Soil Anisotropicity in Modern Methods of Ground Bases Calculating

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Abstract. Calculation sequence of soil bases for deformations, taking into account their deformation anisotropy provided in the article. The calculations were performed by the finite element method using the mathematical planning method of the experiment. After determining the deformation anisotropy index of the soil, it was established the possibility to use the numerical experiment results within the tables of the soil anisotropy coefficients of influence, to calculate the soil base sediment and layers of different thicknesses using a currently existing methods, taking into account their deformation anisotropy. It was revealed that the deformation anisotropy nature of the soils’ studied types is different: for plastic sandy loam the indicator was $\alpha \leq 1$; for loess like sandy loams and loams, as a rule, $\alpha > 1$; for sands of medium density and dense, tested under compression was $\alpha < 1$. Together with an increase in the compressive load, a value increase, and with an increase in $\alpha$, the foundation sediments’ values increase. Taking into account the soils’ natural anisotropy makes it possible to more reasonably assign the sizes of the foundations soles and determine their settlement, and in some cases to obtain a noticeable economic effect.

1. Introduction

The task to develop a reliable apparatus for calculating soil bases is becoming particularly relevant at the present time. Available data on the stress-strain state (SSS) of soil bases mainly confirm the provisions of calculation methods set forth in BN 22.13330.2011 “Foundations of buildings and structures. The updated version of BNR 2.02.01—83 *”[1].

In some cases, there is a need to adjust standard methods for calculating the precipitation of soil foundations. An important issue in SSS study is the consideration of deformation anisotropy in soil masses calculation, which is recommended to take into account modern regulatory documents for the soil bases calculation [1]. It should be noted that the works of many authors [2-6], are devoted to the study of deformation anisotropy, both of experimental and theoretical, including computing [8]. The successful this problem solution is to develop mechanisms for adjusting the method for calculating foundation sediments, based on the use of the linearly deformable half-space scheme according to BR 22.13330.2016 “Foundations of buildings and structures. Updated version of BCR 2.02.01-83 ”[1], which has not been done yet.

2. Materials and methods

The algorithm for taking into account deformation anisotropy in soil foundation calculations, developed by the authors, consists of four main stages. At the first stage (preparatory), soil samples are
taken from the monolith or directly at the construction site in two mutually perpendicular directions: perpendicular and parallel to the bedding (Figure 1).

![Figure 1](image_url)

**Figure 1.** Soil sampling scheme. a - the vertical position of the rings; b – side.

Tests of samples are carried out according to existing standard methods at the second stage (experimental) in the laboratory. The deformations of the selected soil samples in the vertical and horizontal directions can be determined under compression conditions; in the Hydroproject system seals or in a triaxial compression device with independent regulation of the main stresses’ variable values (PTM of A. Kryzhanovsky system) under conditions of plane deformation and equal principal stresses \( \sigma_1 = \sigma_2 = \sigma_3 \), acting in the plane of the samples deformation. Soils must be compacted either by vibration or manual tamping before the experiment starts.

The deformation anisotropy degree of soils can be estimated by comparing the deformation values in two mutually perpendicular horizontal directions for the soils, studied under hydrostatic stress state of the samples, i.e., under the action of principal stresses \( \sigma_1 = \sigma_2 = \sigma_3 \). It is possible to assess the deformation anisotropy degree of soils by the anisotropy index \( \alpha = s_x/s_y = \varepsilon_x/\varepsilon_y \); where \( s_x, s_y, \varepsilon_x \) and \( \varepsilon_y \) are the absolute and relative deformations in the vertical and horizontal directions, respectively, analyzing the obtained results. This estimate is made with respect to \( s_x/s_y \) (in mutually perpendicular horizontal directions \( x \) and \( y \)) for the soils under hydrostatic stress conditions.

\( \alpha \) anisotropy of some types of studied soil are shown in table 1, and the \( \alpha \) values varied from 0.5 to 2.1, i.e. are practically significant. The sand and clay soils studies expanded the area of soils with established deformation anisotropy. Clay soils of Novosibirsk was characterized by values \( \alpha = 1.43 \) (loam) and \( \alpha = 1.24 \) (sandy loam) previously studied by V.P. Pisanenko [7]. From the obtained results’ analysis, we can conclude that the deformation anisotropy nature of the soils’ studied types is different: the indicator is \( \alpha \leq 1 \) for plastic sandy loam; as a rule, for loesslike sandy loams and loams is \( \alpha < 1 \); for medium density and dense sands tested under compression is \( \alpha < 1 \), and for dense sand under hydrostatic stress conditions is \( \alpha > 1 \), and \( \alpha < 1 \) is for dense sand.

