Method of assessing engineering construction in karst territories by considering the geomorphological factors

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Abstract: *Karst territories are still one of the most difficult types of landscape for construction development. This article is devoted to the problem of influence of morphometric, morphodynamic, morphologic factors on the engineering construction assessment of karst areas. Accounting for these factors helps to carry out the engineering construction assessment of research area more precisely and qualitatively and to allocate especially dangerous sites for construction development. The method of creation of an engineering construction assessment map of karst territories was presented which considers the mentioned geomorphological factors.*

Key words: *engineering construction assessment, geomorphological factors, karst territories, morphometric indexes, dangerous geological processes*

Introduction

Engineering geological surveys in the territory of karst landscapes have an aim to ascertain the mechanical properties of dissoluble rocks and hydrogeological conditions of the locality. Besides the above-mentioned investigations, geomorphological researches may be used in particular for allocation of suitable building sites, sites of a little building potential and sites of no building potential in the alleged territory of construction, in the counting of earth work content during the stage of land development, in the anticipation of possible activation of dangerous karst processes, in the selection of methods for engineering protection.

The aim of this article is to describe the method of engineering geomorphological research (morphometric, morphologic, morphodynamic features) of the karst territory by conducting field works, territory reconnoitring, data interpretation by coupled geoinformation analysis in the ArcGIS/ArcMap software product. The classification of the karst territory's local areas for the purposes of construction is the ultimate aim of the engineering construction assessment.

Estimation characteristics, units and scales

Morphometric characteristics of relief present an important part of engineering geomorphological assessment of the karst territory. They determine the future volume of earth works during the stage of land development, influence the configuration and location of buildings. Morphometric characteristic are required in the selection of methods of engineering protection. Zoning of economic areas and settlements need to be realised, that would build on the results of morphometric indexes' assessment.

All morphometric values determine on the basis of 1 km² during local researches and on the basis of 1000 km² during regional researches for territory's engineering assessment for construction. This method implies the account of mentioned values for local researches only.

Morphometric indexes play a key role for construction assessment (Parise, Waele & Gutiérrez 2008): density of relief ruggedness by thalwegs, density of relief ruggedness by karst cavities, density of karst forms, areal karst coefficient, mean diameter of sinkholes, depth of relief ruggedness, gradient of slopes, aspect of slopes.

Justification of estimation scales and units of assessed indexes' is an important stage of engineer construction assessment's method of karst territories. There is no single estimation scale for morphometric indexes of karst relief's assessment. We propose the following: each geomorphological index would be estimated for construction development regarding a three-point scale (Tab. 1).

Tab. 1. *Engineering assessment of morphometric indexes for the purpose of construction*

Morphometric characteristic of the relief	Quantitative value	Points*
Density of relief ruggedness by thalwegs, km/km²	0 – 0.5	3
	0.5 – 2.0	2
	>2.0	1
Density of relief ruggedness by karst cavities, km/km²	0 – 1	3
	2 – 5	2
	>5	1
Density of karst forms, unit/km²	<10	3
	10 – 50	2
	>50	1
Areal karst coefficient, %	<0.01	3
	0.01 – 1	2
	>1	1
Mean diameter of sinkholes, m	<3	3
	3 – 10	2
	>10	1
Depth of relief ruggedness, m/km²	0 – 50	3
	50 – 150	2
	>150	1
Gradient of slopes, º	5 – 15	2
	2 – 5	1
	>15	
Aspect of slopes, compass points	South, South-East	3
	South-West, East	2
	North, North-East, North-West, West	1

*3 – suitable building sites, 2 – sites of a little building potential, 1 – sites of no building potential;

Density of relief ruggedness by thalwegs, km/km² is the index determined as relation of total extent of all splitting streams and erosive landforms to the area of the grid's square. There are such degrees of relief ruggedness: weak– density of relief ruggedness is less than 0.5 km/km²; average – varies between 0.5 to 2.0 km/km²; intense – more than 2.0 km/km². Large-scale topographic maps of the karst territory are necessary to chart the density map of relief ruggedness where thalwegs of erosion forms will be drawn in ArcGIS ArcMap software product (Kalvoda and Rosenfeld 1998). Then, the map will be divided into the system of equivalent squares within which the general length of erosion network is determined using the following formula

$$K_{D1} = \frac{\sum L_T}{S_Q},$$

where $\sum L_T$ is the total length of erosion network in the limits of each area, and S_Q is the area of square.

