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VARIABILITY OF GEOLOGICAL AND ENGINEERING CONDITIONS IN RIVER VALLEYS: THE EXAMPLE OF THE UPPER VISTULA RIVER VALLEY

Abstract: Fluctuations in groundwater levels are usually associated with the seasonal variability of precipitation and evapotranspiration. This has an effect on the carrying capacity of soil and on foundation engineering structures in river valleys. The analysis concerns the example of the Upper Vistula River valley. It presents the geological, groundwater and geological engineering conditions of the researched area through seasonal variations in groundwater level. Based on the results of soil and groundwater analyses, a preliminary assessment was made of the bearing capacity and aggressiveness of the water. An analysis of steel and concrete construction elements was carried out. It was estimated that precipitation has an influence on the strength parameters of soil. With a rise of the groundwater table, physical and mechanical parameters deteriorate. However, a drop in the level of the groundwater table causes an improvement in the strength parameters of soil.

Key words: bearing capacity of the ground, groundwater, substrate construction, Upper Vistula River Valley

Introduction

The following article sets out to determine the influence of the variability of geological engineering conditions on objects located in the Vistula river valley. This variability is conditioned by the periodic rise or fall in groundwater levels. The cyclical nature of these changes is strictly connected with the seasons. In springtime, the groundwater table will be shallower due to high infiltration of groundwater from precipitation and melting snow. However, when precipitation is low, the groundwater table will be deeper. The value of geotechnical parameters is determined based on calculations carried out according to the precisely defined correlations between the mechanical and physical properties of the soil (Wilk 2013). Groundwater levels, identified by means of camera monitoring, mainly affect the geological engineering conditions. A similar analysis was carried out by Traczyński and Grela in 2011. They described the influence of groundwater fluctuations caused by long, heavy rains and floods on the conditions of the Vistula River terrace development in Warsaw.

The researched area is located in the south of Poland, in the western part of the Małopolska Voivodeship, in the county of Oświęcim (Fig. 1). In terms of physico-geographical parameters, this area is located in the heart of the Oświęcim Basin. It stretches across the Upper Vistula drainage basin, into the Silesian-Cracovian Upland in the north and the Silesian Foothills in the south. In the east, the researched area borders with the Cracow Gate and in the west with the Ostrawska structural basin (Fig. 2).

