CONSTRUCTION UNDER SPECIAL SOIL CONDITIONS

DETERMINATION OF DEFORMATIONS OF A BASE OF EXPANSIVE SOIL WITH CONSIDERATION OF ITS JOINT ACTION WITH THE STRUCTURE

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Buildings and structures erected on expansive soils often undergo deformations arising as a consequence of nonuniform lifting of the base following flooding. Observations have established [1] that such deformations appear mainly as a bend of the walls with the occurrence of tensile forces in the upper part, where cracks primarily form. It has also been established that cracks in walls appear at values of relative bending less than those permitted by SNiP II-B.1-62. For instance, in walls of single-story brick buildings cracks form at a relative bending equal to 0.0003-0.0005, whereas according to SNiP II-B.1-62 a relative bend equal to 0.001 is permitted for such buildings. Hence arises the need to determine the possible magnitude of uplift of the base and bending of building walls and, depending on them, to designate various engineering measures to be taken. These magnitudes can be obtained only by solving the problem of the joint deformation of the base and structure. However, the formula for determining the magnitude of uplift of the base given in SN 331-65 [2] was derived without consideration of the joint action of the base and structure and does not permit determination of the magnitude of uplift of the base under a strip foundation in the case of uneven flooding of the base soil, which usually occurs in reality.

An approximate solution of the problem of the joint deformation of the base and wall of a building following nonuniform flooding of the base is given below. We will consider the most unfavorable case from the viewpoint of deformations of the building, where the flooding source is under the middle of the wall. The tensile forces arise in the upper part of the wall, which has a smaller strength than the lower part (the latter acts together with the foundation).

The strip foundation and the wall resting on it are regarded as a beam on two supports, the role of which is performed by outside walls resting on a base not subjected to flooding.

The intensity of the distributed load caused by the pressure of the swelling soil on the beam is represented in the form of a power series

\[ \tilde{p} = z_0 + z_1 x^2 + z_2 x^4 + z_3 x^6 + \sum_{n=0}^{m} a_n x^{2n} \]

where \( \tilde{p} \) is the intensity of the distributed load, equal to \( pb \) (\( p \) is the swelling pressure on the lower surface of the foundation; \( b \) is the width of this surface); \( a_{2n} \) are coefficients determined while solving the problem; \( x \) is the distance from the middle of the beam to the point under consideration.

The differential equation of equilibrium of the beam (without consideration of the effect of shearing forces on displacements) has the form

\[ EI y'''' = \sum_{n=0}^{m} a_n x^{2n} - q = a + \sum_{n=1}^{m} a_{2n} x^{2n} \]

where \( EI \) is the flexural rigidity of the beam; \( q \) is the intensity of the distributed load transmitted by the structure to the base, equal to \( q = p_0 b \) (\( p_0 \) is the pressure transmitted to the soil).

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Integrating Eq. (2) and determining the constant of integration from the condition of equating the transverse force in the middle of the beam to zero, we obtain

\[ Q = EI y'' = 2 \sum_{n=1}^{\infty} \frac{\zeta_{2n}}{2n+1} \]

(3)

After integrating Eq. (3) and determining the constant of integration from the condition of equating the bending moment at the end of the beam to zero, we obtain the formula for calculating the bending moments

\[ M = EI y'' = M_0 + \frac{2}{2} \sum_{n=1}^{\infty} \frac{\zeta_{2n} x^{2(n+1)}}{(2n+1)(2n+1)} \]

(4)

where \( M_0 \) is the bending moment in the middle of the beam, equal to

\[ M_0 = \frac{\alpha l^2}{2} \sum_{n=1}^{\infty} \frac{\zeta_{2n} x^{2(n+1)}}{(2n+1)(2n+1)} \]

(5)

Integrating Eq. (4) twice and determining the constants of integration from the condition of equating the angle of tilt in the middle of the beam and the displacement of the end of the beam to zero, we obtain

\[ \frac{1}{EI} = \frac{5}{24} \sum_{n=1}^{\infty} \left( \frac{(2n+3)(2n+1)(2n+2)(2n+1)}{(2n+1)(2n+1)(2n+1)(2n+1)} \right) \]

(6)

where \( y_3 \) is the displacement in the middle of the beam, determined from the expression

\[ y_3 = \frac{1}{EI} \left( \frac{5}{24} \sum_{n=1}^{\infty} \frac{(2n+3)(2n+2)(2n+1)}{(2n+1)(2n+1)(2n+1)} \right) \]

(7)

We will consider that the end of the beam is not displaced if the transverse force in this section is balanced by the force \( G \) of uplift resistance of foundations [3], the base under which is not flooded, i.e.,

When

\[ \sum_{n=1}^{\infty} \frac{\zeta_{2n} x^{2(n+1)}}{2n+1} \leq G \]

(8)

If condition (8) is not fulfilled, a beam with free ends can be taken as the calculation scheme. In this case, when deriving the formulas for determining the displacements of the beam and the internal forces arising in it, the following conditions are used: when \( x = 0 \), \( y_1 = y_{III} = 0 \); when \( x = y_{II} = y_{III} = 0 \).

We investigate the dependence of the magnitude of uplift of the base under a strip foundation on the pressure transmitted to the soil. Swelling of the soil is prevented by a pressure equal to the sum of the natural pressure of the soil \( p_1 \) and the additional pressure \( p_2 \) transmitted by the foundation. The natural pressure is determined by the formula

\[ p_1 = \gamma(z+h) \]

(9)

where \( \gamma \) is the unit weight of the flooded expansive soil; \( h \) is the distance from the surface to the lower surface of the foundation; \( z \) is the distance from the lower surface of the foundation to the soil layer in question.

The additional pressure in the soil layers at a depth \( z \geq b \) can be determined by the formula proposed by I. A. Rozenfel'd [4]:

\[ p_2 = \frac{0.6 \rho_0 b}{z} \]

(10)

where \( \rho_0' \) is the additional pressure on the soil under the lower surface of the foundation, equal to \( \rho_0' = \)