THE MONITORING SYSTEM OF KARST TERRITORIES (FROM EXAMPLES OF PERM REGION)

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***Abstract**: the practice has shown that karst monitoring is the basis for effective development of karst territories, as well as for the choice of ways of anti-karst protection. The organization of monitoring or its elements under specially developed program is not only reasonable, but also necessary within the bounds of geotechnical monitoring in key areas, in districts of high responsibility and ecological risk.*

The basic kinds of operations aimed at development and creation of system of territorial and objective levels of karst monitoring, include:

– The analysis of spatial distribution and morphometric parameters of underground karst forms (cavities) and karst deformations of surface (dolines, collapses);

– Examination and analysis of structure and properties of karst rocks and overlapping depositions;

– Examination and analysis of elemental composition of underground waters and dynamics of underground waters.

All operations have been aimed at reception of following concrete results:

a) Exposure of a complex of parameters – a complex of objective parameters of system monitoring of compound, structure and condition of geologic environment describing an optimum combination of these parameters for occurrence and development of surface and underground karst forms;

b) Definition of quantitative parameters of complex marks and ranging of the revealed parametrical intervals of marks on a degree of their conformity to conditions of occurrence and development of a concrete underground karst cavity, occurrence of karst deformation on a concrete site of a surface of the ground;

c) Creation of a methodical complex of analytical processing of incoming information;

d) Creation of geoinformation models of development of karst process for areas and sites of development of sulphate, carbon-sulphatic and carbonate karst, including prognostic parameters defining a degree of karst hazard and stability of territory;

e) Development of the general requirements, ideologies and structures of informative system of a condition of karstified territories and creation of specialized software product for processing parameters of system monitoring, calculation of karst jeopardy and estimation of karst risks, as automated workplace – the basic module of information system.

Objects of researches to optimize principles of creation of systems of regional and territorial levels of monitoring were karstified rock masses combined in their radical part by a strata of gypsums and anhydrites (sulphate type of karst), or alternation of stratas of anhydrous gypsum and chalkstones (carbon-sulphatic type of karst), or a strata of chalkstones and dolomites (carbonate type of karst).

Initially territory of Perm Krai has been estimated from positions of occurrence of risks of losses in karstified territories.

The estimation of karst risk is carried out according to the technique of Institute of Geoecology of the Russian Academy of Science (Russia) adapted to the territory of Perm region. Karst physical and karst economic risks have been calculated. The karst economic risk contains two components: risk for industry and risk for agriculture. By results of the regional risk estimation conclusions on necessity of the organization of territorial monitoring for regions of high risks have been made.

Proceeding the definition accepted by us, most of the general problems of creation of basis of karst monitoring were specific blocks of carried out operations, namely:

karst monitoring (the part of lithologic monitoring) is the complex system, appealed to provide:

– Gathering, storage and updating of data considering condition and change of properties of the geohydrogeological environment, karst phenomena, underground and superficial forms of karst;

– The analysis of these data to estimate environmental condition and predict its changes;

– Diversified interpretation of received results of the analysis to accept operative or strategic decisions to decrease or eliminate the risk of complex development of karst territories, substantiate a network of observant posts, choose parameters and criterion intervals of these parameters.

During the execution of work, the author's complex of methods approved on various territorial objects of Perm region to estimate karst (especially urbanized territories) was applied. This combination of methods

of specialized mapping (cartographical 2 and 3 measured modelling) using GIS-TECHNOLOGIES with the subsequent exposure of mechanism of a spatial parity of karst forms and features of geologic, structurally-tectonic, hydro-geological, geomorphological structures of territory; methods of mathematical statistics (processing of numerical parameters), including graphic modelling – construction of diagrams and statistical tables, two-dimensional correlation analysis and unifactorial continuous analysis; methods of conceptual modelling. All graphic constructions were executed on the basis of specific databases created and constantly renewed by results of engineering-geological, hydro-geological, geomorphological, karst, speleological investigations and researches. As «guaranteed» drillings «on karst», methods of electroprospecting and seismic geophysics were applied.

Gathering and storage and updating of initial data has been organized in a separate direction of operations and consists of creation of the specialized territorial DB representing complex information on geologic-hydro-geological conditions of karst process development. The basic informative content of the created databases is presented below:

• Fixed superficial karst occurrence, their morph-metric features and spatial localization;

• Karst cavities exposed while drilling and zones of the raised dissociation of soils with their qualitative and quantitative characteristic;

• Geologic structure of territory expressed in the form of powers of quarternary, neogene-quarternary and radical karst depositions, their absolute marks and stratification depths;

• Hydrogeological structure of the territory, containing data about absolute marks, depths and time of opening of those or other water-bearing horizons, about the pressure of underground waters;

• Physic-mechanical and hydro-physical properties of subsoils, including basic engineering-geological and hydro-geological parameters of their condition and feature of behaviour under loading;

• The elemental composition of underground waters expressed in the content of the basic chemical components, rigidity, salinity, etc. properties of water, and their classification under current standards.

Thereafter databases were transformed into electronic databanks of results of engineering-geological and other investigations and researches in concrete territories.