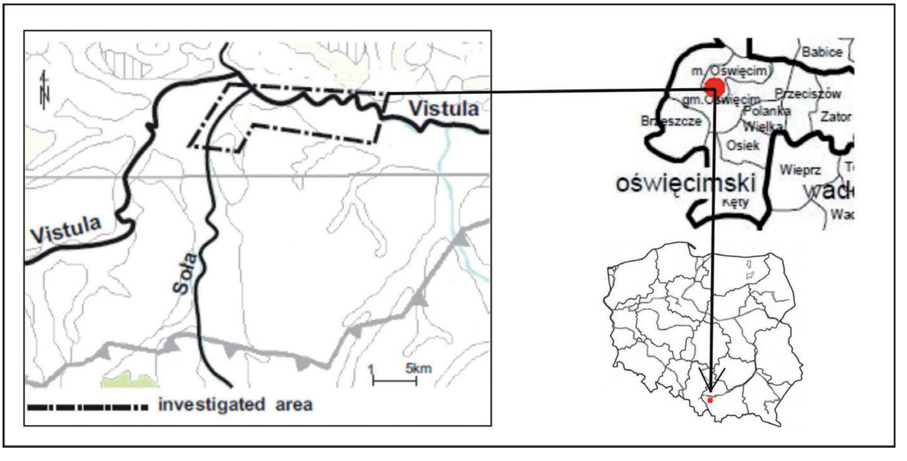

Fig. 1. The location of the study area

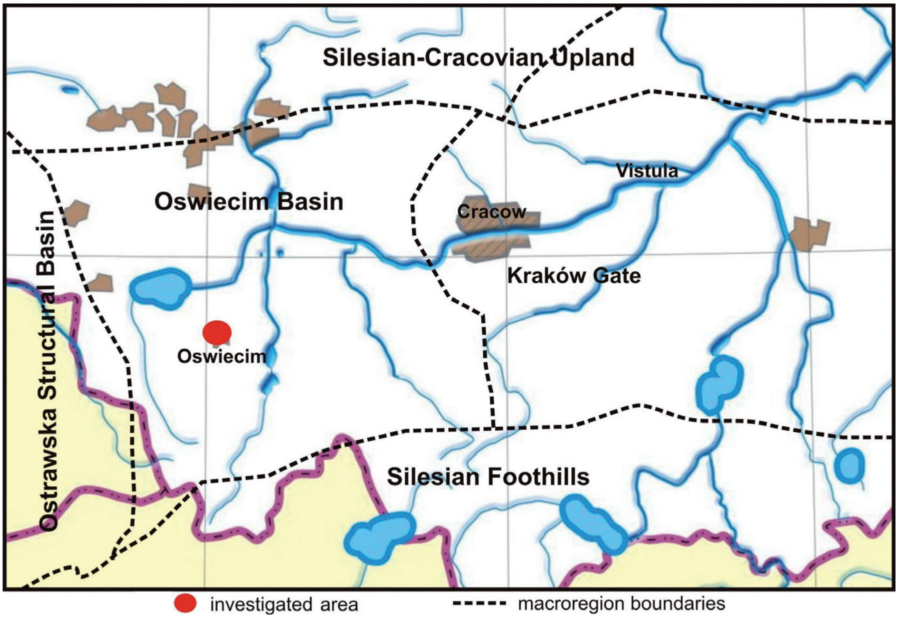

Fig. 2. The location of the investigated area with macroregion boundaries

Natural conditions

In terms of geology, the area under discussion is located within the perimeters of the Polish Carpathian Foredeep, whose bedrock is built of Paleozoic and Mesozoic formations. The Polish Carpathian Foredeep is an extensive tectonic depression with features typical of the foothill graben, filled with loamy formations dating back to the Miocene. Quaternary glacial formations and river and glacial formations (both consisting of sandy and gravelly sediments, sandy silts, sands and clays, and covered with sandy alluvial deposits) lie directly on the Miocene bedrock (Domżał 2007). In the Vistula and Soła valley, formations from the late Vistula glacial period and the Holocene predominate. The youngest Quaternary sediments constitute accumulative covers, consisting of river gravels, sands with gravels, alluvial soils, peat and alluvial clay. During floods, aggregate river mud and gravel covers are formed on low-lying fluvial terraces. The Holocene sediments form the youngest structural level of a discontinuous thickness not exceeding several dozen metres (Domżał 2007).

The outstanding feature of the researched area is the wide and flat bottom of the Vistula River valley. The sandy sediments of the fluvial terraces even contain small dunes. This area abounds in fishponds.

In terms of morphology, the researched area is located within two main fluvial terraces:

- The Holocene fluvial terrace, which includes the bottom of the Vistula, Soła and Macocha valleys with numerous oxbow lakes;
- The Pleistocene fluvial terrace, which includes an area of mounds and uplands covered with loess formations.

The most important denudation processes in this area are: gully erosion, chemical weathering, splash erosion and anthropogenic processes (Domżał 2007).

Appropriable groundwater reservoirs can be found in the Quaternary formations (Gatlik 1997). The characteristic feature of the researched area is a well-developed network of waterways and ephemeral watercourses, some of which function as canals and drainage ditches draining the swampy areas in the Vistula River valley. Areas with fishponds play an important role in the drainage system because they stabilize the level of groundwater in the adjacent areas and can be treated as "small catchment areas" during floods. The area is entirely drained by the right-bank tributaries of the Vistula River. As part of the Vistula water flow regulation project, the Dwory-Las navigable waterway was built, which resulted in the diversion of the Macocha-Porębska torrent estuary directly to the canal (Fig. 3). The navigable waterway lifted the waters of the Vistula River on the Dwory and Smolice impounding barrages and took over the role of river drainage. However, it does not affect the depth of groundwater placement or direction of water flow.

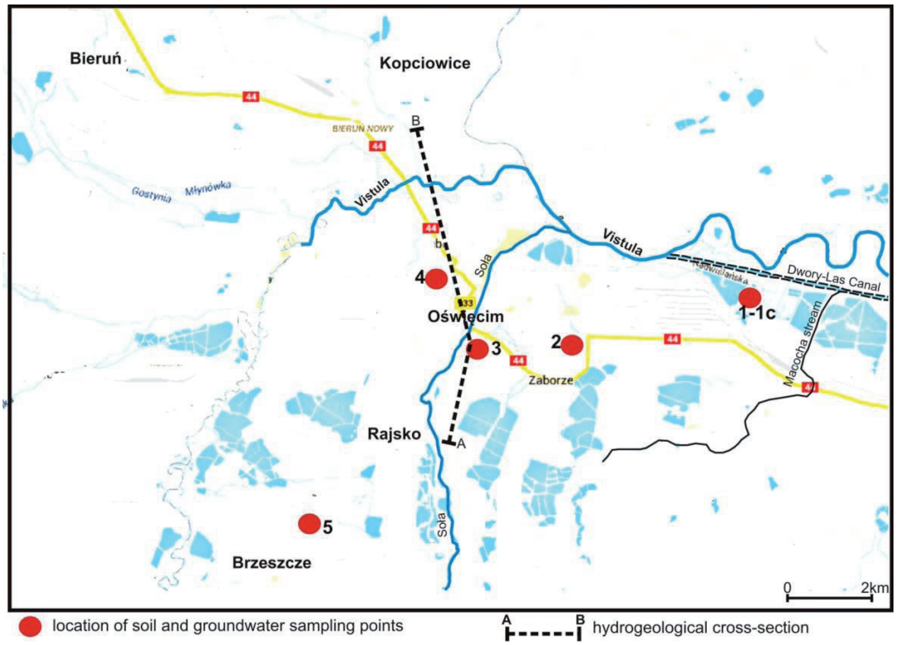

Fig. 3. The location of water and soil sampling points and hydrogeological cross-section

