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REDUCTION OF THE VIBRATIONS CAUSED BY TRANSPORT TO THE GENERAL POST-OFFICE OF MOSCOW

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ABSTRACT

After the completion of base reinforcement with cast-in-place piles, instrumental analysis of foundation vibration parameters was made on the basis of the vibration survey results. The analysis showed a considerable decrease in the level of vibrations caused by transport.

In major cities and megalopolises the vibratory load caused by public transport to foundation soils has dramatically increased and keeps on increasing. As a result of this process, sandy soils often get compacted and settle unevenly. Buildings undergo deformations, load-bearing structures get cracked which hampers their further normal operation. Such buildings are subject to special measures being developed to reduce transport-related vibrations.

Lack of free space, population density growth and state financing decrease result in the development of the territories located near subway tunnels and major motorways. Expensive anti-vibration systems are used there for vibratory impact reduction.

In such cases, foundation soil improvement methods may be used as a more economically efficient alternative. One of such methods implies soil reinforcement with crushed-stone piles with the help of pneumodrilts.

A pneumodrilt is a device having the following parameters: mass – from 90 to 500 kg, diameter - from 90 to 245 mm (depending upon brand), length - approximately 1.5 m, blow energy – 60-230 kJ/min for 8-12 m3/min compressor capacity. As a rule, pneumodrilts have the back stroke capacity.

Crushed-stone piles installation technology involves the following operations:

- vertical or inclined wells construction under foundation with the help of a pneumodrilt;

- filling of wells with small-sized crushed stone;

- compaction of crushed stone with the same pneumodrilt up to the density required;

- cementation of all crushed-stone piles at the final stage.

The aforesaid technology application to buildings 6 and 7 at Verkhnyaya Radischevskaya street, building 16 at Pokrovka street, Rot-Front plant building (during reconstruction), and the building of the Moscow General Post-Office (26, Myasnitskaya street) made it possible not only to increase design resistance of foundation soil by 1.5-2.5 times but also to considerably reduce vibratory impact:

by 10 times for the subway-related impact;

by 5 times for the road-transport-related impact.

Examination of the Moscow General Post-Office, one of the major monuments of architecture, showed that strip and pier rubble foundations at fill-up soil require reinforcement because of non-uniform deformations development. The research showed that the deformations were caused by unfavorable impact made by the vibrations caused by the subway tunnel located under the building and heavy traffic at Myasnitskaya street. Soil deterioration was also caused by process water damping it.

The project on base soil reinforcement under the foundations of walls and columns of the Moscow General Post-Office involved crushed-stone piles installation in inclined wells with the help of IP-4603 type pneumodrilt. This is a self-propelled machine which body driven into soil by a percussion mechanism makes a well having 130 mm in diameter. The friction between the machine's surface and the soil prevents back stroke of the machine's body. Reverse action device returns the body into the initial position. After pneumodrilt extraction, the well gets filled with estimated volume of sand mixed with crushed stone, then the pneumodrilt gets driven down to the bottom of the well again, pressing sand-and-crushed-stone mix into the walls of the well, thereby creating a compacted zone. The process repeats until the design compaction depth is reached. After that the well gets plugged with cement mortar. Compaction quality is controlled by soil penetration tests performed right under the bottom of the foundation.

This is a patented technology of base soil reinforcement under existing foundations (the RF Patent #2026926). The following volumes of inert materials are required in accordance with this patent (see the table below):

Table 1.

Dry soil density after foundation soil reinforcement, t/m^3	Unit consumption (m^3) of inert materials per 1 m^3 of compacted foundation soil for the following values of soil porosity ratio before compaction				
	0.8	0.9	1.0	1.1	1.2
1.5	0.02	0.05	0.08	0.10	0.12
1.6	0.06	0.09	0.12	0.14	0.16
1.7	0.10	0.13	0.15	0.18	0.20
1.8	0.14	0.17	0.19	0.22	0.24

