GEOLOGY

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INFLUENCE OF LOCAL SEISMOTECTONIC AND ENGINEERING-GEOLOGICAL CONDITIONS ON SEISMIC DANGER OF TERRITORIES (EXEMPLIFIED BY A CONSTRUCTION SITE IN UZHGOROD CITY)

Objective. To identify the location of potentially active seismic zones in which local earthquakes may occur. To evaluate the predicted seismic shaking intensity (in MSK-64 scale points) considering impacts associated with the local tectonic and engineering-geological conditions of the study site. **Methodology**. The totality of data on the correlation between the length and magnitude of associated maximum energy earthquakes established seismotectonic potential of active or potentially seismoactive fault segments (lineaments) cut off by faults of the same or a lower order being transverse to their strike and located within the maximum possible vicinity to the studied site. Quantitative assessment of the predicted seismic shaking intensity by seismological analogies for the territory was carried out in accordance with the norms regulated by DBN B.1.1-12-2014. **Results**. Based on the analysis of information on the geodynamic and seismotectonic situation in the vicinity of the projected structures site, we defined the location of potential seismic zones where local earthquakes may occur. The study determined seismotectonic potential of the closest to the site fault segments in terms of their maximum magnitudes which will not be exceeded for the next 50 years with a probability of 99 %. Fault segments (1–5) marked on the tectonic map are located in a close proximity to the site. The greatest seismotectonic potentials M_{max} = 4.32, M_{max} = 4.03 are specific to faults 1 and 4 with lineament lengths L = ~18.91 km, L = ~13.23 km. Faults 2, 3, 5 demonstrate smaller values of seismotectonic potential M_{max} = 3.42; 3.60; 3.48. It is known that earthquakes in the Transcarpathian trough are shallow, i.e. they occur at a depth of 2–5 km. Under these conditions, I_{RM} = 7.27, I_{RM} = 7.34 for faults 1 and 4 is the highest, the remaining faults 2, 3 and 5 have lower I_{RM} = 4.38; 5.49; 3.48 values per MSK-64 macroseismic scale and DSTU-B-V.1.1-28_2010 respectively. For the second category soils the evaluation is made in respect of their seismic properties. The maximum predicted impact of local potential earthquakes on the site area is established as I_{RM} **= 7.34 points** per MSK-64 macroseismic scale and DSTU-B-V.1.1-28:2010. According to the data of engineering-geological surveys, within the limits of a 10-meter layer below a planning mark, the soils of site allocated engineering-geological area are specific for the 2nd category per their seismic properties. The object of reconstruction falls in CC3 class of consequences (responsibility). According to ZSR-2004–C map, the standard (background or input) intensity of seismic shaking within the site is I_N = ***8 points*** per the MSK-64 scale. **Scientific novelty**. Seismic faults within the vicinity of Uzhgorod city were determined; seismotectonic potential and maximum possible impact of local earthquakes on the site territory and designed structures stability was established. **Practical relevance**. The construction site SMZ gives specified values of seismic impacts in relation to the general seismic zoning of the country. This allows considering possible increase in seismic magnitude at the stage of seismic resistant construction design. Taking into account SMZ results at construction of engineering structures allows avoiding human casualties and reducing economic losses at seismic manifestations.

Key words: tectonics, seismotectonic potential, seismic microzoning, method of seismic-geological analogies, magnitude, seismic intensity, seismic properties of soils.

Introduction

Extensive seismological researches have proven that local geological conditions are a decisive factor in the magnitude and volume of earthquake-induced damages. The need to take these conditions into account when assessing seismic hazards and parameters of possible seismic impacts is quite obvious even when it comes to individual construction sites and structures since cases of complete destruction of one house located next to another having the same safety factor but completely undamaged happen quite often [Kendzera, 2015; Kupliovskiy, 2018; Starodub, et al, 2003].

Until the seventies of the last century, it was believed that the main danger on the territory of Ukraine was caused only by the strong Vrancea zone sub-crustal earthquakes. The local seismicity was practically unstudied. The seismic network was not sufficient to determine not only the location of weak local earthquakes foci, but also their mechanism. Recently, the number of seismic stations has increased. The results of the study of local seismicity on the territory of the East-European Platform confirmed that within it, as well as on other ancient platforms, powerful earthquakes can occur though much less frequently than in the seismic belts of the planet [Kutas, 2007].

Objective

To identify the location of potentially active seismic zones in which local earthquakes may occur. To evaluate the predicted seismic shaking intensity (in MSK-64 scale points) considering impacts associated with the local tectonic and engineering-geological conditions of the study site.

Methodology

Seismotectonic potential of active or potentially seismoactive fault segments (lineaments) cut off by faults of the same or a lower order being transverse to their strike and located within the maximum possible vicinity to the studied site is established based on the totality of data on the correlation between the length L and the magnitude of associated maximum energy earthquakes. To calculate the magnitude of a potentially possible maximum earthquake $\boldsymbol{M}_{\text{мах}}$ let us use the known ratio from [Bugaev, 1999]:

$$\boldsymbol{M}_{\text{мах}} = \mathbf{0.54 + 1.87Lg}(\boldsymbol{L}) \pm \boldsymbol{K\sigma}\,, \qquad (1)$$

where L is the length of a lineament (geodynamically active zone), km; σ is a standard deviation which depends on data samples and ranges from 0.6 to 0.76; K is a coefficient defining evaluation confidence $\boldsymbol{M}_{\text{мах}}$. To ensure 99 % non-exceedance of predicted maximum magnitudes values over a 50-year period the K-factor should be 2.326 [Shmoilova, et al., 2011].

