Monitoring of stress-strain state of high-rise building by Fiber Optic Sensors

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Abstract

Tall buildings should be equipped with monitoring systems that monitor the technical condition of the building. Federal law N 384-FZ formulates this requirement. This paper describes a monitoring system based on fiber-optic sensors installed in the multifunctional complex "Monarch Center." This complex includes an office building, hotel and shopping center. Scientific and Production Company "Monitoring Center" has made this system of monitoring. The monitoring system consists of strain gauges and pressure. These sensors are certified and are commercially available.

Keywords: Monitoring, security, sensors, strain, pressure.

1 Formulation of the problem and solution

Office building is the responsible unit of the complex. The designers decided to install a monitoring system for this office building. The above-ground portion of the building has 38 floors and an underground portion consists of three floors. The designers decided to equip an office building monitoring system of 125 sensors. This decision was made in the analysis of geotechnical parameters of the soil, as well as the complex design of the building. The sensors are distributed as follows: 24 pressure transducer installed in the soil under the foundation, 21 strain gauges are installed in the basement and 80 strain gauges mounted in the vertical elements (pillars, columns). Sensors in the vertical elements are installed on four levels. The four levels include the "minus" 3rd floor, the "minus" 1st Floor, 3rd Floor, 18th floor. Schematics of the sensors are shown in Fig. 1 - 3. In Fig. 1 shows the location of the sensors with the index "Ф". This strain sensors that are installed in the upper and lower levels of the foundation. Strain sensors, "Ф" gives full details of the stress field in the longitudinal and transverse directions of the foundation.

Strain gauges, installation of which is carried in a vertical structure, indicated by the letter "B". Technology of the installation of these sensors has been developed taking into account the characteristics of high-rise construction. It was decided to install gauges on every control floor in the 10 of the most important structural points. The sensors were placed on the reinforcing rods, which are in the middle of each of the long sides of the pylon. As a result of this configuration information was obtained about the magnitude of mechanical stress and the load torque, which is experiencing this support. Monitoring of the stress-strain state of the building was divided into two stages: first stage was to gather information during the construction of a laptop computer. The second phase was organized in the mode of continuous monitoring during operation of the building. In the second stage, data were collected in a central control room.

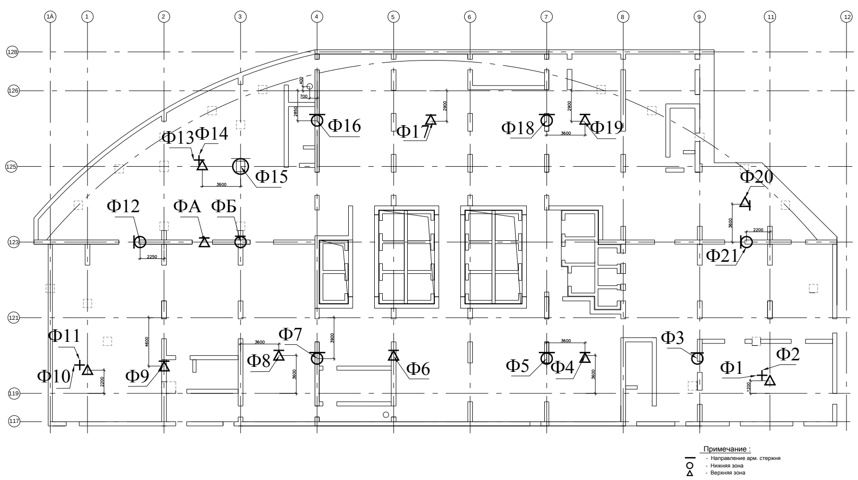


Figure 1. Scheme of the deformation sensors in the base plate. Indicated: Δ - upper zone, ○ - the lower zone, — - the direction of reinforcing bar.

