Requirements for engineering protection of structures and territories for the safe investment project implementation

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Abstract. The article is devoted to the problems of engineering protection of buildings, structures and territories, when organizing territory, formalising principles (conditions), in accordance with which management and construction solutions for engineering protection arrangement are admitted at the planning and design stages. An integrated approach to the engineering protection arrangement is formulated on the basis of these principles (conditions). The approach requires preparation of an engineering protection project, including general layouts, detailed and specified plans, to develop various project solutions, optimize the design process, assess the prevented damage, justify the investment and estimate the consolidated approximate cost.

1. Introduction
The prosperity of the majority of Russia’s population and successful development of the national economy are directly related to the cities and towns’ environment. More than half of Russia’s residents (64%) face with a shortage of public and business infrastructure within walking distance from home. The lack of trade, leisure-and-cultural infrastructure is typical for 70% of the territories of Russia’s residential areas, formed both in the Soviet period and current condition. More than half of the residents of medium and large cities in Russia face with low transport accessibility problems, traffic jams and shortage of car parks.

About 20% of the Russia’s residents live in cramped conditions and need more living space. A lack of parks, squares, low planting level near home, poor ecological situation, noise and atmospheric pollution are especially noted. As a consequence, formation of a high-quality urban environment should make a dent in the solution of the problems, which the majority of Russian residents face with every day.

Spatial development strategy of the Russian Federation for the period up to 2025, approved by the Russian Federation Government order dated 2.13.2019 No. 207-r, is developed to ensure sustainable and balanced spatial development of the Russian Federation, aimed at reducing interregional differences in the living standards of the population, accelerating the pace of economic growth and technological development, as well as ensuring the national security of the country.

As a consequence, formation of spatial development is acquiring a complex structure, covering the leading development areas (socio-economic, ecological, investment ones) [1-5].

Implementation of the main objectives of the national project "Housing and Urban Environment", which are to ensure an efficient land use, increase the level of housing construction, provide affordable housing, develop cities and towns in a holistic way, cardinaly increase the comfort level of the urban
environment, increase the level of constant reduction of unlivable housing accommodation, leads to the increase in building construction.

In this regard, an important component of the integrated (spatial) organization of the territory is an engineering protection of buildings and territories, ensuring infrastructure construction, reasonable placement of construction objects in the ecosystem while preserving its natural relationships, protection of constructed or under construction objects from hazardous natural influences, as well as protection of the population from the risk of possible consequences of introduction into the ecosystem as a result of disruption of natural processes during construction.

2. Methods and materials
The objective of the work is to formulate principles (conditions), based on the current standards and legal requirements, in accordance with which management and construction solutions for engineering protection arrangement are admitted at the planning and design stages.

The Urban Planning Code of the Russian Federation defines the concept “activities for sustainability of the territories”, according to which preparation and approval of documentation for the spatial planning of the capital construction objects for residential, industrial, public, business and other purposes and necessary for the functioning of such objects and ensuring the livelihoods of citizens communal, transport, social infrastructures, architectural and construction design, building construction, reconstruction of these objects are carried out in order to ensure the most efficient use of the territory.

Development of the territory planning projects is carried out to identify elements of the planning structure (district, microdistrict, quarter, common area, transport hub, linear facility, road network), set the boundaries of common and planned capital construction areas, characterize and prioritize the planned spatial development.

It should be noted, that the most important elements of the spatial planning project rationale are:

- a list of measures to protect the territory from natural and technogenic emergencies;
- a site plan, including vertical leveling, ground development and engineering protection of the territory.

Urban planning and technical solutions, taking into account conditions of safety and favorable human environment, limiting the negative impact of economic and other activities on the environment and ensuring the protection and rational allocation of natural resources, provide sustainability of a territory for the benefit of the people.

Modern design requirements take into account the assessment of the impact on the environment of the technogenic loads, but urban planning solutions, adopted without considering the dynamics of the territory properties, basing only on the social, urban planning, technical, economic and environmental requirements, lead to a contradiction with the natural-territorial resource [6-11].

A fairly common negative manifestation of the anthropogenic impact on the natural environment, that is widespread, durable and large scale, is flooding of residential areas. The main causes of flooding are: water table rise, lack of storm sewers in settlements, as well as uncontrolled landscape disruption, increasing urbanization and development, accompanied by an increase in the area of waterproof coatings, which cause the maximum flow in cities [12-14].