Density of relief ruggedness by karst cavities is the index defining the total extent of karst cavities in the area of the grid's square. The value of the exponent depends from the degree of speleological study of the region and character of karst cavities, increases sharply with availability of labyrinth caves.

The density of relief ruggedness by karst cavities (Waltham, Bell and Culshaw 2005) will be determined by the same method:

$$K_{D2} = \frac{\sum L_F}{S_Q},$$

where $\sum L_F$ is the total length of karst cavity in the limits of each area, and S_Q is the area of square.

The value of this index depends from the index of speleological knowledge base and the character of karst cavities, but rapidly increases with the presence of labyrinth cave.

Density of karst forms is the index widely used for comparative characteristic of differing in size karst regions. This index has two serious imperfections: it accounts only the brightest surface karst manifestations (sink holes). Moreover, the density of karst forms depends from their sizes. There can be more than 5 large or 500 small sink holes per 1 km² and this does not mean that the karst activity in second variant run many times higher than in the first case. Though when there is a data about frequency of karst phenomena's occurrence by average occurrence interval, (0.5 – 5 – 50 – 500 – 5000) it is easy to calculate the total quantity of caves in the region. Then dividing this result on the region square (in 1000 km²), we can obtain the average density of karst phenomena. The index of karst forms' density per unit area is the most important morphometric characteristic. It reflects territory's vulnerability by karst processes and determines the volumes of land-planning works, complex of engineering protection measures (Casagrande, Cucchi and Zini 2005). The map will be charted on the base of karst landforms' counting per unit area:

$$K_{D3} = \frac{\sum N_F}{S_Q},$$

where $\sum N_F$ is the total quantity of all karst landforms per unit area, and S_Q is the area of square.

Areal karst coefficient is the indicator determined as relation of sink holes` total area to the area of 1 km² during local researches. During regional researches the square of karst sink holes is adjusted with general square of karst rocks' extension. This index is used for quantitative estimation of karst territories. The largest areal karst coefficient (20-40 %) are typical for gypsum and carbonaceous karst. Carbonaceous karst differs much smaller values of indexes. Areal karst coefficient of each site can be calculated using the following formula:

$$K_C = \frac{\sum S_F}{S_Q} \times 100\%,$$

where $\sum S_F$ is the total square of all karst landforms in the limits of each area and S_Q is the area of square.

The mean diameters of sinkholes are calculated using the special methods of ArcGIS ArcMap software product; pursuant to the above it makes the conclusion about the territory's stability (Beck 2003). There is such variant of calculation of sink holes' irregular circumferences: when square of circumference is known, we need to extract the square root from it and divide the result by π.

$$D_S = \frac{\sqrt{S_C}}{\pi},$$

where S_C is the square of circumference, π is a mathematical constant, the ratio of a circle's circumference to its diameter, commonly approximated as 3.14.

Depth of relief ruggedness is a diversity of absolute altitudes of the locality, comparative exceeding of maximum heights over minimum heights. The index of relief's ruggedness depth reflects the level difference of the surface that is exceeding of positive karst landforms over the bottom of negative forms concerning the peak of positive forms. It has a large value for estimation of land works' volume required for relief levelling and for constrictive features of prospective buildings (Simonov and Kruzhalin 1993):

$$K_{D4} = \frac{H_A - H_B}{S_Q},$$

where H_A is the highest peak of the surface in the limits of each area, H_B is the lowest peak of the surface in the limits of each area, and S_Q is the area of square.

The gradient of slopes has dual value for constructing activity in the karst region. On the one hand the gradient of slope with 2-5° is very suitable for engineering development, on the other we need to take into account that small gradient of steepness is very favourable for sinkholes' progress. The main cause of this fact is the intensive infiltration of the rain and snow waters on glacis. In addition of small angle of inclination, it's also important to take into account the square of gently sloping surfaces.

Narrow and small square surfaces are more compliant for land runoff than wide surfaces, because the last objects are the sides of karst landforms' development and they pour the water deep down of karst massif.