Shaking intensity is calculated using empirical Shebalin-Blake's formula [Kendzera, et al., 2003]

$$\boldsymbol{I} = \mathbf{1.5}\boldsymbol{M} - \mathbf{3.5}\boldsymbol{Lg}(\boldsymbol{\Delta}) + \mathbf{3.0},$$

$$\Delta = \sqrt{R^2 + H^2}\sqrt{R^2 + H^2} \qquad (2)$$

where $\boldsymbol{R}$ is a minimum distance to the site, km, $\boldsymbol{H}$ is a minimum focal depth, km.

Quantitative evaluation of the predicted seismic shaking intensity using the method of seismic-geological analogies for the given territory was carried out pursuant to the regulated norms in accordance with Table 5.1. DBN V.1.1-12-2014 [*DBN V.1.1-12-2014…, 2014*].

Results

Neotectonic conditions and potentially seismic active faults within the site area, their seismotectonic potential in M_{Max}

The projected construction site is located within the Transcarpathian trough.

The Transcarpathian trough is geomorphologically manifested by the Transcarpathian depression and the Vigorlat-Hutyn Ridge. The trough is limited by the Transcarpathian deep fault in the north-east and Panosian deep fault in the south-west. It is divided into longitudinal elements, i.e. the Marginal or monoclinal zone adjacent to the Transcarpathian trough and the Central Zone of salt diapir structures or brachyanticlinal folds. The north-eastern block coincides with the Marginal Zone and is a continuation of the Uzhgorod-Iniachivskiy Slovakian horst. Here the basement is formed by crystalline shales, the sedimentary cover – by the Triassic, Jurassic, Cretaceous sediments and Eocene Pidhale type flysh.

The general basement structure is of block type, the internal structure is characterized by low-angle overthrusts that overlap the Jurassic deposits. For instance, the above is observable in Nevytska-1 well, where the Triassic profile repeats three times. In the Edge Zone sedimentary rocks gently dip to the southwest.

The Transcarpathian trough evolution began with the occurrence of an edge and its accompanying faults along which the basement submerged. The most ancient trough sediments, i.e. the Tereshulski conglomerates, form the basal thickness of a molassic formation.

Sea transgression, intensive trough lowering, and rapid volcanic activity continued in the Early Baden. On average, clays of the Tereblinska suite lower part accumulated in the sea of normal salinity. However, in some areas the open sea regime changed to the lagoon one as indicated by gypsum and anhydrite lenses.

Neotectonics

Neotectonic movements are manifested throughout the territory tending to raise the Carpathians and lowering the Transcarpathian trough. For the Quaternary period, this process is reflected by the evolution of basement terraces, the level of which increases progressively from the lowlands to the main Carpathians watershed as well as the origination of powerful Mynaiska and Chopska suite sediments. The processes of raising and lowering are interrelated and occur in a differentiated way per the system of breaks of the general Carpathian strike, which coincide with the boundaries of blocks, suites and slices. Exogenous-endogenous processes and genetic factors play an important role in the formation of the relief.

Exogenous and endogenous processes and genetic factors play an important role in relief formation.

The history of geomorphological development of the territory starts with the inversion of the Carpathian basin at the beginning of the Neogene, but traces of this ancient relief have not been preserved. In the middle Miocene a significant elevation of the area accompanied by the formation of overthrusts in the Carpathians and intensive volcanic activity in the Transcarpathian trough is registered. A morphostructure had emerged, which then became the basis for the formation of modern relief. Its first stage is fixed by the highest denudation level at a height of 1250–1350 m, which was formed in the pre-Pliocene time [State ..., 2003].

Up to the end of the Sarmatian period in the southwestern part of the Transcarpathian trough a mountain structure formed as a result of volcanic activity and ascending movements. Up to the end of the Pliocene as a result of erosion and denudation only hills remained here.

In the Pliocene on the boundary of the trough and the raised Carpathians block a volcanic activity led to the formation of a large convex shape that blocked the flow of the Uzh and Latorytsia rivers. In the Carpathians the denudation level simultaneously formed at altitudes of 900–1100 m [State ..., 2003].

In the early Quaternary time in the Transcarpathian trough the lake-alluvial deposits of the Chop suite accumulated as a result of intensive lowering.

Inselbergs were heavily denuded. Erosion activity in the Carpathians and on the southwestern slope of the Vigorlat-Hutynskiy ridge led to the formation of several levels of high erosion terraces [State ..., 2003].

In the Middle Quaternary the last erosion cycle started in the Carpathians, the Carpathian rivers broke through the Vigorlat-Hutynskiy ridge (at the level of the 5th terrace) and a complex of low and middle terraces began to form. In the Mukachevo depression, top-down movements occurred and thick alluvial Minay suite sediments became accumulated.

In the Holocene, the nature of relative movements was preserved in the Carpathians and in the trough. The uplift in the Carpathians is fixed by the formation of V-shaped valleys of mountain rivers with a rocky bed, hanging valleys of tributaries. In the lowlands weak depressions are fixed by the displacement of channels, formation of cut-off meanders.

