EFFECTIVE METHODS OF COMPACTION OF WATER-SATURATED SOILS BY BLASTING

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The writer demonstrates the effectiveness of compaction of water-saturated soils by the method of successive blasting of charges in comparison with the method of simultaneous blasting, as a result of rational application of the gravity wave formation phenomenon.

In accordance with the recommendations of [1], for compaction of soils by blasting, the explosive charges are arranged in plan on a square grid at a spacing equal to $2R_{ef}$ between each other (in which $R_{ef}$ is the radius of effective action of the blast, that is, the distance at which uniform compaction of the soil having the specified thickness is reached). In this connection, the charges of a subsequent blasting turn in the same compaction site are arranged in the intervals between the charges of the preceding turn at the same distance from each other.

Based on practical experience [2], preference has been given to simultaneous blasting of all charges in each turn, forming a closed outline in plan. The next blasting has been performed only after full stabilization of the settlements caused by blasting of the charges of the preceding turn. It was considered that the recommended blasting sequence contributed to the most effective disintegration of the structure and increase in the soil density on account of increase in the dynamic action intensity under application of the impact waves. Moreover, it was assumed that blasting of the subsequent charges in the loose soil could contribute only to some expansion of the zone of disintegration of the soil structure, but that it did not result in additional increase in the density.

The writer* has proposed a method for successive rather than simultaneous blasting of the charges in each turn, the advantages of which are based on consideration of both the well-known effect of development of seepage forces in the soil consolidation process under blasting and passage of the subsequent impact wave through the particles of the loose and unsta-bilized soil, and on the phenomenon of formation in the soil mass of gravity waves, first observed by O. A. Savinov [3]. Such waves must be formed under blasting of charges in the loose soil and they must contribute to increase in the compaction effectiveness. Moreover, successive blasting of the charges must contribute to repeated disintegration of the soil structure of the adjoining zones.

For experimental verification of the proposed method, use was made of two adjoining sites (Fig. 1) in dike No. 3 in the zone of construction of a flood protection system in St. Petersburg. The thickness of the layer of technical underwater fill of fine- and medium-grained sands was 7-7.5 m. At the blasting work time, the dike was filled to elevation plus 1.0-1.7 m (for mean elevations of plus 1.2 and 1.4 m, respectively, at the first and second sites); the groundwater level was at an elevation of approximately zero with respect to the ground surface.

As shown by static penetration test results (Fig. 2), all the sand placed under water was loose (the resistance to penetration of the device was basically about 2 MPa), which indicates need for their compaction.

Starting from the thickness of the layer to be compacted and the condition of ensuring camouflaged blasting, the explosive charge mass was determined as 6 kg for an embedment depth of 4.5-5.5 m. The distance between the charges in each turn was 10 m, and the number of blasting turns was four.

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In each site (see Fig. 1), 64 explosive charges were embedded. The charges were installed in a hollow driven by the vibrator of an embedded pipe equipped in its lower part with a plate which was subsequently pulled out together with the embedded pipe from the soil, this operation being carried out when the vibration driver was disconnected.

In the first site (Fig. 1a), simultaneous blasting of all the charges was performed, and in the second (Fig. 1b), successive blasting was applied. The density was controlled from the settlement of the ground surface after each blasting turn and by static penetration testing. Final penetration testing was performed 35 days after carrying out the blasting work. Moreover, for determination of the required minimal time interval between the blasting operations and the static penetration tests in the first site, additional penetration tests were carried out almost immediately after the blasts (the interval was about 1-2 h) and when one day had elapsed.

Thus, in the first site 16 charges were simultaneously blasted in each turn, assembled in a single scheme by means of safety fuse (SF). Intense exit of water in the form of gushing jets was observed. The charges of the next turn were blasted after ensuring completion of the exit of water (approximately after 30 min).

In the second site, each charge (in addition to those shown in Fig. 1b, which could not be blasted during the tests) was blasted separately by a successive "round" of the blasting operator of all the points of the turn. The interval between the blasts of the individual charges was 3-5 min (the time of approach to the place of installation of the charge, connection of the blasting network to the detonator, withdrawal of the blasting operator to a safe distance, and the blasting itself). It should be noted that in this case, it was not necessary to waste SF in the blasting network assembly. After blasting, there was intense pressing-out of water, which was made stronger during blasting of each successive charge, and the surface layer of soil was gradually transformed to an unstable state in which wavelike soil displacements were observed.

From Fig. 1 it is seen that the mean settlement in the site of successive blasting was 23 cm, whereas in the site of simultaneous blasting it was 21 cm. In this connection, the maximum settlements in the first site reached 34-36 cm (Fig. 1a), and in the second they reached 38-42 cm (Fig. 1b).

Even more convincing were the results of static penetration tests. Thus, after four turns in the site of simultaneous blasting (Fig. 2a), compaction of the loose underwater layer of sands to a mean density state from 0.4 to 0.6 was ensured. For successive blasting of the charges (Fig. 2b), the loose sands passed into a state of mean and dense constitution. The resistance to penetration of the device increased from 2 to 14-16 MPa, and the relative compaction exceeded 0.5-0.8.

The static penetration test results showed that attainment of the soil density and strength after one day as well as after 35 days did not exceed 5-10% (Fig. 2a).