The rivers in this area are classified as hydrologically adjusted rivers, with spring (snowmelt) and summer (precipitation) risings, as well as soil-rain-snow supply (Domżał 2007). In the case of heavy precipitation or snowmelt, the maximum water flows and groundwater levels can occur, because immense quantities of water are simultaneously supplied from different directions. This is strictly connected with the location of the area within the hydrological junction of the Oświęcim Basin.

Groundwater

The studied area is distinguished by the Quaternary aquifer horizon formed as sandy and gravelly fluvioglacial series (with a thickness of up to 25 m) lying on Cracovian clays, which constitute a continuous and impermeable layer of considerable thickness - even above 20 m (Fig. 4). During heavy precipitation, the water table rises not only in the nearby rivers, but also in the residual aquifer[1]. Generally, the aquifer has a free water table (Fig. 4), but at times it can be tense, or slightly tense.

According to Gatlik (1997), groundwaters can be found at a depth between 3 and 10 metres. They are supplied mainly by precipitation (Bruczyńska 2008). In several places within the studied area, rainfall soaks through the poorly drained soil (silt, sandy-clayey silt, silt and silty sand) and very poorly drained soil (clay, compact sandy-clayey silt) (Bruczyńska 2008). This kind of situation can be observed on hydrogeological cross-sections (Fig. 3), where almost the whole area of permeable sediments occur in the form of sand or gravel. Only during the drilling of holes 158 and 138 was clay found on the surface. The depth of the groundwater table is strictly connected with location. In the vicinity of watercourses, the water table is just beneath the surface; however, the further it is located from the valley, the deeper the groundwater can be found.

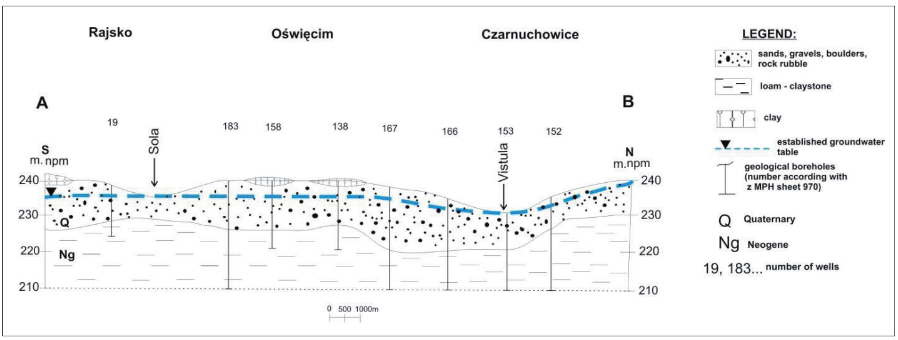

Fig. 4. Hydrogeological cross-section (according to Różkowski 1997)

The depth of the groundwater table fluctuates seasonally. During snowmelt and rainy periods when the groundwater is supplied in great quantities, the surface water level in rivers and torrents is considerably higher than in dry periods. This results in such a rise in the groundwater level that it reaches the foundations of road constructions.

[1] Residual aquifer: the centre of the rock capable of collecting and conducting water. It is delimited by water-impermeable bottom layers.

The groundwater level depends on the hydrological year[2] (Fig. 5). In 2010, the highest water levels occurred in the spring (snowmelt) and summer period. This is connected with the flood which took place in the Vistula River catchment area. In the years 2011 and 2012, the groundwater level decreased slowly due to the fall in precipitation, which is indicated by the graph depicting the water levels in 2012. It was rather a dry year and an insignificant rise in the water levels in March is connected with the impact of the spring snowmelt. Such fluctuations in the groundwater table contribute to variations in geological-engineering soil parameters, which affect, among others, the bearing capacity of cohesive soils. In the case of non-cohesive soils, danger can be caused by groundwater washing out the non-cohesive materials (suffosion), which can, in turn, result in the collapse of the soil surface.