The separate direction of operations makes the analysis of databases aimed to reveal mechanism of a spatial parity of parameters of condition of geologic-hydro-geological environment and karstified karst occurrence. Current direction includes four blocks of actions, namely:

– An expert (subjective) estimation of qualitative and quantitative data of geologic environment condition of investigated territory and exposure of optimum parameters of occurrence and development of karst phenomena;

– Cartographical modelling – the analysis of massif soils structure and creation of a complex of thematic maps and three-dimensional models on various parameters of its condition, with reflection of a spatial combination with fixed karst occurrence;

– Graphic modelling – an establishment of mechanism of quantitative distribution of karst forms depending on their accessory to sites with various parameters of a massif structure by constructing specialized diagrams;

– Mathematical modelling – a substantiation of available dependences between studied parameters and quantity of karst forms, as well as separation of criteria of hazard using the mathematical device.

Results of an expert estimation are made out in the form of corresponding tables.

Cartographical modelling assumes construction of thematic maps which complex allows to carry out the spatial analysis and comparison of those or other parameters within the limits of analyzed territory. As a rule, for territories of cities the cartographical complex on a 1:10 000 scale was created.

The content of cartographical complexes was supplemented depending on specificity of a geologic structure of territory, concrete karst situations or a concrete solvable problem. For some territories the cartographical complex included up to 50 names of thematic maps.

Aside from specialized cartographical models the maps constructed on traditionally used parameters of karst hazard are created.

Construction of cartographical models was accompanied by graphic modelling – an establishment of spatial laws of quantitative distribution of karst forms depending on their accessory to sites with various parameters of a structure of a massif by constructing specialized diagrams. Graphic models of variations of parameters (a spectrum of values), adapted in space (a site with a binding, a geologic structure – type of a section, lithologicaly a homogeneous strata, lithologic complex, separate attention to affinity of karst deformations, affinity of the deformed buildings) and in time (variability on years) as a result were under construction.

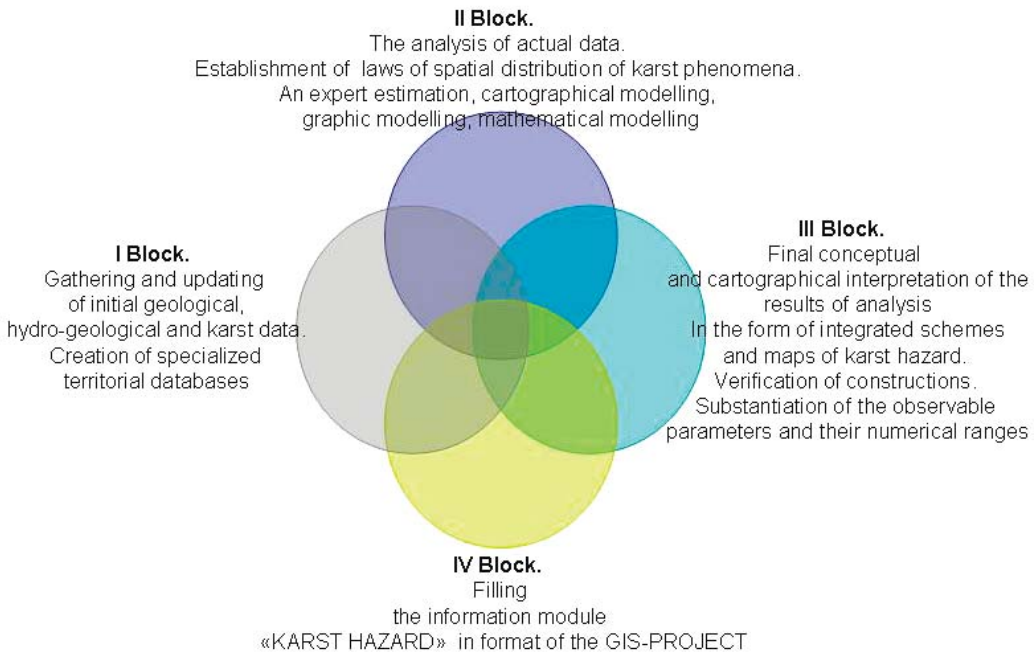

Fig. Basic functional elements of karst monitoring system

Mathematical modelling – a substantiation of available dependences between studied parameters and quantity of karst forms, as well as separation of criteria of hazard using the mathematical device is realized through a complex of mathematical parameters and design formulas to reveal a degree of karst hazard:

• The correlation analysis – definition of closeness of connection between areal distribution of territories with particular condition of geologic environment and a combination of karst forms within their limits;

• The unifactorial continuous analysis –exposure of influence of the factor of a geologic-hydro-geological structure of a strata on the karst activity represented by quantity of karst forms;

• Selection of the theoretical law of distribution for the description of observable empirical dependence between intervals of values of a parameter of a structure of a massif and quantity of karst occurrence;

• Calculation of total karst hazard according to all investigated parameters mark and statistically distributed methods.

As a result, on the basis of the developed mathematical model and algorithm of calculation of karst hazard estimation of the urbanized territories using two design methods of estimation – mark and statistically distributed method, the basic features of karstified territories structure are studied and their influence on activity of karst with complex use of parameters of a condition of geologic environment on five blocks is defined: a geologic structure, a structurally-tectonic constitution, hydro-geological conditions, karst forms, engineering-geological parameters (physic-mechanical, hydro-physical properties).

Logically the conclusion of work on creation of basis of karst monitoring system in Perm region, is creation of the informational module “Karst Hazard” executed in a format of the GIS-PROJECT, including all available fundamental, analytical and cartographical data about karst occurrence and properties of geologic space within the boundaries of administrative areas and the municipal formations, intended for operative reception of versatile information read out from all involved layers from any point interesting to the user.

The basic functional elements of karst monitoring system are presented in figure.