\( \alpha \) values increase as the compressive load increases. The character of anisotropy does not change within an increase in the level of stresses under conditions of plane deformation and hydrostatic compression of dense sand by medium density. Under conditions of plane deformation, the \( \alpha \) index is less than under hydrostatic compression. Indicators \( \alpha \) of medium-density sand in these conditions exceed unity, and of dense sand is less than the unity [9].

The degree of deformation anisotropy can be estimated not only by the ratio of soil samples’ deformations in orthogonal directions, but also by comparing the values of deformation module in two
mutually perpendicular directions [10] \( \alpha = E_z/E_x \), taking into account different values of Poisson coefficients (lateral expansion coefficients of the soil); where \( E_x \) and \( E_z \) are the deformation module in the vertical and horizontal directions (\( \alpha \) is hereinafter, the anisotropy indices).

Numerical studies of the anisotropic soil bases SSS [11] are carried out on computers (on various software systems based on the ideas of the finite element method) at the third stage (numerical experiment), using mathematical design method of the experiment. In this case, a continuous model, linearly deformable, homogeneous, anisotropic medium with a transversely isotropic nature of anisotropy is considered.

**Table 1.** Anisotropy indices of the studied soils (sandy loam and sand), calculated from the averaged values of the samples deformations.

| Soil                        | Values \( \alpha = s_z / s_x \) at stress \( \sigma_x = \sigma_1 \), MPa | \( \alpha_{\text{average}} \) (0.05-0.30) |
|-----------------------------|---------------------------------------------------------------|-------------------------------------|
| Sandy loam fluid           | 1.04 1.07 1.06 1.05 1.02 0.98 1.04                           | -                                   |
| Sandy loam plastic         | 0.50 0.65 0.70 0.71 0.81 0.83 0.7                             | -                                   |
| Sandy loam plastic (flat deformation \( \sigma_1 \) = \( \sigma_3 \)) | 0.57 0.69 0.74 0.69 — — 0.67                                 | -                                   |
| Sandy loam plas            | 1.65 1.43 1.47 1.60 1.54 1.43 1.53                            | -                                   |
| Sandy loam solid           | 2.15 2.27 2.35 2.34 1.92 1.82 2.1                             | -                                   |
| Light loam dusty semi-solid | 1.60 1.37 1.32 1.39 1.48 1.48 1.4                             | -                                   |
| Sand is dense              | 0.58 0.65 0.71 0.78 0.86 0.88 0.74                           | -                                   |
| Sand of medium density     | 0.75 0.90 0.92 0.95 0.97 0.98 0.91                           | -                                   |
| Sand of medium density (\( \sigma_1 = \sigma_3 \)) | 0.10 0.20 0.30 0.40 0.50 0.60 (0.10-0.60)                     | -                                   |
| Sand of medium density (\( \sigma_1 = \sigma_2 = \sigma_3 \)) | 1.30 1.36 1.43 1.50 1.42 1.41 1.36                           | -                                   |
| Sand is dense (\( \sigma_1 = \sigma_3 \)) | 1.15 1.34 1.44 1.39 1.44 1.34 1.32                           | -                                   |
| Sand is dense              | 0.49 0.57 0.66 0.62 0.67 0.69 0.58                           | -                                   |
| Sand of air dry, dense     | 0.70 0.50 0.52 0.50 0.48 0.48 0.52                           | -                                   |

An anisotropic soil base model was used in the calculations, described by the parameters \( E_x, Ez, vzx, vyx, Gxz \).

Hooke’s law for an anisotropic medium under conditions of plane deformation is represented as:

\[
\varepsilon_x = \frac{\sigma_x}{E_x} \cdot \left( 1 - \frac{E_z}{E_x} \nu_{zx} \right) - \frac{\nu_{zx} \sigma_x}{E_x} \cdot \left( 1 + \nu_{yx} \right); \\
\varepsilon_x = \frac{\sigma_x}{E_x} \cdot \left( 1 - \nu_{yx} \right) - \frac{\nu_{yx} \sigma_x}{E_x} \cdot \left( 1 + \nu_{yx} \right); \\
y_{xz} = \frac{1}{G_{xz}} \cdot \tau_{xz},
\]

where \( E_x, Ez \) – modules of the medium deformation in the directions coinciding with the plane of isotropy and perpendicular, respectively;

\( vzx \) – Poisson’s ratio characterizing linear deformations in the plane of isotropy under the stresses along the axis \( z \);

\( vzx \) – the same, in the direction of \( z \) axis under the stresses in the plane of isotropy;

\( \gamma_{zx} \) – shear angle;

\( Gxz \) – vertical shear modulus;

\( vyx \) – Poisson’s ratio in the plane of isotropy.

Each of the anisotropy parameters’ effect on the response (voltage) functions was evaluated, applying the mathematical planning methods of the experiment [11]. Variable factors at three levels were \( E_x, Ez, vzx \) and \( vyx \). The levels and range of variation are shown in table 2.

