Assessment of the pit influence area on the stress state foundations of the nearby buildings

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Abstract. The article solves the problem of the stress state of a heavy half-plane, weakened by a semicircular recess (modeling a foundation pit) and under the influence of a uniformly distributed load (modeling weight from a nearby building). The solution was obtained in a closed form. Visual calculations results in the form of diagrams and isolines of the total voltage are presented. The resulting solution made it possible to consider two practical problems. In the first statement, to assess the pit parameters’ influence on the components of the additional voltage in the corner zone of the distributed load. In the second statement, to assess the distance influence from the pit to the load on the additional voltage components. The analysis of the obtained solutions is carried out. The quantitative character of the change in the additional stress components, on which the dimensions of the influence zone of the construction pit and the existing buildings foundations’ deformation is of particular practical interest.

Introduction
It is often necessary to build the structures in a dense urban area in modern megacities [1,2]. In such cases, new construction has a significant impact on the foundations’ deformation of the nearby buildings, which can lead to a number of negative phenomena, such as unacceptable deformations and the buildings’ rolls [3,4]. Normative documents regulate the influence zone radius from 2 to 5 depths of the pit [5]. In order to ensure the reliable operation of the nearby buildings, it is necessary to study the question of determining the size of the influence zone of new construction and the nature of the change in additional stresses in the buildings’ foundations in more detail.

Main part
To analyze the pit influence zone on the existing buildings’ foundations stress state, the design scheme presented in Figure 1 was adopted. The analytical solution to this problem consists of the total solution of two problems in a linear formulation: the stress state of a heavy half-plane with a semicircular recess (modeling a foundation pit) and the stress state of a half-plane under a uniformly distributed width strip load 2a (simulating a load from the weight of a building). The approximation of the pit with a semicircular recess makes it possible to replace all its characteristic dimensions with one.


parameter - the depth of the pit $H$, which is also the radius of the recess $R$. The idea of this representation belongs to Z. G. Ter-Martirosyan [6].

![Graphical representation of the total voltage components for a heavy half-plane with a semicircular recess radius $R = 5$ m and the distributed load $P = 100$ kPa](image.png)

**Figure 1.** Design scheme for solving a common problem

The solution to the stress state problem of a heavy half-plane with a semicircular recess was obtained by A. Ya. Golovin. The stress components for this case are calculated by the formulas (1):

$$
\sigma_x = \gamma \cdot z \left[ 1 - R^2 \cdot \frac{x^2}{(x^2 + z^2)^2} \right]; \quad \sigma_z = \gamma \cdot z \left[ 1 - R^2 \cdot \frac{z^2}{(x^2 + z^2)^2} \right]; \quad \tau_{zx} = -\gamma \cdot z \cdot R^2 \cdot \frac{x z}{(x^2 + z^2)^2};
$$

(1)

The stress components for a half-plane under the uniformly distributed strip load action are calculated by the formulas (2) [7,8]:

$$
\sigma_x = P \frac{\pi}{a} \cdot \left[ \arctg \frac{a - x}{z} + \arctg \frac{a + x}{z} + \frac{2 \cdot a \cdot z \cdot ((x^2 - z^2) - a^2)}{(x^2 + z^2 - a^2)^2 + 4 \cdot a^2 \cdot z^2} \right];
$$

$$
\sigma_z = P \frac{\pi}{a} \cdot \left[ \arctg \frac{a - x}{z} + \arctg \frac{a + x}{z} - \frac{2 \cdot a \cdot z \cdot ((x^2 - z^2) - a^2)}{(x^2 + z^2 - a^2)^2 + 4 \cdot a^2 \cdot z^2} \right]; \quad (2)
$$

$$
\tau_{zx} = 4 \cdot P \frac{\pi}{a} \cdot \frac{a \cdot (l - x) \cdot z^2}{(x^2 + z^2)^2} - \gamma \cdot z \cdot R^2 \cdot \frac{x \cdot z}{(x^2 + z^2)^2}.
$$