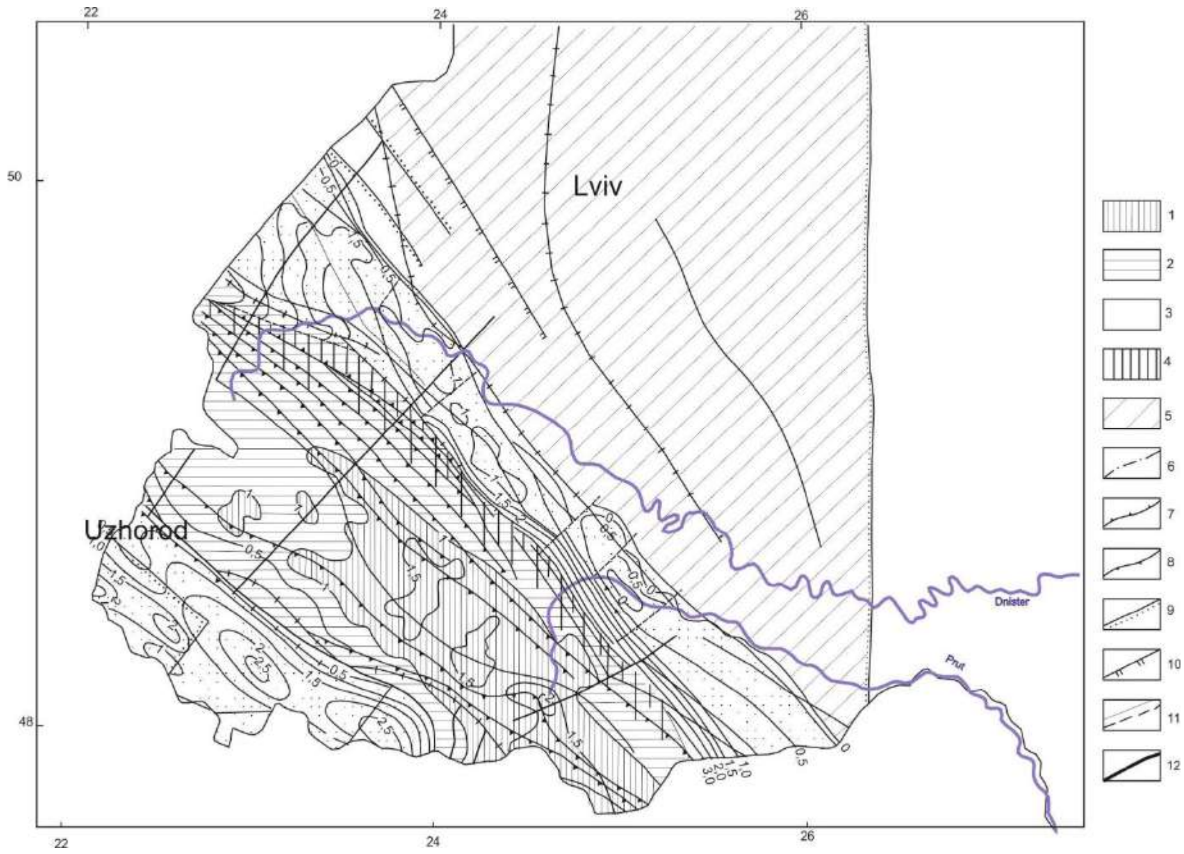

Fig. 1. Map of the latest tectonic movements [*Seismic zoning..., 1980*]:

1–2 – amplitudes of the newest uplifts; 3 – lowering: 1 – 1–2; 2 – 2–0–1; 3 – 0–0–2 cm; 4 – zones of coincidence lowering and allogenic elevation; 5 – The Alpine platform; 6 – margin of the platform and Pre-Carpathian trough; 7 – thrust of the inner zone of the Pre-Carpathian trough over the outer zone and thrust of the Carpathians over the Pre-Carpathian trough; 8 – other overthrusts; 9 – faults; 10 – dip-slip faults; 11, 12 – other faults