As a result of numerical studies [12], arrays of stress values \( \sigma_{z \alpha}, \sigma_{x \alpha} \) and \( \tau_{z \alpha} \) were obtained for an anisotropic medium and the corresponding stresses \( \sigma_x, \sigma_z \) and \( \tau_{zx} \) of the isotropic variant (\( \alpha = 1.0 \)).
Table 2. Variation of the deformation anisotropy parameters.

| Variation Factors | xi | Levels of variation | Range of variation |
|-------------------|----|---------------------|--------------------|
|                   |    | lower   | zero   | upper  |     |
| Ez, MPa           | x1 | 5       | 22.5   | 40     | 17.5 |
| Ex, MPa           | x2 | 5       | 22.5   | 40     | 17.5 |
| vzx               | x3 | 0.25    | 0.30   | 0.35   | 0.05 |
| vyx               | x4 | 0.25    | 0.30   | 0.35   | 0.05 |

A method that took into account deformation anisotropy of the base soil using the coefficients of soil anisotropy influence [thirteen] was developed at the fourth stage (calculation of correction factors), comparing the calculating results of SSS homogeneous anisotropic and isotropic bases in the layers form of different thickness and half-plane. These coefficients showed how much of the stress in an isotropic medium is the corresponding stress in anisotropic. The coefficients values are calculated by the formula:

\[ C_α = \frac{σ_zα}{σ_z}, \]

where \( C_α \) и \( C_α' \) – correction factors for the effect of soil anisotropy, calculated for the central and angular verticals, respectively;

\( σ_zα \) и \( σ_αx \) – vertical and horizontal stresses for an anisotropic medium;

\( σ_z \) и \( σ_x \) – the same for isotropic.

Stresses \( σ_zα \) and \( σ_z \) are calculated for the characteristic points of the soil mass, located on the central and angular verticals of the loaded surface area, in accordance with the requirements of [1].

Correction factors for the effect of soil anisotropy can be used to adjust the values of foundation sediments, calculated by any of the currently existing methods [1].

3. Results
The obtained data are sufficient for calculating the sediment of foundations, located on the half-plane surface or layers of different thicknesses. The coefficients \( C_α \) и \( C_α' \) were calculated for the midpoints of horizontal layers assigned under the foundation base according to [1] in 0.4\( b \) (\( b \) is the loaded section width of the base equal to the width of the foundation base).

An improved practical method for deformation anisotropy accounting can be recommended for putting into practice the design of buildings’ foundations under construction, reconstructed and restored, as well as for the construction of high-rise and long-span buildings and structures in difficult ground conditions. Coefficients determined for angular vertical points are necessary for calculating precipitation taking into account the influence of loads from neighboring foundations. Values of correction factors for stresses \( σ_z \) (central and angular verticals) are given in Tables 4-5.

The soil anisotropy accounting exacerbates the negative consequences caused by the imbalance in the regimes of nature. Anisotropy accounting is also necessary, solving recycling problem and storage various waste, because a characteristic feature of all its forms (landfills, dumps, storages, etc.) is their heterogeneity in density, composition and in strength and deformability. In these cases, it is natural to expect a significant manifestation of anisotropy.
Table 4. Values of correction factors for stresses $\sigma_z$, central vertical (band load).

| relative depth | $0.2\text{V}$ | $0.6\text{V}$ | $1.0\text{V}$ | $1.4\text{V}$ | $1.8\text{V}$ | $2.2\text{V}$ | $2.6\text{V}$ | $3.0\text{V}$ | $3.4\text{V}$ | $3.8\text{V}$ | $4.2\text{V}$ | $4.6\text{V}$ | $5.0\text{V}$ | $5.4\text{V}$ | $5.8\text{V}$ | $6.2\text{V}$ |
|----------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 1-250          | 0.9          | 0.75         | 0.66         | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 2-500          | 0.9          | 0.76         | 0.66         | 0.6          | 0.57         | 0.55         | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 3-750          | 0.9          | 0.77         | 0.67         | 0.62         | 0.58         | 0.56         | 0.55         | 0.53         | 0.52         | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 4-700          | 0.9          | 0.78         | 0.68         | 0.62         | 0.6          | 0.58         | 0.58         | 0.58         | 0.58         | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 6-560          | 0.9          | 0.78         | 0.68         | 0.63         | 0.61         | 0.61         | 0.62         | 0.64         | 0.66         | 0.68         | 0.7           | 0.72         | 0.75         | 0.77         | 0.77         | 0.77         |

Table 4. Values of correction factors for stresses $\sigma_z$, central vertical (band load).