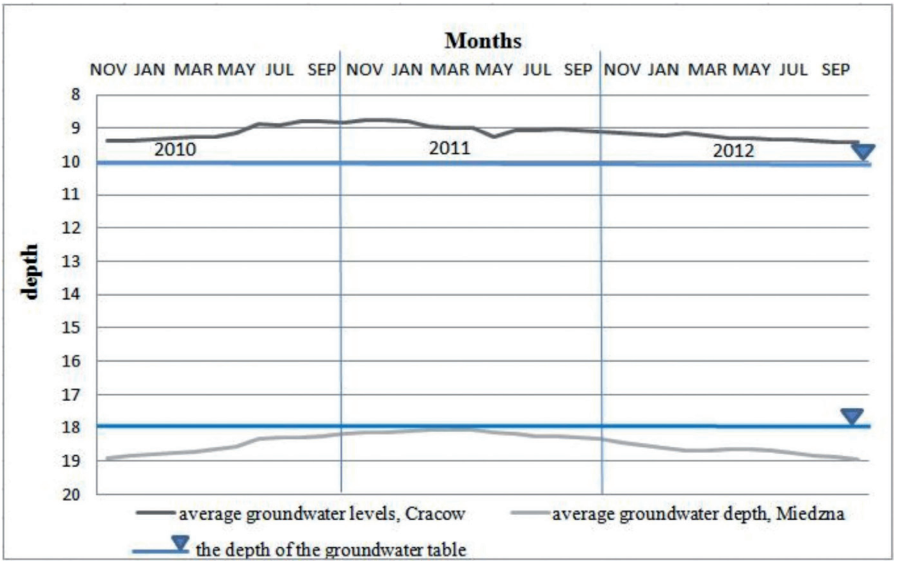

Fig. 5. Average groundwater levels in Vistula between 2010 and 2012 in Cracow and Miedzna (according to Hydrological Annual Report of Polish Hydrogeological Survey)

[2] Groundwater measuring points are located in the valley of the Vistula River

Geological-engineering conditions of the studied area

The studied area consists of layers that have been divided and classified into four geotechnical groups (according to PN-EN 1997-1:2008 and PN-68/B-06050). The names of the soil in the text, tables and cross-sections are in accordance with PN-86/B-02480 (replaced by PN-EN ISO 14688-1). The cross-section (Fig. 6), prepared on the basis of boreholes located in the eastern part of the studied area (points 1 to 1c), shows the classification of geotechnical soils.

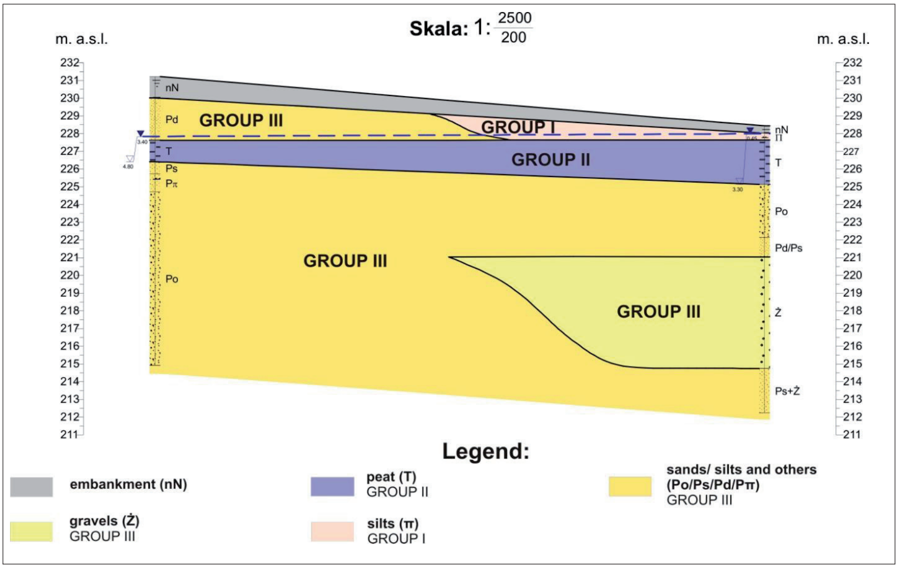

Fig. 6. Synthetic geological cross-section showing the geotechnical classification of soils located in the eastern part of the studied area

- Group I consists of native, Holocene river sediments represented by cohesive soils (river sediments). These are unconsolidated soils of average bearing capacity and compressibility, or weak bearing and compressible soils. They spread within the active area of foundations.
- Group II is represented by native, Holocene river sediments, created in the form of clay, silts and peats. The soils are cohesive and unconsolidated. In terms of origin, content of organic substance, and condition, these soils are considered to be poor, weak bearing and extremely compressible; useless for construction sites.