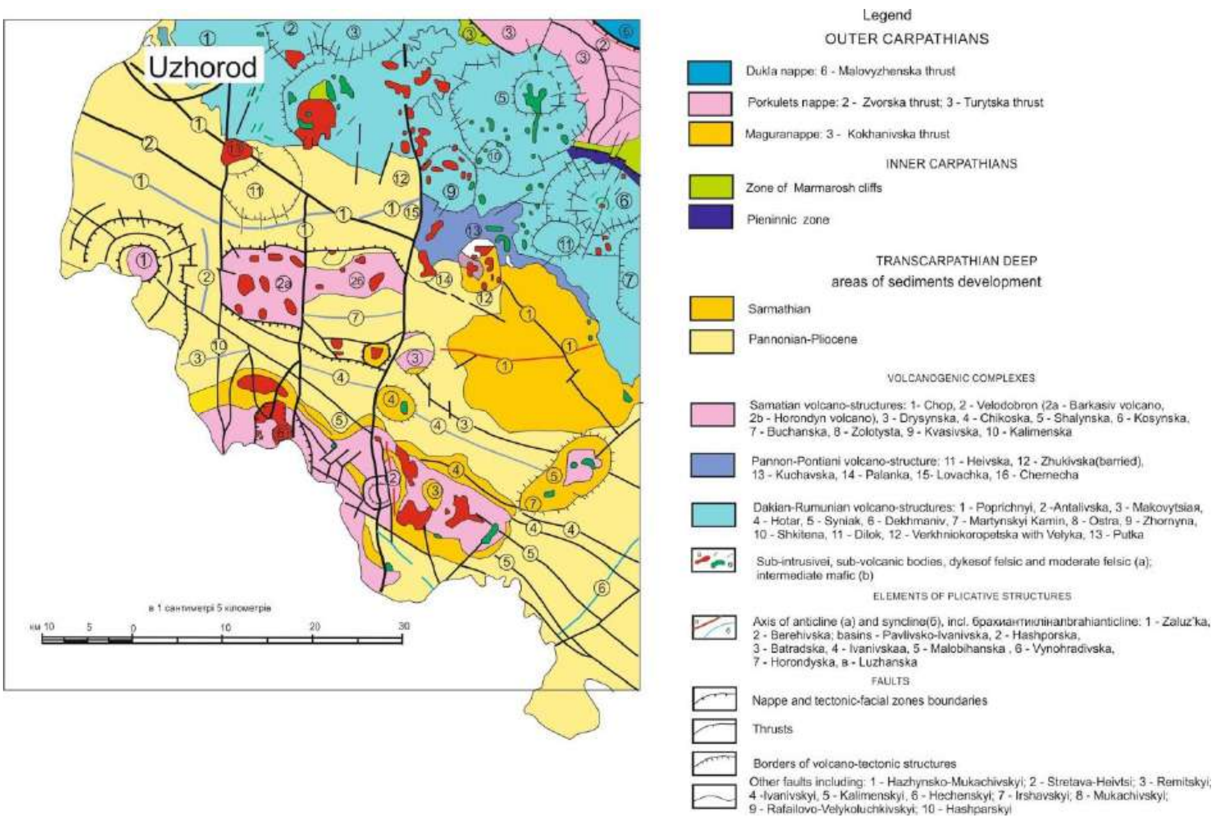

Fig. 2. Tectonic scheme of the study area [*State Geological…, 2003*]

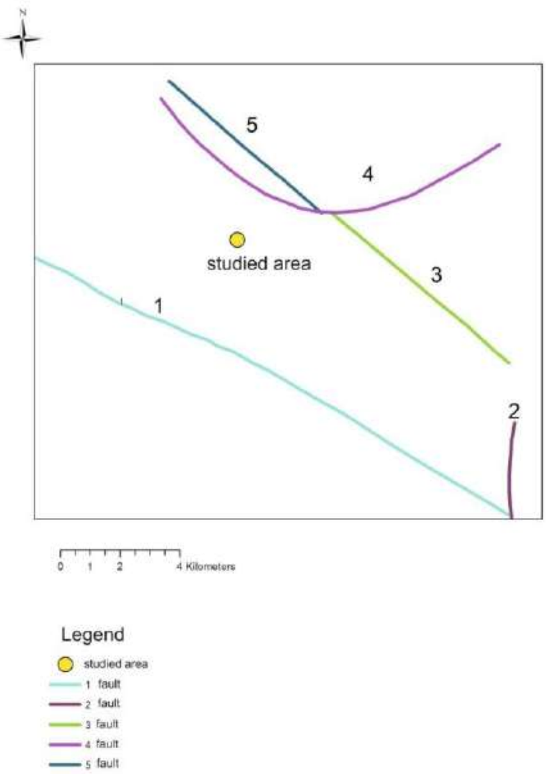

Fig. 3. Fault location (at the study site)

Nowadays the erosion processes, landslides, taluses, floodplain formation are continuing.

Having analyzed information on the geodynamic and seismotectonic situation in the area of the main structures (Fig. 1, Fig. 2) of projected construction objects, we could establish the position of potential seismic zones where local earthquakes may occur (Fig. 3). It was possible to determine seismotectonic potential of the nearest to the site segments of tectonic faults in terms of their maximum magnitudes, which with a probability of 99 % will not be exceeded for the next 50 years. (Table 1).

Table 1

Seismotectonic capacity of potentially active faults in the area of a construction site

Fault	Segment length, km	Focus minimum depth, km	Mini-mum distance to the site, km	M_{Max}	I_{RM}
5	6.74	2.5	2.5	3.48	6.30
3	7.78	2.5	6.3	3.60	5.49
1	18.91	2.5	3.5	4.32	7.27
2	6.20	2.5	11.5	3.42	4.38
4	13.23	2.5	1.8	4.03	7.34

The closest to the site fault segments are indicated on a tectonic map as 1–5, 2, 3, 4, and 5. The most seismotectonic potentials M_{max} = 4.32, M_{max} = =4.03 demonstrate faults 1 and 4 with the lineament lengths L = ~18.91 km, L = ~13.23 km. Faults 2, 3, 5 show much lower values of seismotectonic potential M_{max} = 3.42; 3.60; 3.48.

Literary sources state that in the Transcarpathian trough earthquakes are shallow, i.e. their hypocenters are located at a depth of 2–5 km [*Maksymchuk, 2014*]. Under such conditions, values I_{RM} = 7.27, I_{RM} = 7.34 for faults 1 and 4 are the highest while according to the Macroseismic scale MSK-64 and DSTU-B-V.1.1-28_2010 [*Seismic intensity scale..., 2011*] the remaining faults 2, 3 and 5 demonstrate lower values of I_{RM} = =4.38; 5.49; 3.48 respectively. The evaluation is attributed to the second category of soils per their seismic properties.

The maximum predicted impact of local potential earthquakes on the site area is estimated as I_{RM} **= 7.34 *points*** according to the Macroseismic scale MSK-64 and DSTU-B-V.1.1-28:2010 [*Seismic intensity scale ..., 2011*].

