The strengthening and renewal of damaged reinforced concrete structures by pre-stressed fiber reinforced plastics

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ABSTRACT

The results of experimental studies of the operation of reinforced concrete structures with surface reinforcement of fiber reinforced plastics for various types of stress state under static and dynamic loads are presented. Methodologies have been developed for the restoration of damaged reinforced concrete structures by pre-stressed fiber reinforced plastics. Examples are given of restoring the operational suitability of various objects.

Keywords: soaking grounds, irregular settlements, multistory buildings, flattening, strengthening

1. INTRODUCTION

Heavy rainfall in the city of Almaty, which lasted for two months in 2016, caused significant uneven rainfall in multi-story residential buildings in the Algabas micro-district. This micro-district is built up with the same type of residential buildings, which are 9-storey buildings of a rectangular shape in plan, a cross-wall system with longitudinal and transverse load-bearing reinforced concrete walls and monolithic slabs supported on the contour. The outer walls are insulated with a mineral plate. The internal partitions are made of masonry from concrete blocks

Heavy precipitation caused uneven wall precipitation in a dozen residential buildings and reached 5-10 cm, in two buildings (spots 14 and 16), the wall skew reached 16 cm, and in one building on spot 26, in which the north-west corner of the building deviated from the vertical was 340 mm, and the top of the southwestern corner was 420 mm.

2. HEADING

Geomorphologically, the construction area is located within the erosion outlier. The alluvial-pluvial deposits of the Middle Quaternary age, represented by loam covered by a soil and plant layer, take part in the geological and lithological structure of the site. With intensive urban development of the territory, activation of clay karst processes is possible. To a depth of 16-20 meters developed highly porous loess-like loam, subsidence (the second type of subsidence, a subsidence of soils from external loads, possible subsidence from its own weight and size exceeds 5 cm). Ground water mainly at a depth of 12 m. the Absolute level of the mouth of the workings 752,6-760,9 m. Ehe land potentially flooded.

Loams from a depth of 0.8 m are light brown, subsiding, from solid to semi-solid consistency, macroporous; from a depth of 6.5-11 m loam of fluid-plastic and fluid consistency; and from a depth of 11-15 m from semi-solid to soft-plastic consistency.

According to the results of surveys in 2012, the groundwater level was at a depth of 12 m. The territory is potentially not flooded. Loams have the following physical and mechanical characteristics:

ρi = 1.76-2.15 g / cm3; ρd = 1.47 -1.84 g / cm3; ρs = 2.71 g / cm3; W = 0.182-0.276 cf .; WI = 0.270-0.289 cf .; Wp = 0.171-0.183 cf .; Jp = 0.1-0.106; JI = 0.20-1.0; ε = 0.47-
0.924; St = 0.6-1.0; CI = 28 (7) kPa; ϕI = 230 (160); E = 5.9 (1.2) MPa; (notation: ρ I is the natural density of the soil: ρd is the density of dry soil; ρs is the density of soil particles; W is the

natural humidity; WI is the moisture at the yield point; Wp is the moisture at the plasticity boundary; Jp is the plasticity index; JI is the yield index ; ε-coefficient of porosity; Sr-degree of moisture; CI-specific adhesion; ϕI-angle of internal friction; E-module of deformations; values in soils are shown in brackets for soaked soils).

Buildings on spots 14 and 16, respectively, have dimensions in terms of 21.6 x 11 m and 43.2 x 11 m. The buildings are interlocked and oriented north-south. The base plate of the building at spot 14 was 1.0 m higher than the base plate of the building at spot 16.A detailed examination of the condition of the supporting structures of the residential building on spot 16 revealed the following:

- the building foundation is made in the form of a flat reinforced concrete foundation slab with a thickness of 1000 mm protruding beyond the contour of the building by 1000 mm, for concrete preparation with a thickness of 100 mm and a soil cushion of gravel-sand mixture with a thickness of 1000 mm;

Fig. 1 - Cross section and facade of the building on Spot 16

- bearing external and internal reinforced concrete walls are made with a thickness of 200 mm;
- floor slabs and coatings are made with a thickness of 1600 mm:
- reinforcement and concrete strength in the supporting structures of buildings corresponds to the project;
- uneven settlement of the foundations did not cause additional damage to the load-bearing reinforced concrete structures.

Building restoration measures are provided for:

- ensuring the stability of the building on spot 14;
- restore the vertical position of the building on spot 16;
- Strengthen soils to prevent settlement of buildings during further operation.

The stable condition of the building on spot 14 is ensured by the arrangement of soil piles to a depth of 18.5 m from the ground, placing them at a width of 5-6 m from the side surface of the foundation slab. The piles were combined with a reinforced concrete grillage, which was brought under the foundation plate by 200 mm, ensuring reliable support of the latter. On the border of the foundation plates of the buildings on spots 14 and 16, a dividing screen was made to a depth of 6 m by drilling and drilling a screw with a diameter of 100 mm without excavation with a pitch of 500-800 mm.

The verticality of the building on spot 16 was restored by the local softening method, which was made by artificial excavation of loamy soil under an unpaved cushion at a depth of 5-7 m. The excavation was carried out vertical and deviated wells in increments of 2 m. The diameter of deviated wells is 156 mm, and the diameter of vertical wells is 500 mm.

The reinforcement of the bases was carried out by the device of bored piles with a diameter of 500 mm, a depth of 14-16 m, located in increments of 1.2 m.