In accordance with this methodology, a computer program has been developed and calculations have been made for the reinforcement of the soil as a reinforced base (1) for the foundations of Moscow General Post-Office in order to design foundation soil reinforcement with cast-in-place piles. The development of crushed-stone piles installation technology involved determination of the optimal number (***n***) of piles to be installed under the foundation as well as determination of the driving depth (***S***) for crushed-stone compaction in a well. It was discovered that ***S*** value should not be less than 1.5 m while ***n*** value – should not be less than 10. In this case the respective value of estimated resistance of reinforced base R_a sufficiently exceeds the average pressure under the bottom of the foundation equal to 250 kPa. Within the framework of the base reinforcement project, it was accepted that ***n***=12 which increased the estimated deformation module up to 21 MPa, so that additional foundation settlement would not exceed 2 cm. This is less than the permissible value for this building.

Since the Post-Office building is exposed to the vibrations caused by transport, the objective was set to examine its foundation instrumentally. This involved gauging transport-related vibrations before and after base reinforcement as well as measuring the vibrations caused by the technological impact of the pneumodrilt during wells construction and sand-and-crushed-stone mix compaction.

A set of apparatus, including SM-231 type three-channel vibrometer (vibrograph) of RFT brand, Germany, with an integrating amplifier and a power unit, KV-12 type piezoelectric accelerometers (operating frequency band – 1…250 Hz); H-115 oscillograph with ultraviolet registration of the processes examined. Complex calibration has been peformed for each channel at VEDS-400 vibration-testing machine within the frequency band that was twice wider than the transport-related vibrations spectrum. Vibration transducers were installed in three mutually perpendicular directions at foundation edges in specially dug exploration-pits.

The oscillations registered before the base reinforcement showed that their amplitude level did not exceed 1.5 mkm that is not dangerous for the load-carrying capacity of the building structures. The amplitudes of the oscillations caused by subway trains and road transport remained comparable, being predominantly horizontal, parallel to Myasnitskay street. The biggest amplitudes of the subway-related oscillations were observed in the high-frequency part of the spectrum (45-75 Hz) while the biggest amplitudes of the road-transport-related oscillations were specific for low-frequency vibrations (1.5…3.0 Hz).

Technological vibrations resulting from base reinforcement work were registered in several regimes of pneumodrilt operation: in the beginning of well construction and at various depths as well as in reverse regime during pneumodrilt extraction from a constructed well and also during repeat driving of the pneumodrilt back into the well for compaction of sand-and-crushed-stone mix in the process of cast-in-place pile construction. Oscillations frequency band turned to be narrow (25…30 Hz) and almost independent from pneumodrilt driving depth. As a rule, the biggest amplitudes were registered in the initial phase of driving. Their maximal values did not exceed 3.8 mkm for vertical components and 3.5 mkm for horizontal ones (which is perceptible within a radius of 3…4 m from the well), being great less than the permissible limits which is not dangerous for the load-carrying capacity of the foundations and the building structures.

Upon the completion of base reinforcement with cast-in-place piles, instrumental analysis of foundation vibration parameters was performed on the basis of the measurements provided by vibration transducers installed at the same point as they were at the first stage involving vibration exploration before the start of the reinforcement work. These measurements comparison showed a significant decrease in the level of transport-related oscillations. In particular, before the base reinforcement the maximal amplitude of the vertical components of oscillations reached 1.5 mkm while after the reinforcement it reached 0.25 mkm only, while the respective horizontal components of oscillations decreased by 6…10 times.

It is worth noting that the reinforcement work most considerably decreased high-frequency vibrations caused by subway trains. Before the base reinforcement maximal amplitudes of oscillations could be clearly observed within the range from 45 Hz to 75 Hz while after the reinforcement horizontal components with 0.15 mkm amplitudes could be observed within the range from 25 to 31 Hz only.

After the base reinforcement the maximal amplitudes of the vibrations caused by road transport were registered on 8…14 Hz frequencies that were slightly higher than before the reinforcement (1.5…3.0 Hz) but they did not exceed 0.25 mkm for vertical and 0.2 mkm for horizontal components which is several times less than the level of the respective amplitudes of the oscillations registered before the cast-in-place piles construction.

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