DOI:10.22337/2587-9618-2021-17-1-12-20

IMPLEMENTATION OF GEOTECHNICAL MONITORING ON OPEN-TYPE CARPARKS

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Abstract: Special aspects of the two-year (2018–2019) geotechnical monitoring for the parking buildings in use and their deformational behavior are presented in the article. In 2005, open-type car parks No. 1 and No. 2, fell into the influence zone of a two construction projects, a railway line construction, which connects Vnukovo-1 airport and Kievsky railway station in Moscow, and construction of the new Vnukovo-1 airport building.The article discusses tasks to ensure serviceability of existing buildings. Geotechnical monitoring during building operation allows for a timely documentationof negative processes occurring in building structures and to make prompt decisions to prevent emergencies. Geotechnical monitoring is carried out according to a specially developed program that includes a set of works using various methods. This allows us to assess the state of the supporting structures of the monitored buildings to ensure their strength, reliability, and safe operation.

Keywords: geotechnical monitoring building structures, safety, reliability, parking.

ОПЫТ ПРИМЕНЕНИЯ ГЕОТЕХНИЧЕСКОГО МОНИТОРИНГА НА ПАРКИНГАХ ОТКРЫТОГО ТИПА

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Аннотация: В данной статье рассмотрены особенности проведения двухлетнего (2018–2019 годы) геотехнического мониторинга за деформационным поведением эксплуатируемых зданий паркингов, представляющих собой автостоянки открытого типа №1 и №2, попавших в 2005 году в зону влияния строительства железнодорожной ветки, соединяющей аэропорт Внуково-1 и Киевский вокзал в Москве, и в зону влияния строительства нового здания аэропорта Внуково-1. В статье рассмотрены вопросы обеспечения эксплуатационной пригодности существующих зданий. Проведение геотехнического мониторинга в процессе эксплуатации позволяет вовремя зафиксировать негативные процессы, происходящие в строительных конструкциях и принять оперативные решения для предотвращения аварийных ситуаций. Геотехнический мониторинг проводится по специально разработанной программе включающей проведения комплекса работ с использованием различных методов. Это позволяет получить оценку состояния несущих конструкций наблюдаемых зданий для обеспечения их прочности, надежности и безопасной эксплуатации.

Ключевые слова: геотехнический мониторинг, безопасность, надежность, комплексные наблюдения

INTRODUCTION

Geotechnical monitoring is widely used to assess reliability and of operation of structural elements in a building, both during construction and during its service [1–11]. With its help it is possible to document negative processes occurring in building structures.This will allow us to make prompt decisions to prevent emergencies, and thereby to save significant material resources. Acomprehensive assessment of the structure state is done according to the monitoring results.Behavior of foundations, soil bases, and aboveground structures is predicted.In the event of negative processes development in structures, suggestions to repair and strengthen building structuresare developed.

In this article, we will focus on the results of geotechnical monitoring carried out by MGSU from 2018 to 2020. Geotechnical monitoring was done for the technical condition of building structures and base soils of the open-type parking lots.

During this period, operated parking buildings No. 1 and No. 2, located at the forecourt of the Vnukovo-1 airport, were under comprehensive observations of their deformation behavior.

MAIN PART

During construction period (2005) of the railway line connecting the Kievsky railway station in Moscow and the new building of Vnukovo-1 airport, as well as during the construction of the newest building of Vnukovo-1 airport, these car-parks fell into the influence zone of these objects under construction. To ensure the airport operation at that time, it was decided to preserve car-parks No. 1 and No. 2. (Fig.1,2).

Three-tier open-type parking buildings were built in 2004. The construction volume of each car-park is about 44.3 thousand m^3. The level of responsibility is normalin accordance with GOST 31937-2011 [19]. Car-parks have a framed structural diagram. Frame of the buildings is made of reinforced concrete columns with a section of 40x40cm. Column grid is 6 ÷ 7.2m x 5.1 ÷ 7.2m, with monolithic beam floor structures in the form of 20 cm thick slabs on beams with a rib section of 40 ÷ 30 cm. The structure of the covering is similar tothat of the floor structures [12–18]. The foundations under the columns are pedestal footing, made of monolithic reinforced concrete. The depth of the foundations is 2.9 m.

Geotechnical monitoring of the technical condition of car-parks' structures was done by MGSU from 2005 to 2012.

Inspections of the car-parks No. 1 and No. 2 buildings carried out in 2016 by OOO "RSP" and OOO "Tekhmeh", allowed to generally assess the state of building structures as "Operational to a limited extent".

In this regard, owner decided to conduct geotechnical monitoring to assess the changes in technical state of car-parks' structures over time,



Figure 1. Car-park No. 1. General view of the façade



Figure 2. Facade fragment of the Car-park No. 2.

to timely take appropriate measures to prevent negative consequences during their operation.

