvantage for the urban development in the distant future.

2. Practical significance of engineering-geological zoning of Irpin town.

The practical aspect of the conducted engineeringgeological zoning consists in the creation of a highquality scheme of engineering-construction assessment, which is desirable among the graphic materials of the master plan of the settlement [BC B.1.1-14:2021, 2022]. The allocation of areas unfavorable for construction is of special importance for design engineers and architects. Such areas should be excluded for urban development. In addition, the conducted research helps to highlight planning restrictions of an engineering-geological nature. The engineering-geological zoning map will serve as the basis for the mandatory scheme of engineering preparation and protection of the city. The given engineering-construction characteristics of engineeringgeological sites and subsites will help determine the necessary volume of earth planning works (vertical and horizontal planning of the territory) and choose appropriate measures on engineering protection of the town territory. Engineering-geological zoning provides accurate information about the development of dangerous natural processes and helps to accurately allocate an economically justified volume of planning and protective measures. Engineering-geological zoning allows us to correctly choose the location of buildings, their construction, to determine excavation works, rational types of foundations [Trofimov, Krasylova, 2008]. The obtained materials make it possible to reduce the scope and terms of search works, cut cost of civil and industrial construction and improve the quality of project solutions.

Conclusions

1. Qualitative engineering-construction evaluation as part of the project of the town master plan should be based on the engineering-geological zoning of the territory with the allocation of taxonomic units of different order.

2. The allocation principles of taxonomic units of different levels were established by I.V. Popov. They provide for the distinguishing engineeringgeological regions, as the largest taxonomic unit of engineering-geological zoning according to structuraltectonic features. Engineering-geological provinces are allocated according to morphostructure and hydrogeological structure, subprovinces - according to the first order morphogenetic type of the territory, oblasts - according to the second order morphogenetic type of the territory, districts - according to the common conditions of geological development, subdistricts - according to the engineering-geological complexes of rocks of the Quaternary stratum, sites according to construction conditions. It is recommended to allocate subsites according to the manifestation of geodynamic processes and morphometric characteristics of the relief.

3. Geomorphological, geological and lithological structures, hydrogeological conditions were investigated, the composition and properties of soils were analyzed, a morphometric analysis of the territory was made, dangerous natural and anthropogenic processes were identified for the justified selection of town sites with different degrees of suitability for construction.

4. Eleven engineering-geological sites are allocated with appropriate characteristics of natural and anthropogenic factors of construction conditions in accordance with the principles of engineeringgeological zoning, among which six sites are unfavorable for construction.

5. Subsites with the manifestation of flooding by catastrophic floods of 1 % security level, with the manifestation of rocky and earthen cliffs and with the manifestation of sand deflation are considered unfavorable for construction. In addition, subsites with the manifestation of underflooding refer to both unfavorable and relatively favorable territories for construction. Subsites with high indicators of horizontal and vertical dissection and slope steepness are unfavorable for construction, as there is a high probability of erosion and gravity processes development.

6. The practical aspect of the conducted engineering-geological zoning consists in the creation of a high-quality scheme of engineering-construction assessment, supplementing the scheme of existing planning restrictions. The map of engineeringgeological zoning is the basis for the mandatory scheme of engineering preparation and protection of the town. Engineering-geological zoning allows correct choice of the locations of buildings and their structures. It helps to determine excavation works, rational types of foundations, reduce the volume and cost of prospecting works and construction and improve the quality of project solutions.

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ІНЖЕНЕРНО-ГЕОЛОГІЧНЕ РАЙОНУВАННЯ ЯК НАУКОВО-МЕТОДИЧНА ОСНОВА ДЛЯ СКЛАДАННЯ СХЕМИ ІНЖЕНЕРНО-БУДІВЕЛЬНОЇ ОЦІНКИ (НА ПРИКЛАДІ МІСТА ІРПІНЬ КИЇВСЬКОЇ ОБЛАСТІ)

Мета статті – здійснення інженерно-будівельної оцінки міста Ірпінь Київської області на основі виконання інженерно-геологічного районування населеного пункту, яке передбачає виділення різнорівневих таксономічних одиниць із набором природних та антропогенних факторів умов будівництва від найбільшої одиниці (інженерно-геологічного регіону) до найменших (ділянок та підділянок). Основні методи дослідження – інженерно-геологічне знімання та інженерно-геологічне картографування. Результат дослідження – комплексне зіставлення даних про геоморфологічну, геолого-генетичну будову, гідрогеологічні умови, склад та властивості ґрунтів м. Ірпінь, що у кінцевому випадку надало можливість побудувати великомасштабну синтетичну карту інженерно-геологічного районування та інженернобудівельної оцінки населеного пункту. Виділено одинадцять інженерно-геологічних ділянок із відповідними характеристиками природних та антропогенних факторів умов будівництва, серед яких шість несприятливі для будівництва. Наукова новизна дослідження полягає у застосуванні інженерногеологічного районування як основи для виконання інженерно-будівельної оцінки, що не обмежується лише виділенням планувальних інженерно-геологічних обмежень. Вперше запропоновано методику виділення інженерно-геологічних підділянок за проявом небезпечних геологічних процесів та морфометричними характеристиками рельсфу, що відображають ступінь ерозійної розчленованості, потенціал прояву сучасних рельєфоутворювальних процесів та ерозії грунтів. Практичний аспект здійсненого дослідження полягає у створенні якісної схеми інженерно-будівельної оцінки, доповнення схеми наявних планувальних обмежень, підборі оптимальних та економічно обґрунтованих заходів з інженерної підготовки та захисту територій проти небезпечних геологічних процесів. Інженерногеологічне районування дає змогу визначити безпечні місця для розміщення інженерних споруд, їх конструкційні особливості, вибрати раціональні типи фундаментів, зменшити вартість вишукувальних та будівельних робіт та загалом поліпшити якість проєктування.

Ключові слова: інженерно-геологічне районування; інженерно-будівельна оцінка; таксономічні одиниці; небезпечні геологічні процеси; морфометричні характеристики; геолого-літологічна будова; Ірпінь.

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