The residential building on spot 26, which received the greatest skew of the building, is a two-drive section of a rectangular shape in size 43.2 x 11 m, consisting of 9 residential floors 3.0 m high, a basement floor 2.15 m high and a technical floor high 2.0 m. The structural design of the building is similar to the buildings described above on spots 14 and 16.

A pit about 2 m deep was dug along the western outer wall of the building, which turned out to be filled with water. Water was observed on a part of the basement floor (the pit was temporary and was dug up for laying communications).

Fig. 2 - Facade of the building on Spot 26

According to engineering geological surveys, four engineering geological elements have been identified under the building:

- a soil and plant layer of dark gray loam of solid consistency with a thickness of up to 3-3.5 m, with plant roots 0.2 m thick;
- loam from yellow to brownish-gray in color from a depth of 3-3.5 m is refractory, in the intervals of depths 11-16.5 m a soft-plastic consistency. Loams to a depth of 11-12 m are subsidence, below- (in water) non-subsidence.

Groundwater opened at a depth of 12-12.7 m.

Loams have the following physical and mechanical characteristics:

- subsidence ρI = 1.55 g / cm3; CI = 28 (7) kPa; ϕI = 270 (160); E = 8.1 (2.5) MPa;
- non-subsidence in the depth range from 9.1-13.5 m to 14.9-19 m ρI = 1.97 g / cm3; CI = (9) kPa; ϕI = (180); E = (7.6) MPa;
- non-subsiding, occurring below 14.9-19 m ρI = 1.7 g / cm3; CI = (25) kPa; ϕI = (180); E = (15.2) MPa;

(in parentheses are the characteristics of loams during soaking).

After the end of floods, the groundwater level was recorded at a depth of 7.5-7.9 m. An increase in soil moisture was established. The moisture content of loams to a depth of 4-6 m was 18–20%, and below a depth of 12–15 m, it was 25–28%. After soaking, the consistency of loams is determined from stiff to fluid.

The subsidence properties of soils appeared only in individual layers of loam.

Residential building on spot 26 is oriented in the north-south direction and received unacceptable deviations from the vertical. The deviation of the northwestern corner of the house was 340 mm, and the top of the southwestern corner was 420 mm. The eastern side of the building did not receive noticeable vertical deviations. The basement floor is inclined from the eastern longitudinal wall towards the western wall by 196-225 mm.

A detailed inspection of the condition of the supporting structures of the residential building on spot 26 revealed significant damage to the supporting reinforced concrete structures:

- the building foundation is made in the form of a flat reinforced concrete foundation slab with a thickness of 1000 mm protruding beyond the contour of the building by 1000 mm, for concrete preparation with a thickness of 100 mm and a soil cushion of gravel-sand mixture with a thickness of 1000 mm; the condition of the foundations is satisfactory;
- bearing external and internal reinforced concrete walls are made with a thickness of 200 mm; horizontal cracks were found in the transverse walls of the basement floor, spreading over the entire width of the building, with an opening width of 0.20-0.25 mm; such cracks exist in all transverse walls of above-ground floors, and the width of their opening is in the range of 0.05-0.20 mm;
- floor slabs and coverings are made with a thickness of 1600 mm: In floor slabs on all floors there are cracks with an opening width of 0.05-0.20 mm, and in the floors of the 8th and 9th, the crack opening width reaches 00.35-0.45 mm; in addition, the angle of the ninth floor floor slab is separated by a crack with an opening width of 0.8-0.95 mm;
- the walls of the stairwells and elevator shafts are dissected at the level of the staircases, dissected by horizontal cracks with an opening width of up to 0.35 mm:
- dynamic tests of the building showed that damage to the supporting structures from uneven settlement led to a decrease in the horizontal stiffness of the building in the transverse direction of the building by 50%, and in the longitudinal direction by 25%.

The restoration of the serviceability of the building on spot 26 included the restoration of the verticality of the building, as well as the strengthening of damaged load-bearing reinforced concrete structures of the building.

The verticality of the building is restored by the method of local soil softening.

To prevent gravel-sandy soil from sinking the soil cushion along the perimeter of the foundation slab, an 800 mm wide anti-filter screen was made by injection with vertical and inclined wells to the height of the gravel cushion. The injection was performed with a cement solution on sulfate-resistant cement with the addition of water glass in an amount of 25 kg per cubic meter of solution. A solution with a water / cement ratio of 1 / 10-1 / 3 was supplied with a pressure of 0.3-0.5 MPa.

To moisten the loam to a moisture content above Sr S 0.80, water was pumped through deviated wells. The decrease in the strength of the base soil was provided by an increase in its porosity. To do this, an artificial excavation of loamy soil was made below the soil cushion. Excavation by inclined and vertical wells. Inclined wells with a diameter of 156 mm were drilled to a depth of 3 meters, and vertical wells with a diameter of 500 mm were drilled to a depth of 5 m. The marks of the building were controlled by geodetic methods using control benchmarks located on the outer walls.

The marks of the building were controlled by geodetic methods using control benchmarks located on the outer walls. Monitoring the condition of the building was carried out for several months.

After vertical alignment of the building, reinforced damaged reinforced concrete structures of the building were reinforced. For this, surface reinforcement was applied by gluing composite fiber reinforced concrete onto concrete surfaces.

After vertical alignment of the building, reinforced damaged reinforced concrete structures of the building were reinforced. For this, surface reinforcement was applied by gluing composite fibro-reinforced fabric materials in the form of woven canvas based on bidirectional carbon fiber S&P C-Sheet T50/50 the Chemical Company BASF onto concrete surface.

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