In April 2018, a corresponding agreement was signed with MGSU. Starting from May 2018 and to the present time, MGSU conducts geotechnical monitoring of car-parks No. 1 and No. 2, in accordance with the approved program.

Geotechnical monitoring program of the observed buildings includes assessment of load-bearing structures state to ensure their strength, reliability, and safe operation, based on a set of works using various methods. The monitoring program ensures following operations:

– geodetic monitoring with recordings of vertical displacements (settlements);

– object monitoring – a visual and instrumental surveying, which allows to assess the current technical condition of the main load-bearing structures of buildings;

– electrical contact dynamic sounding of soils. This type of sounding allows us to study the geological section at a point to a depth of 10–11 meters and to determine physical and mechanical properties of soils;

– seismic/acoustic sounding of foundations, to determine the depth of the foundation base, state of the foundation-soil contact, state of the foundation material and to detect large defects and cracks in the body of the foundation.

For the period from May 2018 to September 2019, four cycles of observations were carried out, excluding the initial one. The next fifth cycle was planned to be completed in March 2020, but due to the COVID 19 epidemic and repair works on car-parks, this monitoring cycle, in agreement with the owner, was postponed to October 2020.

The 1st and 2nd cycle of geodetic monitoring carried out at Car-park No. 1 showed that the total settlement of the building of car-park No. 1 does not exceed the maximum permissible value. The maximum sag on the marks installed in the middle of parking flooring structure span also does not exceed the maximum permissible value;

According to the results of the 1st and 2nd cycle of visual and instrumental surveying of the Car-park No. 1 bearing structures, an increase in the area of damage to floor slabs was noted.

Damage to floor slabs manifested itself in the form of wetting, efflorescence, swelling of the paint layer and traces of rebar corrosion on the lower surface of the slabs. There was also an increase in the area and the appearance of new areas of concrete protection layer destruction with exposure of reinforcement rebars. There was an increase in slab sag between dilatation joints, loss of the bearing capacity of the beam and flooring structure due to systematic soaking (Fig. 3,4).

Category of the technical condition of structures was assessed in accordance with GOST 31937-2011 [19], based on the results of 2nd cycle of geotechnical monitoring of car-park No. 1. In accordance with [19], for the period of the

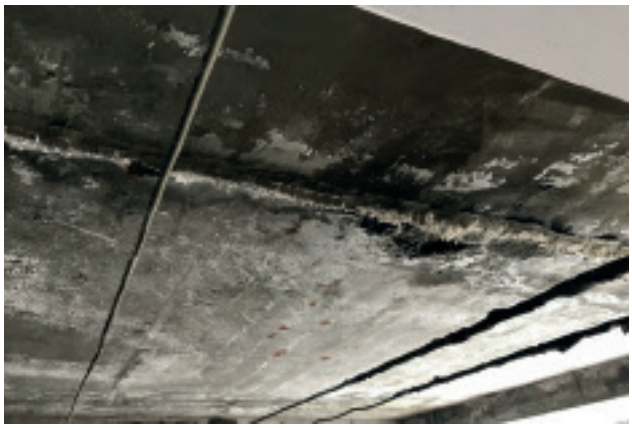


Figure 3. Car-park No. 1. Destruction of the concrete protective layer.



Figure 4. Car-park No. 1. Efflorescences on the flooring surface at the dilatation joints.

survey, flooring structures (slabs and crossbars), coverings, floors and roofing were in "operational to a limited extent" state. Technical state of the rest of the structures was confirmed as operational.

An analysis of all results of the car-park No. 1 surveys for the period of the 2nd monitoring cycle allowed us to draw conclusions about stability, at that time, of the technical state of foundations and base soils, however, trend to an increase in damage of the above-foundation building structures with a deterioration in their technical condition ntinued. The results of the survey showed that further safe operation of Car-park No. 1 is possible for the next 2 years (until February 2021). To extend the life of car-park No. 1 until 2024 it is necessary to carry out repair and restoration works: replacement of asphalt-concrete floors with waterproofing of the flooring structure; creation of dilatation joints in the new floor; restoration of a protective layer of concrete in places of destruction; injection of cracks with an opening width of more than 0.3-0.4 mm.



Figure 5. Car-park №1. Dilatation joints and flooring structure after repair.



Figure 6. Car-park №1. Reinforced flooring structure beam.

According to the assessment of damageability, performed according to the method [20], the residual operation time of the Car-park No. 1 structures was 2 years.