SMZ of the projected plant construction site by the method of seismic and geological analogies

Site SMZ by the method of seismic and geological analogies was carried out taking into account the results of engineering and geological surveys performed by Geologist LLC.

Pursuant to the data, the development site is located in the southwestern suburb of Uzhgorod within the Chop-Mukachevo lowland. Geomorphologically, it is located on the left floodplain terrace of the Uzh river. The site surface is almost flat. Absolute elevations within its limits vary from 109.13 to 110.36 m. The natural relief of the site has been significantly anthropogenically transformed during the planning works. The modern relief of the site is characterised by a flat surface. Geomorphologically, the site is located on the left floodplain terrace of the Uzh river. The surface of the site is flat and planned. Absolute elevations are 109.13–110.36 m.

Engineering-geological model of the site is presented in the form of engineering and geological cross-sections (Fig. 4). Soil stratum is divided into engineering-geological elements (IGE) taking into account their age, origin, texture and structural features, composition, condition, physical and mechanical properties of nomenclature soils based on the results of well drilling data processing and laboratory tests.

Engineering and geological cross-section of the site is represented (from top to bottom) by the following engineering and geological elements: IGE 1 – fill-up soil, IGE 2 – semi-rigid clay, IGE 3 – semi-hard loam; IGE 3a – plastic sticky loam; IGE 4 – fine sand; IGE 5 – coarse gravelly soil.

● IGE 1 – fill-up soil (t Q_{IV}) is represented by loamy soils mixed with crushed stone and construction debris up to 10–35 % by its volume. The soil is dry dumped, settled, lies on the surface, the layer thickness is 2–1.5 m.

● IGE 2 – semi-rigid clay (a $Q_{III\text{-}IV}$), lumpy, light, loam-like and of brown and grey-brown colour. It occurs under the fill-up soil as a layer of variable thickness ranging from 1.0 to 3.3 m. (apparently, the indicators of composition and properties of soils of established IGE should be summarized in the table). The soil demonstrates following physical characteristics:

natural moisture (W) – 0.30; plasticity index (I_p) – 0.20; consistency index (I_L) – 0.13; density (ρ) – 1.99 t/m^3; porosity index (e) – 0.79; wetness degree (Sr) – 1.00.

● IGE 3 – semi-hard loam (a $Q_{III\text{-}IV}$), mainly heavy, in the upper part resembles clay, of dark brown and black colour, in the lower part – with layers of dusty sand, and yellow-brown plastic sticky loam with a thickness of up to 20 cm. It occurs under clay IGE 2in the form of a layer of variable capacity ranging from 0.5 to 2.7 m. The transition between clay IGE 2 and loam IGE 3 is inexplicit, gradual.

The soil demonstrates following physical characteristics:

natural moisture (W) – 0.23; plasticity index (Ip) – 0.15; consistency index (IL) – 0.06; natural composition density (ρ) – 2.05 t/m^3; porosity index (e) – 0.63; wetness degree (Sr) – 0.98.

● IGE 3a – plastic sticky clay (and $Q_{III\text{-}IV}$), lumpy, light, sandy of brown and grey-brown colour. The soil is found under loam IGE 3in the form of a wedged out layer. Its maximum power is 0.8 m.

The soil demonstrates following physical characteristics:

natural moisture (W) – 0.27; plasticity index (I_p) – 0.10; consistency index (I_L) – 0.42; density (ρ) – 2.02 t/m^3; porosity index (e) – 0.70; wetness degree (Sr) – 1.00.

● IGE 4 – fine sand (a $Q_{I\text{-}II}$), of medium density, quartz, clayey, wet of grey and yellow-brown colour. It occurs under loams IGE 3, 3a in the form of lenses. Its maximum power is 1.3 m.

The soil demonstrates following physical characteristics:

natural moisture (W) – 0.20; density (ρ) – 1.75 t/m^3; porosity index (e) – 0.65.

● IGE 5 – coarse gravelly soil (a $Q_{I\text{-}II}$), pebbles of effusive and sedimentary rocks, mainly of small and medium size, well rolled up, the filler is fine sand 29.8 % by weight, wet. The soil was found in all wells at the depth of 4.2–5.8 m.

Ground waters were not found in wells to a depth of 6.0 m. According to the research data of the adjacent areas obtained by Geologist cooperative, the depth of the ground water level is at the absolute level of about 102.00 m. During snowmelt and intense precipitation, local upwelling may occur at IGE 1-2 soil contact as well as in pit hollows and trenches.

