Geological aspects of the suffusion processes development within the city agglomerations

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Abstract. Some examples of suffusion processes in the urbanized territories, connected with the increased technogenic load of soil of the bases of structures and facilities of transport infrastructure are considered. Examples of suffusion development at the facilities of road infrastructure and at the projects of hidrotechnical construction are given. The reasons and regularities of suffusion processes development are revealed. Formation of suffusion holes is demonstrated on the example of the facilities of the largest megalopolis of Russia (Moscow), the city of Volgograd and the federal Moscow-Simferopol highway. The lack of proper consideration of this promptly developing process annually results in significant economic and ecological damage. The generalizing conclusions are drawn and the qualitative recommendations on prevention of suffusion development and minimization of damage in case of suffusion processes are made.

1 Introduction

It is impossible to present the human's activity in the modern world of high technologies and total industrialization without the equipment. This process of change of natural complexes as the result of production activity of the person is known in the scientific literature as technocenez. Since the beginning of the 20th century the activity of technically armed humankind, became comparable to the geological forces, changing the image of Earth. As this process is connected with life and necessary activity of people (growth of population, development of technology and culture, receiving necessary means for maintenance of processes of metabolism of the human), it is inevitable [1].

In CR 116.13330.2012 [2] suffusion is defined as destruction and carrying out by a stream of underground waters of separate components and large mass of the disperse and hardpan detrital breeds including composing structural elements of rocky massifs. Now the suffusion danger to facilities of industrial and civil engineering is perceived is contradictory that finds reflection in the existing normative documents. On the one hand, the suffusion is included in the list of natural influences, dangerous for construction, along with such processes as landslides, the karst and processing of coast of reservoirs [3]; on the other hand, it is considered only in a paragenesis with them and is not recognized as independent geological process [4].

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As a result of it in practice of industrial-and-civil engineering sometimes "forget" about the possibility of emergence and development of a suffusion during construction and maintenance of designed facilities, if they are not located on the landslide dangerous slopes, in karst dangerous territories or in coastal zones of reservoirs. Nevertheless, in these cases the suffusion can develop for various reasons [5], and for the facilities of industrial and civil engineering the greatest danger is constituted by process of formation of suffusion cavities which can proceed in the disperse soil relating to quaternary deposits of various genetic types [6, 7, 8, 9,10, etc.].

Because the suffusion belongs to the processes extremely sensitive to different impacts on the geological environment, places of its distribution considerably coincide with places of the concentrated manifestation of such type of influences. There are no doubts, that in the modern, industrially developed world, the suffusion of technogenic character considerably dominates over natural. In territories of the large cities, the technogenic suffusion represents extremely widespread phenomenon where it is connected with operation of underground waters for water supply, with leaks from the water bearing communications, with various construction works and an underground urbanization [11]. The correlation dependence of intensity of development of suffusion danger in the megalopolis or its area from population, number of storeys and the size of buildings, saturation infrastructure facilities and the industrial enterprises is undoubted.

Suffusion processes are dated for separate hydraulic engineering constructions, thoroughfares, facilities of power and the industrial enterprises. During construction and maintenance of the above-stated facilities, factors, which initiate both suffusion and post-suffusion processes, (processes prepared or initiated by the suffusion), are actively generated. Technogenic influences of the first type are mainly connected with hydrotechnical facilities, and technogenic influences of the second type are connected with facilities of transport, industrial and power construction. In such cases not only soil of the bases, but also land structures, such as dams, embankments and dams and also slopes of dredging are exposed to suffusion and post-suffusion destruction [5].

The suffusion formation of holes in the urbanized territories belongs to extensive group of natural and technogenic geological processes. Existence of suffusion danger negatively influence conditions of activity of the human, because of deformations and complication or impossibility of full maintenance of engineering constructions and systems and also complex decline in quality of a resource of geological space and formation of zones of risk.

Recently cases of holes of soil have become frequent in the capital. In the formed suffusion cavities, cars and the construction equipment failed, in adjacent houses numerous cracks appeared. There were various destructions of infrastructure facilities. Suffusion cavities or holes arise in the most various places of the capital megalopolis, and residents of one and all areas, from sleeping to elite are subject to such risks. Studying of the matter has proved that the mechanical suffusion in the territory of the city of Moscow is the most striking example of the technogenic process, creating serious economic and environmental problems.

2 Materials and Methods

We will carry out the analysis of some examples:

1. Highway in Moscow.

In the morning on June 20, 2015 at 7-30 in the morning the hole, with the size 3,0 *4,5 m and more than 2,5 m deep was formed in the second row of inside of Moscow Circle Highway (MCH); just before this incident, a similar hole has been liquidated in the same place (Fig. 1). The numerous interviews, given by various services, which arrived to the place of accident, came down to the fact that the hole was formed because of the construction works,

connected with reconstruction of Kashirskoye Highway in this place. When studying the situation, the authors found out the true cause of the hole.