– Group III includes non-cohesive, fluvioglacial deposits consisting of waterlogged and medium-concentrated silty-clay and gravels, pebbles and unsorted sands. These are poorly deformable, load-bearing soils. They constitute good building subsoil, suitable for the direct construction of building foundations.
– Group IV includes the Miocene native marine sediments, represented by dark grey, silty clay and silty clay with thin interlayers of sandy silts and sands. These are very cohesive soils with hard and plastic texture. These formations can be found beneath the layer of waterlogged silty-clay and fluvioglacial gravels as they constitute an impermeable insulating layer for the Quaternary groundwater level. They are deposited horizontally in the form of a continuous lithological layer. The formations from this group belong to good load-bearing soils of medium compressibility. They create very good engineering-geological conditions for standard foundations.

Locally, plastic malleable organic alluvium silts with the addition of medium-grained sand can be found, which are not suitable for the direct construction of building foundations due to their low mechanical parameters.

The analysis of the dynamics of engineering-geologic conditions

While designing the method of contracting foundations for a building, subsurface and groundwater conditions that can be found within the area of future investment are meticulously analysed. A preliminary analysis is carried out on the basis of detailed geological and geological-engineering maps (according to PN-68/B-06050). The maps provide averaged values and that is why it is worth analysing potentially extreme conditions and their impact on the future construction work. In order to determine the variability of engineering-geologic conditions (which is inextricably connected with the variability of physical and mechanical parameters of the formed layers) the depth of the groundwater tables must be taken into consideration as it affects the bearing capacity and compressibility of soils and the method of building foundations. Another factor is the type of the water table; whether it is a confined or unconfined aquifer.

According to the flood risk map of Poland (Nowicki 2007), the studied territory is in a flood risk area. In periods of snowmelt (spring) and heavy rainfall (summer, autumn) groundwater will rise freely to the land surface level. As a result, buildings founded much below the surface can be displaced by groundwater if, for example, the gravel pack around the foundation was not properly thickened during geotechnical works.

In order to properly assess the soil's strength and strain parameters, it is necessary to carry out specific examinations that take into account the impact of different factors on the obtained measurements (Wilk 2013). The soils should be examined allowing for three potential situations: the natural state of the soil, the state of maximum soil moisture and drainage. During the rise of the water table, dry soils will become irrigated. This may lead to a sudden deterioration of engineering-geological conditions. The consistency, degree of plasticity, humidity and compaction of grounds, among others, will be altered (Wiłun 2012). These factors immediately affect overall soil compressibility.

The bearing capacity of the surface is affected both by water from precipitation and by groundwater flowing through the aquifer. Supersaturation of the soil by water reduces the intermolecular friction and native cohesiveness of the soil and causes a softening of the upper surface of the layer as well as reducing the friction on this surface (Wiłun 2012). In the eastern part of the studied area, in the foundation impact zone, interstratified clay or organic soil can appear. Clays in their dried condition form soils of considerable strength and bearing capacity. The strength and strain parameters of clay were affected by the glacial load, which significantly enhanced the strength of these soils. Clays constitute, on the whole, a good surface of considerable unit loading (Kaczyński 2011); however, even during insignificant drainage, they become malleable and flexible.

The alteration of soil conditions may damage the foundations of a building. Due to groundwater or surface water, the density of the soil may change, which can result in the sinking of a building. The foundation of buildings on soils with weak load-bearing capacity and compressible soils (which include clays among others) requires enhancement and strengthening of the subsoil (Dobak and Kowalczyk 2011).

In most of the studied area, load-bearing and compressible soils are strongly affected by flooding. In summertime, when droughts can occur, the water level in rivers decreases. Consequently, the depth of the groundwater table increases. Well-irrigated soils become dry. This may cause a change in the properties of soils, and its strength and strain capacity. The change in these properties is short-lived and temporary.

Table 1. The research results concerning the physic-mechanical parameters of soils in the studied area (Sordyl 2002; Surdel 2005; Sobol K.M. and Sobol K. 2008; Pinkosz and Skrzypczek 2009; Hrebenda and Orlak 2010)

point 1					
	Cu [kPa]	Mo [Mpa]	M [Mpa]	Eo [Mpa]	E [Mpa]
Sandy-clayey silt	30.20	32.00	55.00	–	–
Medium sand	–	75.00	90.50	–	–
Gravely sand	–	115.0	117.0	–	–
point 1a					
Fine sand/ medium sand	–	35.50	–	–	–
Silt/ soil	11.00	17.00	–	–	–
Medium sand	–	70.00	–	–	–
point 1b					
Sandy-clayey silt/ sandy silt	21.06	37.35	62.25	25.20	42.00
Sandy-clayey silt with clay interlayers	15.30	27.90	46.00	18.90	31.50
Silty sand/ sandy silt with fine sands	10.80	18.90	31.50	13.05	21.75
Coarse and medium sands with gravely sand	–	73.80	82.00	62.10	69.00
Gravels with gravely sand	–	121.5	121.5	108.0	108.00
Aggradate silt with sands	5.85	10.80	18.00	7.20	12.00
Clay	54.00	35.55	44.43	19.80	24.75
point 1c					