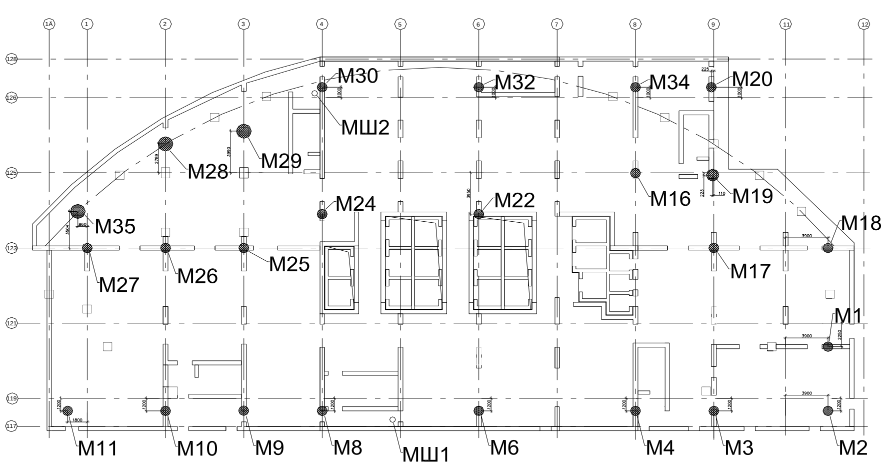
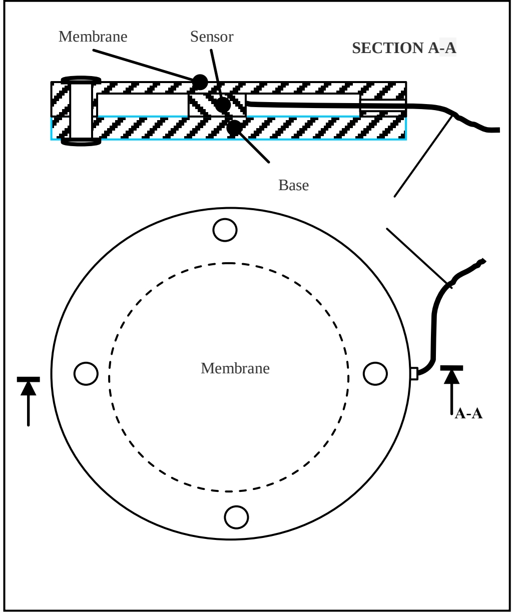


Figure 2. Scheme of the installation of pressure sensors on the bottom of the basement.

2 Technical characteristics of the monitoring system

The principles of fiber optic sensors are described in [3]. Schematically, the sensors with the major components are shown in Figure 3 and 4. The main technical characteristics of the sensor are shown in Tables 1-2. In Europe, the fiber-optic systems for monitoring buildings occupy a leading position.



Fiber optic sensors are accurate, and able to operate in extreme conditions in buildings [4,6]. Various mounting technology sensors have been developed and tested during the construction of the office building.

Figure 3. Fiber-optic pressure sensor.

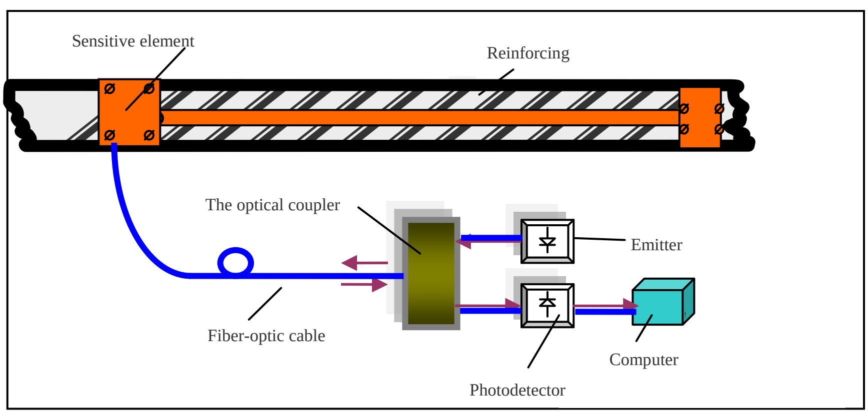


Figure 4. Fiber-optic strain sensor.

The main problems that were solved during the installation process, the following: installation of equipment in the absence of laboratory cleanliness, development of methods for protecting switching devices from damage during pouring of concrete at pylons.