Aspect of slopes has a very important engineering value for the competent organization of building development and for the segregation of the most compliant lands to karst processes. The southern slopes are the most favourable for civil engineering. Fast evaporation of moisture, weak strength of wind, high index of solar radiation on the southern slopes, are all factors that may cause karst processes to reduce. High-lit room illumination is especially the case for south-east, south-west, east Aspect of slopes. The northern aspect slopes are less favourable for location of constructing due to the minor natural heating and to the violation of moisture and temperature rate indoor air. The water on the northern slopes will evaporate very slowly, resulting in an intensification of sinkholes' development. The western slopes of the surface are the most unsuitable sites for civil engineering and the main cause of this phenomenon is the overheating of apartments from the postmeridian sun (Galve et al. 2009).

Besides the morphometric features, it is necessary to take into consideration the morphodynamic properties of the karst relief. Morphodynamics shall be understood to change the form and structure of karst relief temporally.

The photointerpretation and remote sensing materials on different time spans will be required for the realization of morphodynamic analysis. Morphodynamic investigation involves such geomorphological indexes: 1) average annual intensity of sinkholes' formation; 2) average annual area of sinkholes' vulnerability; 3) average annual sinkhole's volume growth (Veni 1999).

The next task is the creation of estimation scale for morphodynamic indexes of the karst relief. All morphodynamic indexes are measured by scoring system: 3 points – suitable for construction; 2 points – little use for construction; 1 point – useless for construction (Tab. 2).

Tab. 2. *Engineering assessment of morphodynamic indexes for the purpose of construction*

Morphodynamic characteristic of relief	**Quantitative value**	**Points***
Average annual intensity of sinkholes' formation, unit/km² x year	<0,01	3
	0.01 – 1	2
	>1	1
Average annual area of sinkholes' vulnerability, %	0 – 1	3
	2 – 6	2
	>6	1
Average annual sinkhole's volume growth, m³/km² x year	<0.01	3
	0.01 – 1	2
	>1	1

*3 – suitable building sites, 2 – sites of a little building potential, 1 – sites of no building potential;

If an average annual intensity of sinkholes' formation is more than 1 unit/km² in year, the constructing site will be unstable and the construction of buildings in limits of site is therefore not recommended. If this index is to 0.01 unit/km² in year, the construction site will be relatively stable, the application of engineering protective measures will be kept to minimum (Parise and Gunn 2007). This index can be calculated using the following formula:

$$I_F = \frac{\sum N_F}{S_Q \times t},$$

where $\sum N_F$ is the total quantity of all karst landforms per unit area, S_Q is the area of square, and t – span respectively equal to 1 year.

An average annual area of sinkholes' vulnerability can be calculated using the following formula:

$$I_V = \frac{\sum S_F}{S_Q \times t} \times 100\%,$$

where $\sum S_F$ is the total square of all karst landforms in the limits of each area, S_Q is the area of square, and t – span respectively equal to 1 year.

An average annual sinkhole's volume growth can be calculated using the following formula:

$$I_G = \frac{\sum V_F}{S_Q \times t},$$

where $\sum V_F$ is the total volume of all karst landforms in the limits of each area, S_Q is the area of square, and t – span respectively equal to 1 year (Dublyansky and Dublyanskaya 1992).

In addition, all possible natural dangerous processes such as landslides, avalanches, rockfalls, mudflows, failures of the carbonate breeds roof, screes should be counted in order to select the unsuitable sites for construction or to design the special engineering protective erections (Milanovich 2000).

Each element of relief would be estimated for construction development and their direct impact on the engineering preparation of the territory (Gutierrez 2010). It is necessary to take into consideration the following landforms (morphologic criteria) restricting the possibility of construction: limestone pavements, ponors, sinkholes, moats, gullies, poljes, sinkhole wells, karst channels, caves (Vahrushev 2008).

We also plan to use 3-point scale, depended on the degree of morphologic complexity of karst landforms. Such landforms greatly complicate the process of land development: caves, sinkhole wells, screes, rockfalls, poljes and ponors. Karst channels, blind gullies, moats, blind sinkholes make difficulties for land development. Limestone pavements slightly complicate land development (Tab. 3).