point 2					
	Cu [kPa]	Mo [Mpa]	M [Mpa]	Eo [Mpa]	E [Mpa]
Silts (hard and plastic)	16.0	29.4	–	20.6	–
Silts/ between Sandy-clayey silt / sandy-clayey silt	12.5	23.6	–	16.5	–
Sandy-clayey silt	9.0	15.7	–	11.0	–
Fine and silty sand	0.0	51.3	–	38.3	–

point 4					
	Cu [kPa]	Mo [Mpa]	M [Mpa]	Eo [Mpa]	E [Mpa]
Fine sands with pebbles	–	64.0	80.0	55.0	69.0

point 5					
	Cu [kPa]	Mo [Mpa]	M [Mpa]	Eo [Mpa]	E [Mpa]
Fine sands turning into silty sands	–	60.0	75.0	45.0	56.0
Silts/sandy silts	28.0	45.0	75.0	32.0	53.0
Sandy silts/ sandy-clayey silt with sand interlayers	17.0	30.0	50.0	21.0	35.0
Silts/ sandy silts	13.0	22.0	36.6	16.0	26.6
Organic soils/ sandy-clayey silt	–	–	–	–	–

Table 1 (Continued)

Silt/ sandy silts	7.0	13.0	21.0	9.0	15.0
Silty-clay loams/ silts/	12.0	21.0	35.0	15.0	25.0
Sandy-clayey silt (compact sandy-clayey silt)/ compact silt	18.0	33.0	55.0	23.0	38.0
Peats	---	---	---	---	---
Silty aggradate muds	---	---	---	---	---
Fine-grained silty sands	---	51.0	64.0	38.0	47.0
Medium-grained sands with gravels	---	79.0	88.0	67.0	74.0
Gravely sand with gravel	---	133.0	133.0	120.0	120.0
Silty clay with sandy silt interlayers	58.0	35.0	43.0	20.0	25.0

Key to Abbreviations: Cu - cohesion[a],
Mo – modulus of primary compressibility[b],
M – modulus of secondary compressibility[c],
Eo – initial deformation modulus[d],
E – secondary deformation modulus[e]

[a] cohesion: the resistance of soil to external forces and the mutual attraction of soil particles (Pisarczyk 2005)
[b] modulus of primary compressibility: the ability of the soil to reduce its volume as a result of applied loads (Wiłun 2012)
[c] modulus of secondary compressibility: the ability of soil to increase in volume under reduced load (Wiłun 2012)
[d] initial deformation modulus: the ratio of the increase in the effective normal stress to the increase in the total relative deformation (Pisarczyk 2005)
[e] secondary deformation modulus: the module which is denoted at the second stage of test loading (Pisarczyk 2005)

The analysis of the physical and mechanical parameters presented in the Table 1 clearly indicates that the highest compressibility modulus[3] can be attributed to sands with gravels, or with gravels and pebbles (although they may contain patches of other soil types, such as, clay). It shows that soils of higher compressibility modulus have a lesser ability to reduce their volume under loads. Soils belonging to this group have the best geotechnical parameters. Due to the considerable depth of these sediments, it is not always practical for them to be used as the substrate for building foundations.

Variously-grained sands (possibly with the addition of gravels with pebbles) are soils of good physical and mechanical parameters and they constitute a good substrate for the construction of foundations. However,

[3] Compressibility modulus: determined resistance to change in volume of a body under the influence of pressure changes.

despite their good parameters, they are inferior to gravels, or sands with gravels and pebbles.

The obtained results can be ambiguous because, with a rise in water level, the load-bearing capacity of soils diminishes. The greater the moisture in the non-cohesive soil, the weaker the friction forces among grains, and consequently, the greater the sinking of the building (Wiłun 2012). However, the enhancement of cohesive soil moisture results in an unwelcome change in the level of density. According to the graph (Fig. 5) between the months of July and October 2010 precipitation rose, as evidenced by the enhanced level of groundwater. In such cases, the engineering-geological parameters will be different from those in normal conditions. Therefore, the soil's suitability for construction work can change.

Groundwater can periodically interact with the foundation of a building; therefore it is essential that water chemistry tests be conducted. This will determine whether it is chemically aggressive to building constructions. The aggressiveness of water is a function of its chemical composition, and can result in the destruction of rocks, concrete or metal structures remaining in contact with it. Water aggressiveness can affect the concrete of foundations and metal components of the construction, and depends on a number of factors. The most important of them is acidity (pH), with the presence of aggressive, dissolved carbon dioxide, or high sulphate, ammonium or magnesium ion content. When chemically aggressive water affects the concrete of the foundations, it can lead to cracks in concrete and corrosion of metal constructions, and this in turn can led to a reduction in the strength parameters of a given material.