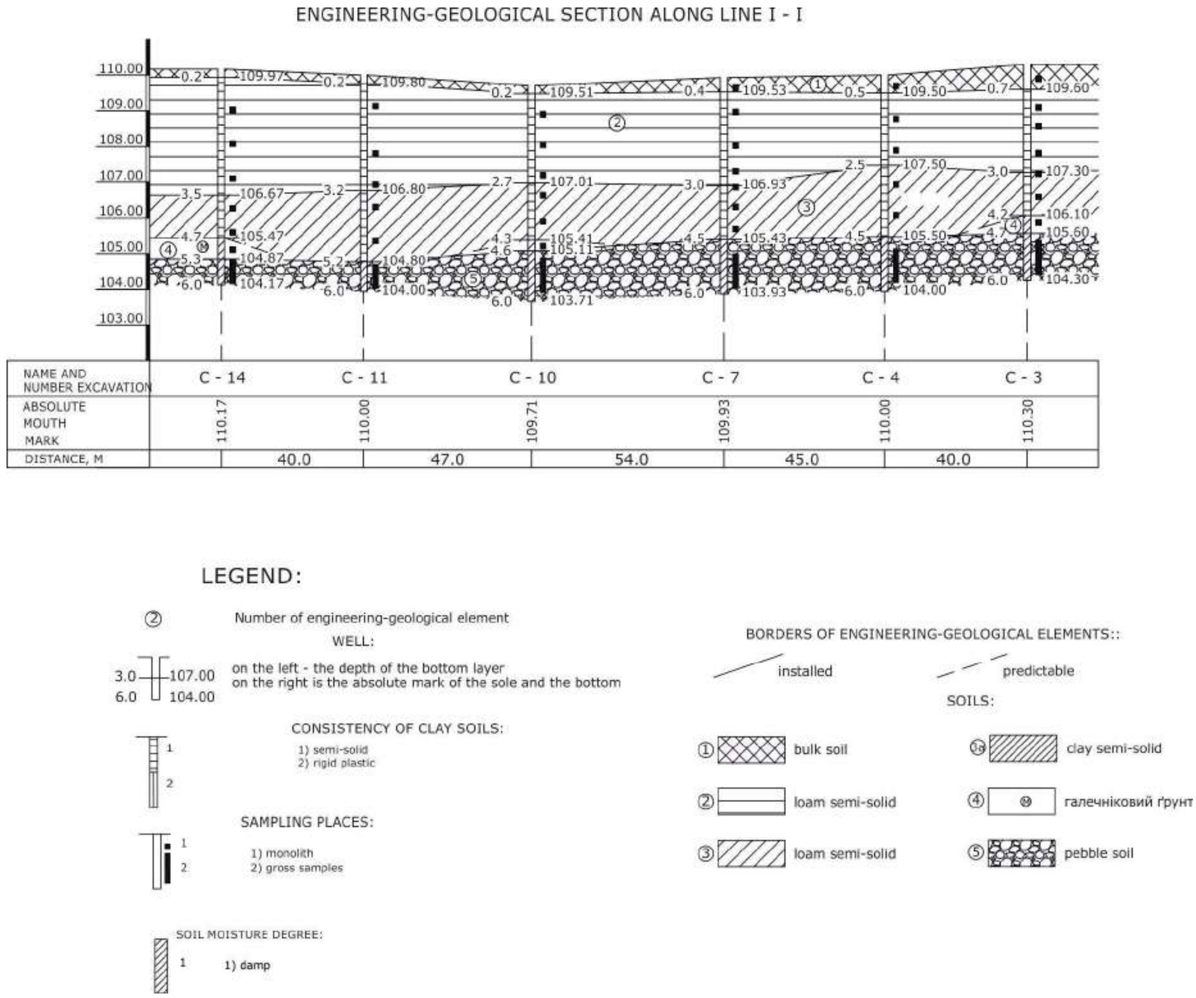

Fig. 4. Engineering-geological cross-section of the projected construction site.

From the data presented it is clear that taking into account the above results and peculiarities of the distribution of sediments of different genetic types, lithological and facial composition within the site, the territory of the studied site can be attributed to one engineering-geological region (taxon) with a relatively homogeneous geological structure. It can also be considered as one engineering-geological region.

According to Table 5.1. DBN V.1.1-12-2014 [*DBN V.1.1-12-2014..., 2014*], the soils of identified IGE belong to different categories per their seismic properties. In particular, technogenic soils (IGE-1) belong to the IV IGE-2-5 category – to the 2nd category. Taking into account the lithology and physical condition of soils, in the sedimentary thickness located within the Engineering-geological region five engineering-geological elements were determined up to the depth of 10 m. Their geological and lithological characteristics are given below:

IGE 1 – Fill-up soil. Horizon thickness is 1.0 m. According to Table 5.1. DBN V.1.1-12-2014 [*DBN V.1.1-12-2014…, 2014*], the soil of this layer should be attributed to the 4th category per seismic properties.

IGE 2 – Semi-rigid clay. Horizon thickness is 2.0 m. According to Table 5.1. DBN V.1.1-12-2014 [*DBN V.1.1-12-2014…, 2014*], the soil of this layer should be attributed to the 2nd category per seismic properties.

IGE 3 – Semi-hard loam. Horizon thickness is 2.0 m. According to Table 5.1. DBN V.1.1-12-2014 [*DBN V.1.1-12-2014…, 2014*], the soil of this layer should be attributed to the II category per seismic properties.

IGE 3a – Plastic sticky clay. Horizon thickness is 0.5 m. According to Table 5.1. DBN V.1.1-12-2014 [*DBN V.1.1-12-2014…, 2014*], the soil of this layer should be attributed to the II category per seismic properties.

IGE 4 – Fine sand. Horizon thickness is 1.0 m. According to Table 5.1. DBN V.1.1-12-2014 [*DBN V.1.1-12-2014…, 2014*], the soil of this layer should be attributed to the II category per seismic properties.

IGE 5 – Coarse gravelly soil. Horizon thickness is 5.0 m. According to Table 5.1. DBN V.1.1-12-2014 [*DBN V.1.1-12-2014…, 2014*], the soil of this layer should be attributed to the 2nd category per seismic properties.