In addition to the above impacts, the territory development is influenced by natural hazards (NH) and unfavorable weather conditions (UWC).

For example, according to the Federal State Statistics Service from 2010 to 2018 dangerous hydrological phenomena and heavy rains, snowfalls, heavy hail occur more than one third of emergencies (33.73%) from all natural emergencies, that took place on the territory of the Russian Federation, and are 16.72% and 17.01% respectively, only large wildfires (28.85%), as well as frost and drought (19.53%) are less (they total 48.38%).

According to the data [13, 15-18] the territory of the Far Eastern, Southern Federal Districts, Irkutsk region had undergone the greatest impacts of moisture-saturated air masses. The regions with the greatest risk of heavy rainfalls, rains are concentrated in the areas, where high intensity of precipitation is combined with high density of population and economic entities.
Authors [19] report the results of the data analysis for the period from 1991 to 2017 on the changes in the frequency of dangerous and unfavorable hydrometeorological nature phenomena, distributed linearly with a clear increase in the frequency of phenomena as observations continue. The research notes an increasing trend of changes of dangerous hydrometeorological weather phenomena, affecting some sectors of the economy, as well as the population. A clear growing trend of damage to housing and utilities (including linear infrastructure) is noted among the considered sectors (agriculture, power industry, motor transport enterprises, housing and utilities).

Authors [20], applying the results of the data analysis on the natural hazards and unfavorable weather conditions, suggest indices for assessing the intensity of the impact on the social and economic systems of Russia. The first index shows the effect of recurrence of the NH and UWC in a specific area on the population density of this area. The second index shows the effect of average annual density of the NH and UWC on the gross regional product, thus being an assessment of the impact on the economic component.

In terms of the intensity of the impact of the NH and UWC on the socio-economic system the most unfavorable economic area is the North Caucasus region. Among the other Russian Federation’s subjects, where the probability of the hazardous impact on the population is great, Moscow and Moscow region, Samara region and the Republic of Tatarstan are noted.

An example of the tragic impact of the NH and UWC on the regional socio-economic system is the 2019-20 catastrophic flooding of settlements of the Irkutsk region, as a result of which 25 people died, more than 160 settlements and 10 000 houses, most of which cannot be reconstructed, were flooded. The economic damage is estimated at more than 35 billion rubles. Earlier in 2013 there were no less severe catastrophic floods in the Amur, Magadan regions, the Republic of Sakha (Yakutia), Primorsky and Khabarovsk regions, as well as in the Jewish Autonomous Region with a comparable economic damage.

The list of publications [21-26] should be noted, the authors of which shows, that anthropogenic impact enhances the negative effect of the unfavorable hydrological phenomena on the landslides and mudflows activity (for example, on the territory of Greater Sochi, right bank of the r. Volga near Ulyanovsk and Volgograd). Authors list the following main kinds of technogenic impacts: unauthorized storage of spoils on the slopes, cutting the slopes off during the construction of Olympic infrastructure, uncontrolled redistribution of the surface and underground runoff, development of the coastal (slope) territory. As a consequence, an increasing technogenic load on the slopes, low natural area stability (strength reduction of the ground) provoke soil deformations under the impact of hydrological phenomena, that leads to dangerous negative consequences for humans, economic facilities and the environment.

Thereby, the integrated development of territories depends on a large number of factors and requires taking into account:

- geographical, meteorological, seismic features of the Russia’s territory;
- terrain and hydrographic conditions (reservoir configuration);
- design natural restrictions (flooding areas or areas with possible uneven subsidence of the earth's surface or ground shear after underground mining);
- heterogeneity and diversity of climatic, landscape, geocryological, geological, hydrogeological conditions;
- technogenic impacts.

3. Results
Any construction (of a facility or group of facilities) is preceded by site preparation, aimed at ensuring the necessary conditions for quality and timely erection of buildings and structures and including ground development and engineering protection.