Tab. 3. *The influence of karst landforms on the construction development*

Index of influence on land development	Karst landforms	Points*
Slight complications	Limestone pavements	3 points
Casing difficulties	Sink holes	2 points
	Moats	
	Blind gullies	
	Karst channels	
Great complications	Ponors	1 point
	Poljes	
	Sinkhole wells	
	Caves	

*3 – suitable building sites, 2 – sites of a little building potential, 1 – sites of no building potential;

Engineering construction assessment involves the measures of territory's engineering protection. The assessment of engineering measures is accounted on the basis of engineering geological, morphometric, morphologic, morphodynamic features of building sites. Preventive measures (organization of rain outfalls' system, covering of karst breeds by layer of fat clay. measures against aggressive industrial and utility fluids) are the simplest methods of engineering protection's organization (3 points). Technical methods of the earth stabilization (strengthening karst rocks using liquid glass, clay mud and hot bitumen in cracks and small cavities) belong to more complex measures (2 points). The most difficult measure is using of constructive methods (using piles foundation, above-foundation and floor belts, reinforced soils) – 1 point (Ford and Williams 2007).

Stages of assessment

The assessment procedure consists of ***three stages:***

1) Field survey;
2) Cameral work;
3) End-point engineer construction assessment of the karst landscape.

Field survey. To fix dangerous processes during the field works for the construction purpose and for the choice of engineering protection methods (screes, mudflows, landslides, avalanches, landslides, rock-falls, failures of the carbonate breeds roof, tectonic breaches) on the karst territory it is required to realize reconnoitring routes. To realize this aim it is required to use GPS navigator during the reconnoitring routes, which will be fix the "points" of dangerous processes manifestation with their simultaneous description in the field journal.

Using GPS navigator during the field works, we can calendar surface and underground karst landforms (limestone pavements, sink holes, moats, blind gullies, karst channels, ponors, poljes, sinkhole wells, caves) to the influence's extent on the construction development: 1) slight complications; 2) casing difficulties; 3) great complications. The GPS navigator colors the location of karst landforms. Given marks of each landform will be put in the field journal.

The possible measures of engineering protection in the places of dangerous processes' manifestation and in determining the level of land development for complicated karst landforms need to be evaluated during the field works.

Cameral work. The next stage is cameral work. The capacity to gather a lot of cartographical materials on the karst territory (topography maps, aerial mapping, earth remote sensing/ERS) should play a key role in the beginning of cameral work. Some part of this material is available on the cartographical websites. The remaining parts all involve a trip back to the cartographical funds or to specialized agencies. Aerial mapping and earth remote sensing must be represented by different periods of time. It is made to provide on dynamic tracing of karst landforms or general changes of karst landscape in the course of time. The time interval between the surveys is at least 5 years. All collected paper cartographic materials will be transferred to an electronic form. The next step is cartographical and analytical work in the specialized ArcGIS ArcMap software product.

Detailed digitization of the relief elements from topographical maps is next step of cameral work. Overlaying of reconnoitring lines and points of observation from the GPS navigator is the next operation. The main result of the morphometric operation is creating 3D terrain model and, on her basis, maps for analysing gradient of slopes, aspect of slopes, depth of relief ruggedness, density of relief ruggedness. To derive density of relief ruggedness by erosion pattern we must create the map of thalwegs of the karst landscape. This process can be clone mechanically in ArcGIS ArcMap software product. Using a map of relief density involves such sequential step: to draw manually lines in contours of caves and other cavities of the karst territory. It includes data about length and location of karst cavities gathered during the field work.

Next, layers of sculptures and underground karst landforms are overlaid on the digital surface of the karst landscape. The information concerning this layer is received from the field journal and also contains analyses of photointerpretation and ERS materials. Using the analytical tools of ArcGIS ArcMap software programme creates maps of karst landforms density, areal karst coefficient and mean diameter of sinkholes. It is important to note that only modern cartographical materials (last updating) can be used for creating the above maps. For karst landform's growth, counting of average annual sinkholes' intensity formation, counting of average annual area sinkhole's vulnerability and counting of average annual sinkhole's volume growth with the help of analytical ArcGIS ArcMap tools should be used photointerpretation and ERS materials on different time spans. Our ultimate aim of the geomorphological researches will be the creation of engineering construction assessment of the karst landscape by geoinformation coupled method**.**

End-point engineer construction assessment of the karst landscape. Morphometric, morphodynamic indexes, engineering aspects of karst morphology, degree of complexity of engineer protection development have to be estimated for the construction assessment (Dublyansky and Dublyanskaya 1992).

For this aim we propose to create such cluster of construction assessment's data in the specialized ArcGIS ArcMap software product:

Morphometric cluster. Each morphometric index would be estimated for construction development regarding a three-point scale**.** To form the final morphometric cluster, one should the mean arithmetical value for the each cell. Graphically this cluster would look like polygonal coloured filling without allocation of contours.