The chemical composition of groundwater is influenced by precipitation, the duration and rate of water circulation and land cover. During heavy rainfall, the saturation zone is affected by pollution from arable fields and illegal waste dumps. This may enhance groundwater aggressiveness because the water and soil can acquire compounds such as sulfates, ammonia, or magnesium which react with the calcium in the concrete. It may also change the pH of the water, making the water more aggressive. In the case of direct contact between concrete constructions and groundwater, the class of exposure of chemically aggressive environments labelled with symbols XA1 (low aggressive chemical environment), XA2 (moderately aggressive chemical environment) and XA3 (highly aggressive chemical environment) is determined: these labels concern the chemical aggressiveness of natural soils and groundwater (according to PN-EN 206-1 Concrete. Part 1: Requirements, Properties, Production and Conformity). Table 2a shows the limits for each class on the aggressiveness of the groundwater according to PN-EN 206-1.

Table 2b shows the averaged results of water aggressiveness tests from points 1 to 1c. These tests were carried out between 2004 and 2010. On the basis of these tests it could be concluded that groundwater is not aggressive in relation to concrete (according to PN-EN 206-1, XA1 class signifies a low aggressive chemical environment). All the examined factors remain within or below the accepted criteria or norms.

According to the research on the groundwater body conducted by the Polish Geological Institute – National Research Institute in 2011, groundwaters in the Upper Vistula River valley have a poor chemical status (Kazimierski 2010 and 2011). The groundwater quality ranges from class IV (in 2009 there was a high concentration of ammonia in the water) and class III (in 2010 there was a borderline value of iron concentration). Due to the negative impact of ammonia on concrete (corrosion and subsequent leakage in concrete walls), constant surveillance of its concentration should be maintained in order to prevent it from exceeding the established permitted limits.

Table 2a. Limit values for the aggression classes groundwater (according to PN-EN 206-1)

Chemical characteristic	XA1	XA2	XA3
SO_4^{2-} [mg/dm³]	≥ 200 and ≤ 600	> 600 and ≤ 3000	> 3000 and ≤ 6000
pH	≥ 5.5 and ≤ 6.5	≥ 4.5 and < 5.5	≥ 4.5 and < 4.0
CO_2 aggressive	≥ 15 and ≤ 40	> 40 and ≤ 100	> 100 to saturation
NH_4^+	≥ 15 and ≤ 30	> 30 and ≤ 60	> 60 and ≤ 100
Mg^{2+} [mg/dm³]	≥ 300 and ≤ 1000	> 1000 and ≤ 3000	> 3000 to saturation

Table 2b. Averaged results of water aggressiveness tests from the north-east part of the studied area from samples 1 to 1c (according to Hrebenda and Orlak 2004; Górka 2010)

Aggresiveness	Factor	Result	Unit	Level of Aggressiveness[a]
Acid	pH	6.797	---	XA1
Leach	hardness	21.43	---	---
Carbonate	aCO_2	21.03	mg/dm^3	XA1
Magnesium	Mg	41.87	mg/dm^3	<XA1
Ammonium	NH_4^+	4.18	mg/dm^3	<XA1
Sulphate	SO_4^{2-}	142.42	mg/dm^3	<XA1

[a] level of aggressiveness of the groundwater indicates whether it will react with the concrete or metal construction engineering objects. This will allow you to apply the relevant sponges, which covers the above mentioned elements of the structure.

Conclusion

In a typical plot of land there is a relation between the level of groundwater and load-bearing capacity of the soil. The deeper the first aquifer layer can be found, the smaller the impact of the groundwater on the load-bearing capacity of the soil above its level and the foundation of buildings. While designing a building, we should bear in mind the fact that the depth of groundwater will undergo seasonal changes. This is strictly connected with high seasonal precipitation (floods) and snowmelt periods.

Groundwater in the studied area will periodically interact with the foundations of buildings. This fact is connected with heavy rainfalls. Due to the groundwater chemistry, the water should not have any negative impact on concrete constructions of buildings because of the low aggressiveness of the chemical environment. This area should be kept under surveillance for the concentration of ammonium in the groundwater, due to the fact of the established permitted limits having been exceeded in 2009. The load-bearing capacity of soils and foundations of buildings will be affected mainly by meteoric water, which will cause the softening (yielding) of the soil (the presence of clays, which instantly yield and resist compaction). This in turn leads to the degradation of strength properties of the soil and constitutes a hazard for foundations of buildings.

References

BRUCZYŃSKA J., MYŚLIWIEC A., 2008, Dokumentacja hydrogeologiczna określająca warunki hydrogeologiczne w związku z wykonaniem piezometrów obserwacyjnych do prowadzenia monitoringu lokalnego wód podziemnych w rejonie składowiska wapna i popiołu (Osadnik III), na terenie Miejsko - Przemysłowej Oczyszczalni Ścieków Sp. z o.o. w Oświęcimiu.