During the 3rd cycle of visual and instrumental survey for the period from February to June 2019 at Parking No. 1, as predicted in the 2nd cycle, there was an increase in the area of damage in the form of wetting, efflorescence, swelling of the paint layer and traces of corrosion of rebars on the bottom surface of the slabs. Area of concrete protective layer destruction with exposure of reinforcement rebars also increased, and appearance of the new areas with such damage was noted. There was an increase in slab sag between dilatation joints. The bearing capacity of the beams and floor slabs in some areas was completely exhausted due to systematic soaking. Noted damage was caused by the accumulation of melt and rainwater in the lowered area of the covering, which developed especially intensively in the winter-spring period.

In accordance with [19], at the time of the survey, category of the technical condition of the flooring structure area of the 2nd and 3rd floors was assessed to be in emergency state, and category of roofing, covering, flooring structures and floors was assessed as operational to a limited extent, technical state of the rest of the structures was assessed as operational.

Analysis of all survey results carried out within the 3rd cycle of geotechnical monitoring allowed to draw conclusions about stable technical condition of the foundations and soil bases. But, at the same time, the operated to a limited extent and emergency state of the flooring structures in certain areas and likelihood of further development of damage, and, as a consequence, the deterioration of the technical condition of the above-foundation building structures in the winter-spring period were confirmed.

It should be noted that in connection with the appearance of emergency areas, service life of the car-park No. 1 before the major repairs was exhausted.

Thus, as of June 2019, further safe operation of Car-park No. 1 without restrictions was possible not only after a complex of repair and restoration works indicated earlier, but also after taking measures to strengthen individual structures. At the end of June, car-park No. 1 was closed for repairs.

Due to the need to strengthen individual sections of the flooring structures, MGSU developed a project, according to which reinforcement was carried out.

At the time of the 4th cycle of geotechnical monitoring in September 2019, repair and restoration work on the building of Car-park No. 1 was almost completed.

During repair and restoration works, following repairs of following elements were carried out: protective layer of concrete in damaged areas; dilatation joints; metal mesh fencing; individual sections of flooring structures (Fig. 5, 6)

As a result of the repair and restoration work carried out at Car-park No. 1, previously identified defects and damages affecting the bearing capacity of building structures were eliminated. Technical condition of building structures and the building as a whole as of September 2019, according to GOST 31937-2011 [19], was assessed as corresponding to the norm.

2nd cycle of geotechnical monitoring at Car-park No. 2 and analysis of the obtained results testified to the stability, at that time, of the technical state of the foundations and soil bases, however, there was a trend to an increase in the damageability of the above-foundation building structures with a further deterioration in their technical condition. (Fig. 7,8)

Assessment of the technical state of Car-park No. 2 by the results of the geotechnical monitoring cycle showed that, in accordance with [19], columns, flooring structures, coverings, floors and roofings are in a operational to a limited extent condition. The rest of the structures are operational.

Damageability assessment carried out according to the method [20], showed that the residual operation time Car-park No. 2 structures is absent. In this regard, MGSU recommended to close the parking lot and carry out a complex of repair and restoration works with strengthening of individual structural units.

Based on the results of the 2nd cycle of geotechnical monitoring, Car-park No. 2 was closed by the ownerfor repair and restoration works.

By the time of the 3rd cycle (June 2019), repair works at Car-park No. 2 were completed. Based on the results of the monitoring, bearing and enclosing structures were brought into a



Figure 7. Car-park No. 2. Destruction of the plaster layer of the columns.



Figure 8. Car-park №2. Reinforcement rebar corrosion marks on the concrete surface

normative state. According to the assessment of damageability [6], it was found that further safe operation of Car-park No. 2 is possible until 2024. Residual operation time before major repair works as of June 2019 is 31 years.

During the 4th cycle of visual and instrumental survey in September 2019 no increment of existing and formation of new damages was found on the building of Car-park No. 2. It should be noted that as of September 2019, settlement values of the foundations of the Car-park No. 1 and No. 2 are within the measurement accuracy and do not cause concern.

CONCLUSIONS

Realized comprehensive geotechnical monitoringprogramon the state ofopen-type car parks'structural elementsover a two-year period allows us to draw the following conclusions:

– as part of geotechnical monitoring, it is necessary conduct complex, mutually complementary surveys. The combination of geodetic, surveying, geophysical and computational-analytical methods allow for timely detection and prevention of the possible emergencies in building structures at an early stage of their development;

– geotechnical monitoring during operational cycle for the buildings affected by the new construction several years ago, ensures safety and reliability of building structures

– as part of the monitoring, engineering proposals were developed to prevent and eliminate deviations exceeding permissible values.Implementation of thoseproposals was monitored;

– it was found that the highest intensity of damage to car parks' structural elementswas observed during the winter-spring period due to wetting, efflorescence, destruction of concrete protective layer, exposure and corrosion of rebars;

– assessed impact of damage to building structures on their reliability,discovered during geotechnical monitoring allowed to determine remaining lifetime for safe operation of car parks.

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