An engineering protection is a set of measures, ensuring favorable conditions for construction and operation of settlements, setting-out and erection of buildings, laying of streets, utilities and other facilities of urban planning with the obligatory consideration of environmental requirements.
Engineering protection of the residential territory includes the following measures:

- vertical leveling of the earth's surface, providing the most expedient and economical conditions for placing buildings and structures, drainage of rain and melt water to places of discharge into water treatment facilities and reservoirs;
- creation of the necessary longitudinal slope of the streets and roads for car and pedestrian traffic, as well as laying of the underground engineering networks of gravity sewerage and drainage;
- territory protection from flooding during high water, lowering the watertable in the areas where it is needed, drainage of wetlands and anti-landslip and anti-mudflow measures, watering and irrigation of the territory in arid regions;
- control of ravine formation and erosion;
- recovery of the areas disturbed by human activity (waste dumps, spent quarries etc.).

Dangerous processes and phenomena, which may develop on the future construction territory, formed under the above factors, proves the necessity for their detailed research, forecasting and assessing risks, as well as the development of engineering protection measures from hazardous processes for both territories and buildings and structures.

Engineering protection of the territory always was an integral part of the infrastructure construction works, and at the same time, relatively recently, it began to stand out as a distinct large-scale section of the project documentation, having the city- and object-forming value.

The necessity for engineering protection of the territory from natural emergencies, caused by hazardous natural processes and phenomena, is determined in accordance with the Urban Planning Code in terms of urban development of the Russian Federation’s subjects, cities and towns, taking into account the risk assessment of hazardous geological processes:

- in the general layout project, taking into account the variability of planning and technical solutions, for territories under development and reconstruction;
- in the construction, reconstruction and overhaul projects of buildings and structures, taking into account existing planning solutions and customer requirements, for built-up territories.

A complex of measures, preventing flooding of territories, should be developed when designing engineering protection of the territory against flooding according to the requirements for the functional use of this area and environmental protection or elimination of the negative effect of flooding.

The system of engineering protection against flooding should be geographically consolidated and should unite all local services of separate areas and objects. At the same time, it should be connected with general layouts and urban planning integrated plans.

Engineering protection measures should be designed comprehensively, taking into account possible deformations and impacts, the level of responsibility and cost of the protected areas, buildings and structures, their structural and operational characteristics.

Design of the urban and rural planning and development projects on the territory of the Russian Federation is carried out taking into account the requirements of SP 42.13330.2016. An engineering protection from floods, inundations, mudflows, landslips and avalanches should be included in the designing project, if necessary.

Surface water drainage should be carried out through closed rainwater sewerage with preliminary wastewater treatment. Application of the open sewerage facilities, which are ditches, cuvettes, trays, is permitted in the areas of one- and two-storey buildings and rural settlements, as well as in the parks with bridges or tubes at the intersection with streets, roads, driveways and sidewalks.

Lowering the watertable by closed drains in the area of capital construction should be provided in settlements with high watertable and wetlands.

 Territories of settlements, located on coastal areas, must be protected from wind setup, inundation during high water and from groundwater flooding by ground bedding (inwash) or embankment.

Maximum preservation of the forest, planting of trees and shrubs, slope terracing, strengthening the banks of mudflow rivers, construction of barrages and weirs in the mudflow formation zones, dams, changing the mudflow direction, and tail races on the fan are necessary to be provided in hazardous mudflow areas to protect existing buildings.
Streamlining of surface runoff, interception of groundwater flows, protection of the natural buttress of the landslide massif from destruction, increasing the stability of the slope by mechanical and physico-chemical means, slope terracing, planting green spaces are necessary to be provided in cities and towns, located in landslide-prone areas.

Anti-landslip measures should be carried out basing on the comprehensive study of geological and hydrogeological area conditions.

When planning and building settlements, environmental safety and public health protection requirements should be fulfilled, measures for nature protection, rational application and reproduction of natural resources, improving the environment should be provided for. The regulations and standards, establishing the quality of atmospheric air, water, soil, as well as level of noise, vibration, radiation and other factors of natural and technogenic origin, are necessary to be complied.

According to SP 104.13330.2016 area protection from flooding should be carried out by the following ways:

- area embankment from the river, reservoir or other water facility. An embankment plan of the protected territory should be selected on the basis of a technical and economic comparison of options, taking into account the requirements of standards;
- grade elevation of the completely, temporarily or partly flooded areas should be artificially raised to the flood-free elevation for the building development;
- accumulation, regulation, removal of surface waste and drainage waters from the completely or temporarily flooded and lowland disturbed areas. At the same time, facilities, regulating surface runoff in the areas, protected from flooding, should be designed taking into account the estimated surface water discharge on these territories (rain and melt water, temporary and permanent streams) and according to the class of the protective facility.