Fig. 1. Hole in the second row of inside of MCH. "The asphalt patch" of the previous hole is visible.

Fig. 2. Plentiful rainfall led to overflow of the existing collectors and to the increase in pressure head gradients (photo by I.A. Lavrusevich).

First, the emergence of the hole was preceded by plentiful rainfall, the led to overflow of the existing collectors and impossibility of short-term dumping of the collected water (fig. 2).

The second cause is the increase in the pressure head gradient in the place of the exit of the pipe of water disposal from regional shopping centre to the highway of the drain in MCH. The third, and the main cause of formation of the hole under the roadbed, was the low-quality joining of pipes of the water highway (Fig. 3). During the increase in water level, water, which took out sandy soil of the basis of an asphalt covering of the Moscow Circle highway at the expense of a pressure and whirl, began to come to leaky interface of drainage reinforced concrete pipes.

Fig. 3. Leaky joining of pipes of the water highway, the width of the opening is 56 mm.

2. The street in Alexeyevsky district, of the North-Eastern Administrative District of Moscow.

On February 3, 2016, in the first half of the day, on the 3rd Mytishchinskaya Street, near the house 5, the suffusion hole in the soil under asphalt, covering of 3*5 meters in size and about 3 meters deep was formed. Because of the formed cavity on the parking space, two parked cars have suffered. (Fig. 4).

Fig. 4. Hole on the 3rd Mytishchinskaya Street, near the house 5, the city of Moscow (photo from VK.COM).

In the same day, the emergency services, which have arrived to the scene, liquidated the suffusion hole by filling with sandy soil, with the subsequent consolidation and laying of a new asphalt covering. Clarification of circumstances of the incident was entrusted to competent authorities. However, during inspection of the scene and studying of the situation, authors proved, that emergence of the hole was also preceded by plentiful rainfall and was the main reason partial destructions of the basis of the sewer well that has in turn provoked flood and the subsequent carrying out by the turbulent stream of sandy soil from under the basis of an asphalt covering.

It is possible to continue this list, however, the negative operating experience of the section of the highway without suffusion danger is of the greatest interest.

Fig. 5. Partial destruction of the brick basis of the sewer well (photo by I.A. Lavrusevich).

3. Federal Highway M-2 "Crimea"

On the 326th kilometre of the section of the highway, water drainage was not provided because of an error of design and the wrong arrangement of drainage system. Two suffusion holes were the result created [12]. The time interval, which was required on formations of suffusion holes made 65 calendar days. The approximate volume of the taken-out soil was 2.2 metres³.

Fig. 6. Suffusion hole. The photo is made on 03.11.2015 (the volume of the taken-out soil is 2.2 m). (photo by I.A. Lavrusevich).

Diameter of the hole was 2.5 metres, up to 0.5 m deep. The hole was divided by a crossing point 0.4 meters wide. Formation of the crossing point is caused by consolidation of soil under the friable blanket. Lower on the slope, in 3 metres, the exit of the suffusion gully to the surface is visible. There is a carrying out of the soil, composing the road slope and the edge part of the roadbed in the form of a carrying out cone in 11 m from the suffusion holes [10].

Repeated inspection of the site 30 calendar days later, on April 11, 2015, revealed the increase in diameter of the suffusion hole up to 3 metres, and up to 0.8 metres in depth. The approximate total amount of the taken-out soil was 3.8 m³ (fig. 7).

Fig. 7. Suffusion hole. The photo was made on 04.11.2015 (the volume of the taken-out soil is 3.8 m³) (photo by I.A. Lavrusevich).

Absence of a complex of the timely actions, directed to elimination of this problem will lead to failure of the site of the federal highway.

For prevention of further development of process, it is possible to make the following recommendations:

1. Urgent recultivation of the slope of the highway struck with suffusion;
2. Consolidation of soil and the device of the waterproofing substrate;
3. Installation of the drainage system in the form of open combined reinforced concrete telescopic trays of trapezoidal cross section.

It is fair to note, that the variety of events of suffusion danger is not limited to the capital region and holes in soil of the roadbed.

4. Volga River Embankment in the city of Volgograd. Embankment of river port

The subject of the research is on the right bank of the Volga River in the centre of Volgograd (the embankment of the Volgograd river passenger port, in 300 m lower on the river flow) [13].