Fill-up soil, widespread within the site, is characterized by unfavourable engineering, geological and seismic properties, and cannot be used as the basis for foundations. Due to the fact that its capacity is insignificant it does not affect the stability of a designed structure. Since the soil thickness is up to 1.5 m this does not influence the choice of design solutions (*according to Note 1 to Table 5.1. DBN V.1.1-12-2014 [DBN V.1.1-12-2014..., 2014]*). It is not recommended to use soil IGE 1 as a natural basis for foundations. Soils IGE 2 or IGE 3 are recommended to be used as a natural basis for foundations.

Evaluation of plant site seismicity by the method of seismic-geological analogies

Engineering and geological survey data for a 10-meter layer below the planning level, according to Note 1 to Table 5.1. DBN V.1.1-12-2014 [*DBN V.1.1-12-2014 ..., 2014*], show that the projected construction site soils can be attributed to the 2nd category per their seismic properties.

The object of the planned construction (with the consent of the customer) belongs to the class of consequences SS-3, so for the calculations of the input intensity, the map ZSR-2004-S was chosen [DBN B.1.1-12-2014…, 2014].

According to GSZ-2004–C map the normative (background or input) intensity of seismic shaking of the site equals to I_N = ***8 points*** per MSK-64 scale. Earthquakes of such intensity here can occur once in 5.000 years (seismic risk is 1 %). Seismic shaking intensity of 8 points will not be exceeded for the next 50 years with a probability of 99 %. The refined normative value of seismic amplification in respect of the study site area obtained by the method of seismic hazard calculation presented in thematic scientific collections "Seismicity and seismic zoning of Northern Eurasia" [*Seismicity and seismic zoning ..., 1995*] with the accuracy of 0.01 for the repetition period of once in 5.000 years is I_{RN} = **8.2 points**. The specified evaluation data correspond to the conditional seismic risk of 1 %. It refers to the soils of the 2nd category per seismic properties and does not consider the possible impact of local soil conditions. The sources of shaking of such intensity are strong sub-core earthquakes of the Vrancea zone.

The maximum estimated impact of local potential earthquakes on the site is I_{RM} = **7.34 points** per the macroseismic scale MSK-64 and DSTU-B-V.1.1-28:2010 [*Seismic intensity scale ..., 2011*]. The values of I_{RN} and I_{RM} are related to the soils of the 2nd category per seismic properties, which form the upper 10-meter part of a soil cross-section in the engineering and geological area of the construction site.

Without carrying out seismic microzoning of the study site by instrumental methods, i.e. by the method of seismic impedances and by the method of registration of high-frequency microseisms, the increase in the site seismicity due to the local ground conditions can be assumed to be equal to ΔJ=**0** ***points*** against the refined background (normative) seismic intensity I_{RN}.

Macroseismic scales are descriptive and have only integer values of seismic amplification. Fractional amplification values are used only for calculations, but their results should be approximated to whole values. The obtained seismic value for the study site is equal to **8** points and refers to the soils of the 2nd category per seismic properties, which make up the upper 10-meter part of the soil cross-section of the engineering and geological areas of the study site.

Scientific novelty and practical relevance

Seismically active faults located in the vicinity of Uzhgorod city were determined; seismotectonic potential and the maximum possible impact of local earthquakes on the city territory were calculated.

SMZ of construction sites gives refined data of seismic impacts against the general seismic zoning of the country, which allows taking into account the exact values of seismic manifestations at the stage of designing earthquake resistant construction. Consideration of the SMZ results during the construction of engineering structures allows avoiding human casualties and reduces economic losses for the region during seismic shaking.

Conclusions

The information on the geodynamic and seismotectonic situation in the area of the planned construction site helps to establish the disposition of main structures (Fig. 1, 2) and defines the location of potential seismic zones in which local earthquakes (Fig. 3) may occur .

The seismotectonic potential of the nearest to the site segments of tectonic faults in terms of their maximum magnitudes, which will not be exceeded for the next 50 years with a probability of 99 %, was determined (Table 1).

The maximum predicted impact of local potential earthquakes on the site area is estimated as I_{RM} **= 7.34** ***points*** per MSK-64 macroseismic scale and DSTU-B-V.1.1-28:2010 [*Seismic intensity scale…, 2011*].

According to GSZ-2004–C map the normative (background or input) intensity of seismic shaking of the site equals to I_N = **8** ***points*** per MSK-64 scale. Earthquakes of such intensity here can occur once in 5.000 years (seismic risk is 1 %). Seismic shaking intensity of 8 points will not be exceeded for the next 50 years with a probability of 99 %.

The refined normative value of seismic amplification in respect of the study site area obtained by the method of seismic hazard calculation presented in thematic scientific collections "Seismicity and seismic zoning of Northern Eurasia" [*Seismicity and seismic zoning …, 1995*] with the accuracy of 0.01 for the repetition period of once in 5.000 years is I_{RN} = =**8.2 points**. The specified evaluation data correspond to the conditional seismic risk of 1 %. It refers to the soils of the 2nd category per seismic properties and does not consider the possible impact of local soil conditions. The sources of shaking of such intensity are strong sub-core earthquakes of the Vrancea zone.

The values of $\boldsymbol{I_{RN}}$ and $\boldsymbol{I_{RM}}$ are related to the soils of the 2nd category per seismic properties, which form the upper 10-meter part of a soil cross-section in the engineering and geological area of the construction site.