When designing engineering protection of the permafrost residential areas, warming effect of the settlement and city development, reduction of evaporation from the surface of built-up areas and roads, increased snowdrift extent, significant thawing and watering effect of the thermal services and utility collectors, water pipes and sewerage, causing bedding and foundation deformations, should be considered.

Engineering protection systems should be designed taking into account features of environmental, sanitary and hygienic and antiparasitic requirements for each natural zone, as well as data of territorial integrated environmental protection schemes.

To protect territories from flooding, the following facilities should be applied:

- drainage systems;
- groundwater barriers and cutoffs;
- vertical leveling of the territory with the control of surface runoff, cleaning open courses and other elements of natural drainage, regulation of the water level in reservoirs.

Protective structures in flooded areas should be selected depending on the flooding kind (permanent, seasonal, episodic one) and the amount of damage it cause.

A wide range of measures and technical means are applied for engineering protection of buildings, structures and territories from hazardous processes, they are:

- regulation and control of surface runoff;
- bank strengthening and coastal slope improvement;
- consolidation and improvement of ravine areas;
- barrage water protection systems: diversion ditches, head and coastal drainages, groundwater cutoffs;
- horizontal drain system;
- local protection systems – drainages (pipe, flat, wall), waterproofing, groundwater barriers and cutoffs;
- vertical wells and special drains, i.e. combined, vacuum, ventilation, pneumatic ones;
- landslip protection measures: changes of terrain and watercourses, drainage, redistribution and strengthening of soil, construction of protective and regulatory structures;
- strengthening structures, i.e. retaining walls (on a natural or pile foundation), including reinforces ground structures, piles and pillars, anchors and dowels, buttresses, gabions;
- catchers: walls, nets, shafts, trenches, shelves with curb walls, posts;
- protection galleries;
- agroforestry, protective coatings and soil consolidation;
- mudflow control facilities and measures: mudflow protection structures (mudflow check-dams), mud flow ducts (check canals, mudflow chutes), mudflow-directing structures, slope stabilizing structures (retaining walls, drainages), channel stabilizing structures (debris dams);
- filling (grouting) of karst sediments during karst-suffusion processes (when designing tunnels);
- a set of measures to localize possible deformations of the surrounding buildings along the tunnels, routes: structural measures (for example, soil consolidation) and technological measures (advanced temporary support for mining methods, mechanized shields with face protection and sealing of the construction gap, slurry wall method, soil stabilization and others);
- technical measures of engineering protection of the above the tunnel under construction territory: compensatory filling of water into the ground after water table depression, artificial thawing of soil after its freezing, prevention of ground and surface water pollution with harmful substances during chemical soil consolidation, grouting or compensation injection of stabilizing compounds into the soil and other methods.

4. Conclusions
Organization and design of engineering protection of buildings, structures and territories, as spatial planning development factor, are carried out both at the stage of formation of spatial planning documentation and during architectural design stage taking into account the requirements and regulations for the project documentation development. Engineering protection includes measures and structures, designed and implemented at the site preparation, erection and operation stages of the capital construction. Engineering protection ensures safe operation of objects, territory and stay of citizens from all kinds of natural and technogenic hazards and dangerous geological processes.

In this regard, engineering protection of buildings, structures and territories is an important part of the integrated (spatial) territory organization, it provides infrastructure construction, reasonable placement of construction objects in the ecosystem, preserving its natural relationships, protection of constructed or under construction objects from hazardous natural impacts, as well as protection of the population from the risk of possible consequences of introduction into the ecosystem as a result of disruption of natural processes during construction.

Thus, based on the foregoing, it may be concluded, that engineering protection of buildings, structures and territories has a significant meaning in the infrastructure construction implementation and requires an integrated approach. Wherein a specific engineering protection project should be designed, including general layouts, detailed and specified plans, to develop various project solutions, optimize the design process, assess the prevented damage, justify the investment and estimate the consolidated approximate cost.

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