Morphodynamic cluster involves the extent determination of possible dangerous natural processes' influence on the stability of buildings. We also plan to use 3-point scale, depended on the degree of expressiveness of karst process's dynamics. To form the final morphodynamic cluster, one should the mean arithmetical value for the each cell. Graphically this cluster would look like multi-coloured contours without internal filling.

Morphologic cluster. It is necessary to take into consideration the following landforms restricting the possibility of construction: limestone pavements, ponors, sinkholes, moats, gullies, poljes, sinkhole wells, karst channels, caves. We also plan to use 3-point scale, depended on the degree of morphologic complexity of karst landforms. Point graphing is possible for denotation of those landforms. To form the final morphologic cluster, one should the mean arithmetical value for the each cell. Graphically this cluster would look like multi-textural contours without internal filling.

Engineering cluster involves the measures of engineering protection of the territory. The assessment of engineering measures is accounted on the basis of morphometric, morphologic, morphodynamic features of building sites. Preventive measures are the simplest methods of engineering protection's organization (3 points). Technical methods of the earth stabilization belong to more complex measures (2 points). The most difficult measure is using of constructive methods (1 point). To form the final engineering cluster, one should the mean arithmetical value for the each cell. Graphically this cluster would look like multi-textural hatch.

End-point analysis: engineering construction assessment map of the karst territory. There are 4 shapes with attribute data in each of received cluster. Our final step is engineering assessment of constructing zones of the karst territory (tab. 4) in the allocation of: a) sites of no building potential (4-6 points); b) sites of a little building potential (7-9 points); c) suitable building sites (10-12 points). We should use here coupled geoinformation method. Each cell contains mean arithmetical value of assessed characteristics in each of received cluster that need to be totalized. We'll have the final grid, which will be stated the final total in the result of 4 clusters' overlaying. Sites of no building potential shall be painted with red colour with a counter. Sites of a little building potential shall be painted with orange colour with a counter. Suitable building sites shall be painted with green colour with a counter. To make the map more smoothly, it will be necessary to create a new shape file and to mark the points in the centre of each total sum's cell. It will be necessary to specify number of points equal to a total sum of points within each cell. Any interpolation method (for example Kriging ordinary method) is used to create the interpolated raster. The final interpolated raster of constructing sites is our main result which will help to choose the correct decision during design, construction and operation of buildings.

Tab. 4. *Engineering construction assessment of the karst territory*

Characteristics	Suitable building sites	Mark	Sites of a little building potential	Mark	Sites of no building potential	Mark
Morphometric cluster						
Density of relief ruggedness by thalwegs, km/km^2	0 – 0.5	3	0.5 – 2.0	2	>2.0	1
Density of relief ruggedness by karst cavities, km/km^2	0 – 1	3	2 – 5	2	>5	1
Density of karst forms, $unit/km^2$	<10	3	10 – 50	2	>50	1

Characteristics	Suitable building sites	Mark	Sites of a little building potential	Mark	Sites of no building potential	Mark
Areal karst coefficient, %	<0.01	3	0.01 – 1	2	>1	1
Mean diameter of sinkholes, m	<3	3	3 – 10	2	>10	1
Depth of relief ruggedness, m/km^2	0 – 50	3	50 – 150	2	>150	1
Gradient of slopes, º	-	-	5 – 15	2	2 – 5 >15	1
Aspect of slopes, compass points	South, South-East	3	South-West, East	2	North points, West	1
Morphodynamic cluster						
Average annual intensity of sinkholes' formation, unit/km^2 × year	<0.01	3	0.01 – 1	2	>1	1
Average annual area of sinkholes' vulnerability, %	0 – 1	3	2 – 6	2	>6	1
Average annual sinkhole's volume growth, m^3/km^2 × year	<0.01	3	0.01 – 1	2	>1	1
Morphologic cluster						
	Slight complications		Causing difficulties		Great complications	
The influence of karst landforms on the construction development	Limestone pavements	3	Sink holes Moats Blind gullies Karst channels	2	Caves Ponors, poljes Sinkhole wells	1
Engineering cluster						
Measures for engineering protection	Absence or preventive measures: organization of rain outfalls' system, covering of karst breeds by layer of fat clay. Carrying out measures against aggressive industrial and utility fluids.	3	Besides preventive measures, it is necessary to strengthen karst rocks using liquid glass, clay mud and hot bitumen in cracks and small cavities.	2	Besides preventive measures and using technical methods of the earth stabilization it is necessary to organize such constructive measures: using piles foundation, above-foundation and floor belts, reinforced soils.	1