Without carrying out seismic microzoning of the study site by instrumental methods, i.e. by the method of seismic impedances and by the method of registration of high-frequency microseisms, the increase in the site seismicity due to the local ground conditions can be assumed to be equal to $\boldsymbol{\Delta J=0}$ ***points*** against the refined background (normative) seismic intensity $\boldsymbol{I_{RN}}$.

Macroseismic scales are descriptive and have only integer values of seismic amplification. Fractional amplification values are used only for calculations, but their results should be approximated to whole values. The obtained seismic value of the seismic amplification for the study site is equal to **8** points and refers to the soils of the 2nd category per seismic properties, which make up the upper 10-meter part of the soil cross-section of the engineering and geological areas of the study site.

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ВПЛИВ ЛОКАЛЬНИХ СЕЙСМОТЕКТОНІЧНИХ ТА ІНЖЕНЕРНО-ГЕОЛОГІЧНИХ УМОВ НА СЕЙСМІЧНУ НЕБЕЗПЕКУ ТЕРИТОРІЙ (НА ПРИКЛАДІ МАЙДАНЧИКА ЗАБУДОВИ В м. УЖГОРОД)

Мета. Виявити положення потенційних сейсмоактивних зон, в яких можуть виникати місцеві землетруси. Дати кількісну оцінку розрахункової інтенсивності сейсмічних струшувань (у балах шкали MSK-64) з урахуванням ефектів, пов'язаних із локальними тектонічними та інженерно-геологічними умовами досліджуваного майданчика. **Методика**. Сейсмотектонічний потенціал активізованих, чи потенційно сейсмоактивних, сегментів розломів (лінеаментів), які відсікаються поперечними до їх простягання розломами такого або нижчого порядку, розташованих максимально близько від досліджуваної ділянки, встановлюють на основі усієї сукупності даних про зв'язок між довжиною та магнітудою приурочених до нього максимальних за енергетикою землетрусів. Кількісну оцінку розрахункової інтенсивності сейсмічних струшувань методом сейсмогеологічних аналогій для цієї території виконано згідно із нормами, регламентованими ДБН В.1.1-12-2014. **Результати**. На підставі аналізу інформації про геодинамічну і сейсмотектонічну ситуацію у районі майданчика розташування проєктованих споруд встановлено положення потенційних сейсмоактивних зон, у яких можуть виникати місцеві землетруси. Визначено сейсмотектонічний потенціал найближчих до майданчика сегментів розломів у термінах максимальних магнітуд, які з імовірністю 99 % не будуть перевищені за найближчі 50 років. Безпосередньо поблизу майданчика розташовані сегменти розломів (1–5), позначені на тектонічній карті. Найбільші сейсмотектонічні потенціали $\boldsymbol{M}_{\mathbf{max}}$ = 4,32, $\boldsymbol{M}_{\mathbf{max}}$ = 4,03 у розломів 1 і 4 з довжинами лінеаментів L = ~18,91 км, L = ~13,23 км. У розломів 2, 3, 5 менші значення сейсмотектонічного потенціалу $\boldsymbol{M}_{\mathbf{max}}$ = 3,42; 3,60; 3,48. Відомо, що землетруси у Закарпатському прогині неглибокі, тобто відбуваються на глибинах 2–5 км. За таких умов $\boldsymbol{I_{RM}}$ = 7,27, $\boldsymbol{I_{RM}}$ = 7,34 для розломів 1 і 4 є найбільшим, у решти розломів 2, 3 і 5 менші значення $\boldsymbol{I_{RM}}$ = 4,38; 5,49; 3,48 бала, за макросейсмічною шкалою MSK-64 і ДСТУ-Б-В.1.1-28 2010 відповідно. Оцінку взято для ґрунтів II категорії за сейсмічними властивостями. Максимальний розрахунковий вплив від місцевих потенційних землетрусів на територію майданчика оцінюється як $\boldsymbol{I_{RM}}$ = 7,34 бала за макросейсмічною шкалою MSK-64 і ДСТУ-Б-В.1.1-28:2010. За даними інженерно-геологічних досліджень, у межах десятиметрового шару, нижче від позначки планування, ґрунти виділеного на майданчику інженерно-геологічного району зараховано до II категорії за сейсмічними властивостями. Об'єкт реконструкції належить до класу наслідків (відповідальності) СС3. Згідно із картою ЗСР-2004–С нормативна (фонова або вхідна) інтенсивність сейсмічних струшувань майданчика становить $\boldsymbol{I_N}$ = 8 *балів* за шкалою MSK-64. **Наукова новизна**. Визначено сейсмоактивні розломи в околі м. Ужгород, розраховано сейсмотектонічний потенціал та максимально можливий вплив від місцевих землетрусів на територію ділянки забудови та стійкість проєктованих споруд. **Практична значущість.** СМР майданчиків будівництва дає уточнені значення сейсмічних впливів щодо загального сейсмічного районування країни, що дає змогу на етапі проєктування сейсмостійкого будівництва враховувати можливий приріст сейсмічної бальності. Врахування результатів СМР під час будівництва інженерних конструкцій дає змогу уникнути людських жертв і зменшити економічні втрати за сейсмічних проявів.

Ключові слова: тектоніка; сейсмотектонічний потенціал; сейсмічне мікрорайонування; метод сейсмогеологічних аналогій; магнітуда; сейсмічна інтенсивність; сейсмічні властивості ґрунтів.

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