As for the geomorphological relation, it is the southern part of Volga Hills. Surface. The right bank is hypsometric higher than the left bank. The slope is reverted with reinforced concrete plates of 2,5*2,5 metres in size, between which joints are filled in with concrete, the slope corner is about 300, put by fine-grained sands of late Quaternary Period. In the spring of 2015, there was a hole of the plate of the covering, adjoining the lower grillage, dividing the strengthened slope and the bottomland of the Volga River (Fig. 1).

Fig. 8. Hole in the plate, adjoining the lower grillage differentiating the strengthened slope and floodplain of the Volga River (photo by I.A. Lavrusevich).

The suffusion cavity 1.5*0.8 metres large was found during survey of the hole in the plate and the adjacent territory, higher on the slope, behind the grillage crest (Fig. 9). The measured cavity depth was more than 2.3 m. The direction of carrying out of soil (down, under concrete plates of facing of the slope) is visible. Suffusion holes with diameter from 0.7 to 1.3 m are visible (to 0,4m) in the platform adjoining the top grillage, not blocked by asphalt and plates in the area of the section (Fig. 9).

Fig. 9. Suffusion hole in the top part of the slope. The direction of carrying out of soil towards the hole in the lower part of the slope. b - the Scheme of the section of the right bank of the Volga River, struck with suffusion. (photo by I.A. Lavrusovich).

The absence of civilized dumping of surplus of water when watering the platform was provoked by emergence and development of the suffusion passage. Development of the suffusion passage and the increased hydrodynamic pressure in the lower part of the slope caused carrying out of sandy soil and the subsequent hole in the plate (Fig. 10).

There is a danger of a hole of plates of facing of the slope as under them. Now suffusion cavities are already formed.

Fig. 10. Scheme of the section of the right bank of the Volga River, struck with suffusion.

During detailed survey of the plates of facing of the slope small deformations, caused by carrying out and loosening of soil from under the basis of plates are visible. Not acceptance of emergency measures in the shortest possible time, will lead to the shift of plates of the covering, the subsequent destruction of the slope and great financial costs of restoration.

3 Results

Two versions of the solution of the problem arisen are possible: they are passive and active solutions. Passive actions are carried out after suffusion appearance in the form of holes on a surface. The causes of a cavity are removed, its filling with the condensed soil or concrete mix is made. The active option represents the warning actions, interfering the suffusion development. The careful waterproofing of the water bearing communications and regime observations of their state as well as monitoring of water consumption, for timely detection of the uncontrollable consumption of water are included.

4 Conclusion

During the research of numerous holes in the urbanized territories, the following regularities were revealed:

- leaks from the water bearing communications were the cause of suffusion holes in 92% of cases;
- speed of suffusion process development, formation of cavities and the subsequent holes is often estimated by several days or even hours, depending on the volume and the speed of the movement of a stream and physicommechanical properties of soil s well;
- superficial forms of suffusion process are usually holes of roundish or ellipse form or extended along the created underpass;
- formation of suffusion holes in the urbanized territories, is usually followed by deformations of buildings and structures, motor transportation accidents and other emergencies.

References

1. A.A. Lavrusevich, O.V. Vdovina, I.A. Lavrusevich, *Geoecological Problems of the Present VI*, 18-22 (2014)
2. Russian Standard CR 116.13330.2012
3. *Construction Norms and Regulations 22-01-95, Geophysics of dangerous natural influences* (Moscow, Ministry of Construction, 1996)
4. Russian Standard CR 11-105-97
5. V.P. Homenko, *Regularities and forecast of suffusion processes* (Moscow, GEOS, 2003)
6. A.A. Lavrusevich, V.S. Krashenninikov, I.A. Lavrusevich, *Engineering geology* **3**, 48-58 (2012)
7. A.A. Lavrusevich, V.P. Homenko, *MGSU Bulletin* **10**, 213-220 (2012)
8. A.A. Lavrusevich, V.P. Homenko, I.A. Lavrusevich, *Industrial and civil engineering* **11**, 11-13 (2012)
9. A.A. Lavrusevich, F.F. Bryukhan, I.A. Lavrusevich, V.P. Homenko, *Industrial and civil engineering* **11**, 15-18 (2014)
10. A.A. Lavrusevich, *Investigation and protection of subsoil* **7**, 65-70 (2013)
11. F.V. Kotlov, *Anthropogenic geological processes and the phenomena in the territory of the city* (Moscow, Science, 1977)
12. I.A. Lavrusevich, *Engineering researches in construction XVIII*, 178-183 (2015)
13. T. Verminskaya, V. Zinatullin, A. Kuhta, I. Rubtsov, E. Chibisova, *Almanac of modern science and education* **7**, 37-39 (2008)