Table 1. Technical characteristics of the fiber-optic pressure sensor

Measurement range (kg/cm2)	Resolution (kg/cm2)	Accuracy (%)	Operating temperature (°C)
$0 \div 10$	0,2	2	-20 to 60

Table 2. Technical characteristics of the fiber-optic strain gauges

Measurement range (relative deformation)	Resolution (με)	Accuracy (%)	Operating temperature (°C)
$0 \div 2{\cdot}10^{-2}$	10	1,5	-30 to 60

3 Mounting of sensors

As mentioned above, the monitoring system was formed from three main blocks of control (Fig. 5): pressure control on the base of the foundation, control of the strain of reinforcement in the foundation, control of the strain of reinforcement in the pylons.

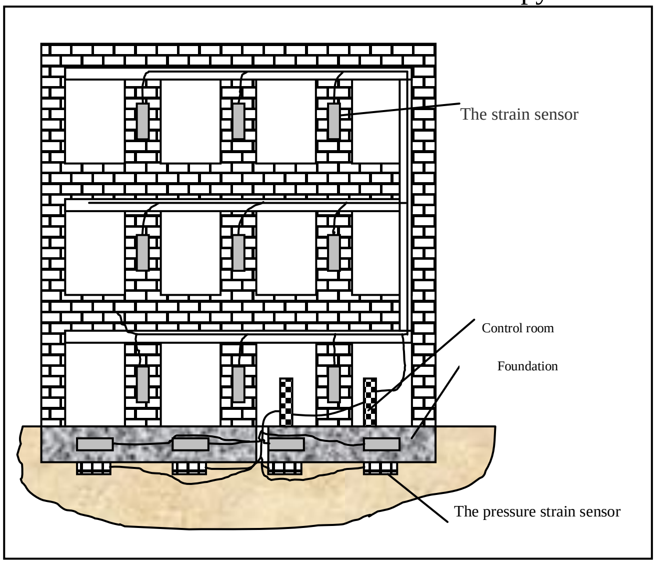


Figure.5 Arrangement of sensors.

Several methods have been developed to mount the sensors. Before installing the pressure sensors in the ground sprinkled sand and gravel layer with a thickness of 40 cm, and then poured the sand layer with a thickness of 10-15 cm, and the sensor was placed by diaphragm down. The cable from the sensor and the switching unit were fixed by 3-5 meters above the ground. This place is a temporary room for storage of switching units. Strain sensor in the base is firmly attached to the reinforcement, cable and breakout box are output to a temporary room for storage of switching units. Similarly, strain sensors are mounted in the pylons. Then, the temporary room is equipped with a computer. This room is the control station, where data are collected from the monitoring system.

4 The results of measurements

In Fig. 6 – 7 shows the measured distribution of pressure under the foundation. These measurements were recorded on 18-19 January 2007. According to these data the situation is satisfactory. Indications of the strain gauges in the foundation give good correlation with the calculations. The pressure distribution under the base (Fig. 8) gives information about the grounds during the period from 10.01.2011 to 31.122011. In general, according to the observations of the strain gauges and pressure during the construction period, there is a satisfactory correlation between design and actual parameters of the building.

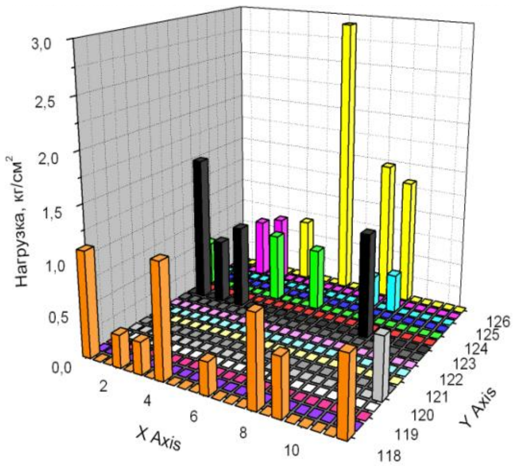


Figure 6. Diagram of the pressure distribution on the ground in the surveying axes.

