STRENGTHENING MACHINE FOUNDATIONS

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Damage to machine foundations associated with the formation of cracks in them causes parts of the supported machines to undergo various deformations which were not allowed for in their design, and consequently to become disabled. Only correctly performed repairs of the foundation will enable the machinery operation to be continued without any restrictions.

Let us examine typical methods of strengthening such foundations using concrete examples from the practice of the Leningrad Branch of Fundamentproekt.

The most effective strengthening method is to construct reinforced-concrete yokes which embrace the whole foundation or its spalled-off part along the perimeter. As the result of concrete shrinkage, an inward squeezing of the damaged parts of the foundations occurs along the yoke perimeter during the hardening process. The effectiveness of the stressed yokes is determined, not only by virtue of the simple increase in section and the transfer of loadings from the existing to the new part of the foundation but also primarily through joining the cracked parts into a single whole and putting them back into service. The inward squeezing also provides a reliable joining of the existing foundation concrete and the new, strengthening concrete, into a unity performing as a single whole, and it is therefore essential during the design phase to provide for an increased hardening shrinkage of the concrete and to take measures against the formation of shrinkage cracks; and, in carrying out the work, to ensure the necessary inward squeezing.

An increase in the hardening shrinkage of concrete can be secured either by keeping the water/cement ratio constant but increasing the plasticity of the mix, i.e., the cement content compared with the design value; or, without changing the cement content, to raise the water/cement ratio to the maximum. However, in this case concrete strength is reduced and this requires the use of a high standard of cement. In order to increase the hardening shrinkage of concrete it is necessary to use rapid-hardening (quick-setting) cements and pozzolanic (trass) cement, and also to include hydraulic additives and hardening accelerators in the mix, in quantities recommended for their principal designation. This is also promoted by limestone and dense sandstone aggregates: During their slow absorption of water in the hardening process of the concrete, a practical reduction of the water/cement ratio, i.e., an increase in concrete strength, occurs.

The hardening shrinkage of concrete as a function of its content of cement and water can be calculated according to various, very approximate empirical formulas which were published, e.g., in [1], but the effects of the other ingredients can be determined experimentally only.

The yokes, being elements similar to framed foundations of machines, should be reinforced in accordance with Construction Norms and Regulations (SNIP) II-B.7-70 [2], as columns with working rods of 12-20 mm diam. out of steel Class A-H, spaced 150-200 mm apart; also, with stirrups in accordance to general rules, but out of reinforcement of periodic section.

Such reinforcement can even by itself resist the concrete shrinkage stresses, with a yoke side length of 5-6 m. For greater lengths the reinforcement should be checked by calculations according to formulas for thermal expansion [3]. Insofar as the concrete-hardening shrinkage is 0.3-0.6 mm/m, whereas thermal deformations amount to 0.01 mm/deg C, then for ordinary concrete the design can be made approximately for a temperature change of 50°C, and, where special measures are taken to increase shrinkage, for 100°C.

A volume change in the concrete can also occur as the result of a change in the moisture content; therefore, it is desirable that at the time of concreting the existing foundation be saturated.

However, an inward squeezing occurs only if hardening of the whole of the yoke concrete occurs simultaneously around the perimeter. Construction joints along the yoke length are permitted. Where it is im-
Fig. 1. Strengthening foundation of vertical compressor, with a reinforced-concrete yoke: a) of lower slab; b) of wall of above-ground part; 1) lower slab; 2) yoke; 3) wall; 4) cracks.

Fig. 2. Strengthening the foundation of two gyratory crushers with a reinforced-concrete yoke. 1) Foundation; 2) yoke; 3, 4) upper and lower gyratory crushers.

possible to carry out the concreting in a short time, the concrete is placed along the whole yoke perimeter, but to a part of its depth, i.e., a horizontal construction joint is provided.

Presented in Fig. 1 are strengthening systems by yokes around the lower slab and pedestals of a reinforced-concrete foundation of a vertical compressor in a chemical plant. The vertical out-of-balance 65-kN force of the compressor has a frequency of 300 rpm. All the reinforcement was effected with rods of Class A-II steel, spaced 250 mm apart. The lower yoke (equal in height to the slab thickness of 1.2 m) was reinforced with 20-mm-diam. rods spaced around the profile of its cross section, and with transverse stirrups of 10-mm diam. The upper yoke embraced the pedestal over its whole height (4.6 m), and was reinforced with vertical rods and closed double stirrups (inside and outside the yoke) of 16-mm diam., since, in this case, it is difficult to determine the "working" direction. All the corners of the yoke were reinforced as in framework corners. A notch was cut in from the surface, and the concrete impregnated with oil was totally removed, but there was no deliberate removal of the protective cover and exposure of the reinforcement. Normal concrete of standard type M 300 was used.

If cracks extend over a foundation of large dimensions, it is not possible to close them with a yoke without undertaking special measures. Presented in Fig. 2 is the reinforced-concrete foundation for two gyratory crushers arranged in a cascade series, which has operated for several years at the Mizur Ore-Dressing Plant.

The horizontal forces exerted by the upper crusher amount to 35 kN, those for the lower unit develop 81 kN; the frequencies are, respectively; 252 and 224 rpm. The foundation had a low concrete strength (the cube strength as actually measured ranged from 44 to 112 kgf/cm², compared to the design value of 150 kgf/cm²).

During the operation of the crushers, six lines of horizontal cracks developed along the construction joints of the foundation. It was decided firstly, in order to increase the strength of the concrete, to inject cement grout into the foundation, and then to strengthen it with a reinforced concrete yoke.

Some 460 holes 42 mm in diam. were drilled to a depth of 500 mm into the foundation walls. Pipes of 20-mm diam. and 200 mm long, spirally wound with 4-mm diam. wire welded thereon, were set in them with mortar of rapid-hardening cement type M-500. Grouting was effected with a slush pump.