Conclusions

The presented method of the karst territory's construction assessment is one of attempts to show the basic indexes and criteria that need to be noted in the definition of level of complexity for land development and allocation of the most dangerous sites, which need to be excluded from development. During the assessment the following goals were achieved:

- morphometric characteristics of the karst territory were evaluated according to the following indexes: density of relief ruggedness by thalwegs, density of karst forms, areal karst coefficient, mean diameter of sinkholes, depth of relief ruggedness, gradient of slopes, aspect of slopes;
- geomorphodynamics of the karst territory was presented based on the indexes, such as: average annual intensity of sinkholes' formation, average annual prevalence of the sinkholes' area, average annual growth of landforms' volume, geohazard dangers;
- each element of the georelief was estimated in the degree of his complexity for construction development and their direct impact on the engineering preparation into the categories: slight complications, causing difficulties, great complications;
- measures for engineering protection need to be accounted for understanding the level of land development price rise for construction activity in complicated natural conditions;
- method of creation of engineering assessment map of karst territory's constructing zones was presented with due accounting for the above mentioned assessed indexes and criteria. The main aim of this method was an allocation of sites of no building potential, sites of a little building potential, suitable building site.

However, the improvements of estimation scales for all criteria and progress in method of calculation's end-point engineering assessment of constructing zones are still required in the accounting of morpholithologic factors. Because the only one allocation of morphometric, morphodynamic and morphologic factors is not so correct for engineering assessment of karst territories. By engineering aspects morpholithology involves the comparison between the karst landforms and geotechnical properties of sedimentary rocks, which compose this form (Ananyev and Potapov 2006). Allocation of the structural and genetic subtypes of karst rocks within their strength, deformation and hydrophilic properties should be made in the limits of constructing sites. The accountancy of lithological factor of karst relief formation remains insufficient. It should be the aim for future research for all interested specialists.

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Method of assessing engineering construction in karst territories by considering the geomorphological factors

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Summary: *This article presents the short engineering geomorphological analysis of the karst landscape for construction (building) purposes on the basis of morphometric and morphodynamic indexes, by considering the morphologic characteristic of the relief and complexity of engineering conditions of karst territories' development. Density of relief ruggedness by thalwegs within suitable building sites' limits of karst territories will aggregate not more than 0.5 km/km². Density of relief ruggedness by karst cavities per 1 km² for suitable building sites ranges from 0.1 to 1 km. Density of karst forms should not exceed 10 units and areal karst coefficient should not exceed 0.01% for suitable building sites. Building sites are considered to be suitable if sink holes' diameter is less than 3 meters. Depth of relief ruggedness should not exceed 50 meters per 1 km² for suitable building sites. There is no ideal slope gradient of karst relief with regard to construction development. Slight and significant gradient of slopes both create a big risk for construction development. The average gradients in the limits of 5 – 15° are the most acceptable for such construction activity. Southern and south-eastern exposures' slopes of the karst relief are the most optimal for construction development. There are such the most acceptable morphodynamic indexes in karst conditions: average annual intensity of sinkholes' formation is less than 0.01 unit/km²×year, average annual area of sinkholes' vulnerability is less than 1%, average annual sinkhole's volume growth is less than 0.01 m³/km²×year. Of course, ponors, poljes, sinkhole wells, caves are unsuitable for construction development among karst's morphoelements. Sink holes, moats, blind gullies, karst channels considerably complicate construction development. Limestone pavements slightly complicate land development. The absence of need in engineering protection or such engineering land development that requires only organization of rain outfalls' system, covering of karst breeds by layer of fat clay and measures against aggressive industrial and utility fluids is considered the simplest for construction development of karst territories.*

Tab. 1. *Engineering assessment of morphometric indexes for the purpose of construction*

Tab. 2. *Engineering assessment of morphodynamic indexes for the purpose of construction*

Tab. 3. *The influence of karst landforms on the construction development*

Tab. 4. *Engineering construction assessment of the karst territory*

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