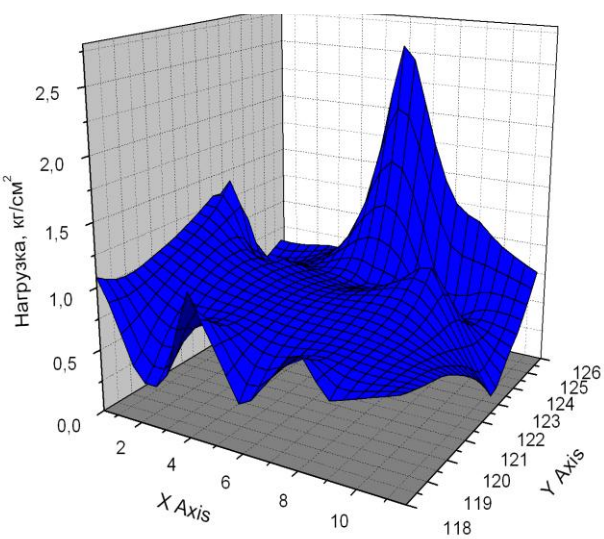


Figure 7. Spatial distribution of pressure on the ground in the surveying axes.

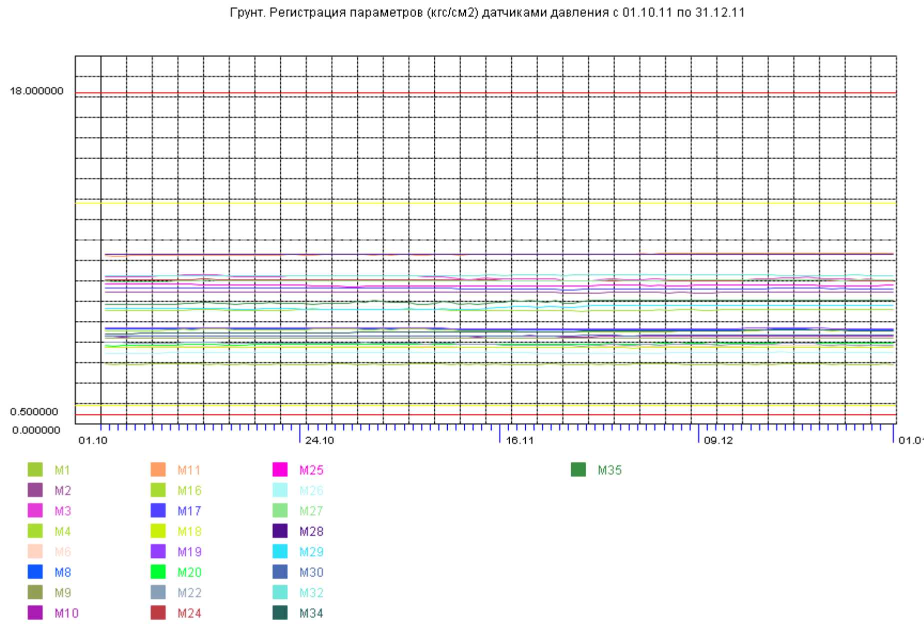


Figure 8. Indications of pressure sensors on the ground in 2011

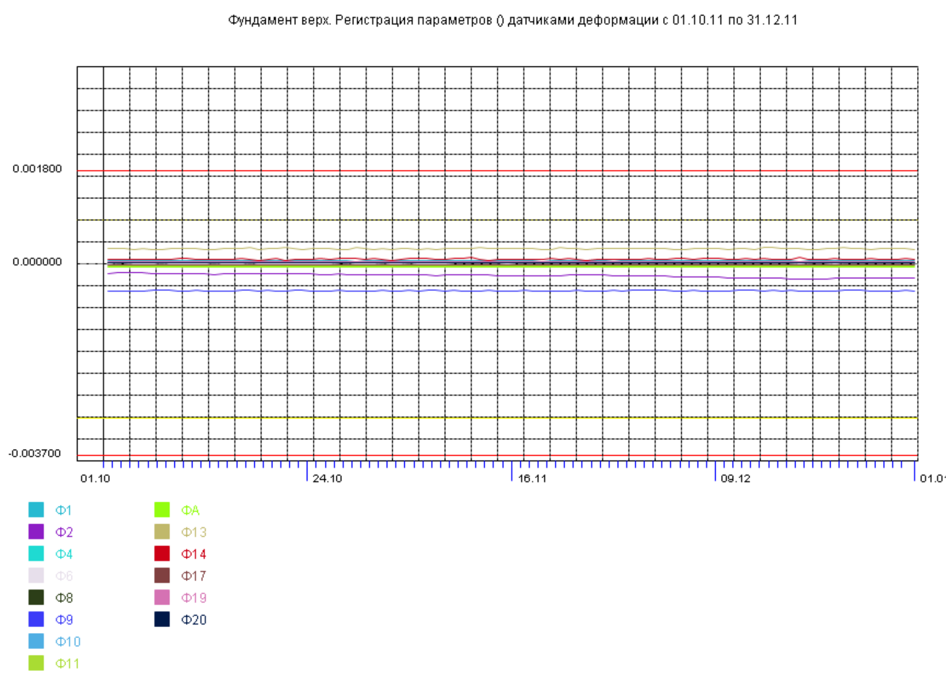


Figure 9. Indications of strain gauges in the basement in 2011.

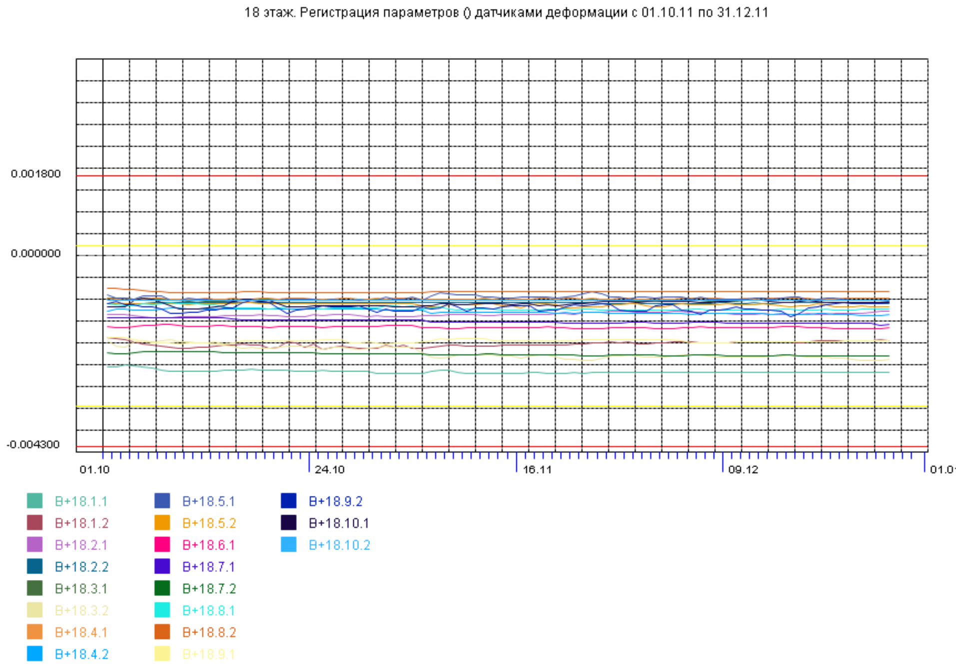


Figure 10. Indications strain gauges in the pylons in 2011.

5 Monitoring during operation. Perspectives

The results of observations in 2011 are shown in Fig. 9 - 10. These data indicate the stability of the stress-strain state of the design and safe operation. With the described monitoring system based on fiber-optic sensors can be solved many practical problems of modern construction. In particular, such systems can provide systematic information about the complex structure and properties of concrete. In addition, such systems allow solving many issues in the dialogue of the "designer-architect-builder." These systems provide the measured parameters, which should be considered in the development of new non-standard designs.

6 Conclusions

Described in this paper work was the first in a series of complex construction tasks. After an office building "Monarch Centre", such systems have been installed at several high-rise buildings in the "Moscow City", unique sports facilities, as well as in tunnels. Development of a monitoring system in Russia is very fast. Ensuring security is the main task in the building. This problem can be resolved without such a monitoring system.

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