In accordance with the superposition principle, the solution to the general problem is the total solution of the two tasks. Thus, taking into account the design scheme of Fig. 1, as a result of the solution, the following components of the total voltage are obtained (3):

$$
\sigma_x = P \frac{\pi}{a} \cdot \left\{ \arctg \frac{a - (l - x)}{z} + \arctg \frac{a + (l - x)}{z} + \frac{2 \cdot a \cdot z \cdot ((l - x)^2 - z^2 - a^2)}{((l - x)^2 + z^2 - a^2)^2 + 4 \cdot a^2 \cdot z^2} \right\} + \gamma \cdot z \left[ 1 - R^2 \cdot \frac{x^2}{(x^2 + z^2)^2} \right];
$$

$$
\sigma_z = P \frac{\pi}{a} \cdot \left\{ \arctg \frac{a - (l - x)}{z} - \arctg \frac{a + (l - x)}{z} - \frac{2 \cdot a \cdot z \cdot ((l - x)^2 - z^2 - a^2)}{((l - x)^2 + z^2 - a^2)^2 + 4 \cdot a^2 \cdot z^2} \right\} + \gamma \cdot z \left[ 1 - R^2 \cdot \frac{x^2}{(x^2 + z^2)^2} \right]; \quad (3)
$$

$$
\tau_{zx} = 4 \cdot P \frac{\pi}{a} \cdot \frac{a \cdot (l - x) \cdot z^2}{((l - x)^2 + z^2 - a^2)^2 + 4 \cdot a^2 \cdot z^2} - \gamma \cdot z \cdot R^2 \cdot \frac{x \cdot z}{(x^2 + z^2)^2}.
$$

A graphical representation of the total voltage components for a heavy half-plane with a semicircular recess radius $R = 5$ m and the distributed load $P = 100$ kPa is presented in Figure 2.
Figure 2. Plots of vertical $\sigma_z$ (a), horizontal $\sigma_x$ (b), tangent $\tau_{zx}$ (c) components of the total stress in the heavy half-plane with a semicircular recess and a locally distributed load for the horizontal axis $z = R$.

The isolines of the total stresses are presented in Figure 3.

Figure 3. The contours of the vertical $\sigma_z$ (a), horizontal $\sigma_x$ (b), tangent $\tau_{zx}$ (c) components of the total voltage.
To analyze the obtained solutions, two problems were considered. The solution of the first is made to assess the pit parameter $H(R)$ influence on the components of the additional and total stresses in the angular zone of the distributed load (vertically passing through the point - a). The solution to the second problem was obtained to assess the influence of the parameter $x_a$ (the distance from the pit edge to the distributed load) on the components of the additional and total voltages. The design schemes are presented in Figure 4.

![Design schemes of the first (a) and second (b) problems](image)

**Figure 4.** Design schemes of the first (a) and second (b) problems

As a result of the stresses redistribution during the development of the pit, the additional deformations occur at the load base. The strain values depend on the additional stress, which is the difference in the total stress before and after the pit’s excavation [9, 10]. Thus, in the course of solving these problems, the differences of the stress components in the heavy half-plane without a recess and with it at the angular zone base of the distributed load were analyzed.

Figure 5 presents the results of solving the additional voltage components’ problem in the form of graphs, taking into account the increase in the recess $R$ radius.
The nature of the change in the additional voltage components depending on the depth of the pit is close to a parabolic form. The foundation pit has the greatest influence on the horizontal stress component, less on the tangent and the least impact on the vertical component of the additional stress.

For the second task, Figure 6 shows the results of its solution in the form of graphs of the stress components' differences in the heavy half-plane without a recess and with it for the angular load zone with increasing the dimensionless parameter \( x_\alpha/H(R) \) (\( x_\alpha \) – is the distance from the edge of the pit to the distributed load).

A graph of the distance \( x_\alpha \) effect on the averaged additional voltage components at the base of the building at \( z < H(R) \) is presented in Figure 7. It is significant that the qualitative picture of the obtained dependence practically does not change when the absolute depth of the pit changes.
Figure 7. Distance effect $x_a$ on the additional voltage components in (%). For 100%, the effect is taken at $x_a = 0$

The solutions analysis showed that the change nature in the additional voltage components from the distance between the pit and the load ($x_a$) has a hyperbolic appearance. The foundation pit has the greatest influence on the horizontal component of the stress, less on the tangent and the least impact on the vertical component of the additional stress. For different voltage components, a decrease with different intensities occurs, but at the distance $x_a = 5H(R)$ for all the additional voltage components the influence is already insignificant for all the additional voltage components’ influence is already insignificant.

Summary
In conclusion, we can conclude that the parameters of the pit have a maximum effect on the horizontal component of the additional voltage that occurs at the distributed load base, simulating the weight of the existing building.

Thus, additional deformations at the base of buildings located in the immediate vicinity of the construction pit (arranged without building envelopes) should be predicted taking into account not only the vertical, but also the horizontal additional stress components. Moreover, the joint venture position on the construction pit influence zone is confirmed. So, if the distance from the edge of the pit to a nearby building exceeds five depths of the pit, its effect on the stress-strain state of the building base is insignificant and can be neglected.

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