DOBAK P., KOWALCZYK S., 2011, Geologiczno-inżynierska analiza występowania gruntów organicznych w podłożu wybranego odcinka autostrady A2, Biuletyn PIG, 446 (2), 257–264.

DOMŻAŁ J., 2007, Strategia rozwoju gminy Oświęcim 2007–2013, załącznik do uchwały nr V/29/07.

FARBISZ J., 2002, Dokumentacja warunków geologiczno-inżynierskich i hydrogeologicznych w podłożu projektowanej stacji paliw Orlen w Oświęcimiu, ul. Chemików – Olszewskiego.

GATLIK J., 1997, Mapa Hydrogeologiczna Polski w skali 1:50 000, arkusz 970 Oświęcim, PIG-PIB Warszawa.

HREBENDA M., 2010, Dokumentacja geologiczno-inżynierska dla rejonu planowanego składowiska odpadów niebezpiecznych i innych niż niebezpieczne i obojętne zlokalizowanego w zachodniej części działki nr 1354/3, obręb Monowice w Oświęcimiu, Krakowskie Przedsiębiorstwo Geologiczne „ProGeo" Sp. z o.o.

HREBENDA M., ORLAK M., 2010, Dokumentacja geologiczno-inżynierska dla projektowanego składowiska zawierającego azbest, zlokalizowanego na obszarze północnej części działki nr 10445/5, obręb Monowice w Oświęcimiu, Krakowskie Przedsiębiorstwo Geologiczne „ProGeo" Sp. z o.o.

KACZYŃSKI R.R., 2011, Geologiczno-inżynierskie charakterystyki typowych gruntów występujących w Polsce, Biuletyn PIB, 446 (2), 329–340.

KAZIMIERSKI B. (ed.), 2010, Rocznik Hydrogeologiczny Państwowej Służby Hydrogeologicznej. Rok Hydrogeologiczny 2009, PIG-PIB, Warszawa.

KAZIMIERSKI B. (ed.), 2011, Rocznik Hydrogeologiczny Państwowej Służby Hydrogeologicznej. Rok Hydrogeologiczny 2010, PIG-PIB, Warszawa.

MARKS L., 2006, Mapa Geologiczna Polski w skali 1:500 000, PIG-PIB Warszawa.

NOWICKI Z. (ed.), 2007, Mapa obszarów zagrożonych podtopieniami w rejonie dolin rzecznych, PIG-PIB Warszawa.

PINKOSZ J., SKRZYPCZAK M., 2009, Dokumentacja geologiczno-inżynierska dla określenia geotechnicznych warunków posadowienia stacji paliw płynnych w Brzeszczach przy ul. Ofiar Oświęcimia, Ekoid, Katowice.

PISARCZYK S., 2005, Mechanika gruntów. Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2005.

PN-68/B-06050. Geotechnika. Earthworks. General requirements.

PN-86-B-02480. Building soil. The terms, symbols, classification and description of the soil.

PN-EN 1997-1:2008, Geotechnical design – Part 1: General principles.

PN-EN 206-1:2003, Concrete. Part 1: Requirements, Properties, Production and Conformity.

SOBOL K.M., SOBOL K., 2008, Dokumentacja geologiczno-inżynierska dla określenia warunków geologiczno-inżynierskich w rejonie składowiska odpadów komunalnych w Oświęcimiu przy ul. Nadwiślańskiej 36. GEOLOGIA Krzysztof Marian Sobol, Bielsko-Biała.

SORDYL L., 2002, Dokumentacja geologiczno-inżynierska – Oświęcim, ul. Zatorska – stacja paliw. Geosond s.c., Kęty.

SURDEL S., 2005, Dokumentacja geologiczno-inżynierska dla terenu przeznaczonego pod budowę instalacji unieszkodliwiania odpadów niebezpiecznych i innych niż niebezpieczne o charakterze organicznym według technologii PYRO-Kat opartej na procesie niskotemperaturowej quasi-pyrolizy na terenie Miejsko – Przemysłowej Oczyszczalni Ścieków Sp. Z o.o. przy ul. Nadwiślańskiej 46, Przedsiębiorstwo Wiertniczo-Geologiczne Tychy Sp. z o.o.

TRACZYŃSKI K., GRELA M., 2011, Wpływ zmian poziomu wód gruntowych wywołanych powodziowym stanem rzeki Wisły na warunki zabudowy w rejonie Warszawy, Biuletyn PIG, 446 (2), 493–497.

WILK K., 2013, Zależność parametrów konsystencji od uziarnienie gruntów madowych, Budownictwo i Architektura, 12 (3), 121–128.

WIŁUN Z., 2010, Zarys geotechniki, Wyd. Komunik. i Łączn., Warszawa.