| relative depth | $0.2\text{V}$ | $0.6\text{V}$ | $1.0\text{V}$ | $1.4\text{V}$ | $1.8\text{V}$ | $2.2\text{V}$ | $2.6\text{V}$ | $3.0\text{V}$ | $3.4\text{V}$ | $3.8\text{V}$ | $4.2\text{V}$ | $4.6\text{V}$ | $5.0\text{V}$ | $5.4\text{V}$ | $5.8\text{V}$ | $6.2\text{V}$ |
|----------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 1-250          | 0.97         | 0.93         | 0.89         | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 2-500          | 0.97         | 0.93         | 0.89         | 0.86         | 0.85         | 0.84         | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 3-750          | 0.97         | 0.93         | 0.89         | 0.86         | 0.85         | 0.84         | 0.82         | 0.82         | 0.81         | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 4-700          | 0.97         | 0.93         | 0.89         | 0.86         | 0.85         | 0.84         | 0.84         | 0.83         | 0.82         | 0.82         | 0            | 0            | 0            | 0            | 0            | 0            |
| 6-560          | 0.97         | 0.93         | 0.89         | 0.87         | 0.86         | 0.85         | 0.85         | 0.86         | 0.86         | 0.86         | 0.87         | 0.88         | 0.88         | 0.88         | 0.88         | 0.88         |

Table 4. Values of correction factors for stresses $\sigma_z$, central vertical (band load).

| relative depth | $0.2\text{V}$ | $0.6\text{V}$ | $1.0\text{V}$ | $1.4\text{V}$ | $1.8\text{V}$ | $2.2\text{V}$ | $2.6\text{V}$ | $3.0\text{V}$ | $3.4\text{V}$ | $3.8\text{V}$ | $4.2\text{V}$ | $4.6\text{V}$ | $5.0\text{V}$ | $5.4\text{V}$ | $5.8\text{V}$ | $6.2\text{V}$ |
|----------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 1-250          | 1.02         | 1.06         | 1.09         | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 2-500          | 1.02         | 1.05         | 1.09         | 1.11         | 1.13         | 1.14         | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 3-750          | 1.02         | 1.06         | 1.11         | 1.13         | 1.14         | 1.15         | 1.16         | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 4-700          | 1.02         | 1.05         | 1.11         | 1.13         | 1.14         | 1.15         | 1.16         | 1.16         | 1.17         | 1.17         | 0            | 0            | 0            | 0            | 0            | 0            |
| 6-560          | 1.02         | 1.06         | 1.11         | 1.13         | 1.14         | 1.15         | 1.15         | 1.14         | 1.14         | 1.14         | 1.13         | 1.13         | 1.13         | 1.13         | 1.13         | 1.13         |

Table 4. Values of correction factors for stresses $\sigma_z$, central vertical (band load).

| relative depth | $0.2\text{V}$ | $0.6\text{V}$ | $1.0\text{V}$ | $1.4\text{V}$ | $1.8\text{V}$ | $2.2\text{V}$ | $2.6\text{V}$ | $3.0\text{V}$ | $3.4\text{V}$ | $3.8\text{V}$ | $4.2\text{V}$ | $4.6\text{V}$ | $5.0\text{V}$ | $5.4\text{V}$ | $5.8\text{V}$ | $6.2\text{V}$ |
|----------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 1-250          | 1.04         | 1.12         | 1.21         | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 2-500          | 1.04         | 1.12         | 1.21         | 1.28         | 1.32         | 1.35         | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 3-750          | 1.04         | 1.12         | 1.21         | 1.28         | 1.32         | 1.35         | 1.37         | 1.38         | 1.39         | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 4-700          | 1.04         | 1.12         | 1.27         | 1.31         | 1.34         | 1.36         | 1.37         | 1.38         | 1.38         | 1.38         | 1.38         | 1.37         | 0            | 0            | 0            | 0            |
| 6-560          | 1.04         | 1.12         | 1.27         | 1.31         | 1.34         | 1.35         | 1.36         | 1.37         | 1.37         | 1.37         | 1.36         | 1.35         | 1.33         | 1.36         | 1.36         | 1.35         |
| relative depth | calculated values of correction factors for: | correction factors $\alpha = 0.222$ | SIGMA 1 | Vertical 2 |
|---------------|---------------------------------------------|--------------------------------------|-------|----------|
|               | 0.2V | 0.6V | 1.0V | 1.4V | 1.8V | 2.2V | 2.6V | 3.0V | 3.4V | 3.8V | 4.2V | 4.6V | 5.0V | 5.4V | 5.8V | 6.2V |
| 1-250         | 0.97 | 0.91 | 0.8  | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| 2-500         | 0.97 | 0.91 | 0.8  | 0.71 | 0.65 | 0.62 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| 3-750         | 0.97 | 0.91 | 0.81 | 0.72 | 0.67 | 0.62 | 0.59 | 0.57 | 0.56 | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| 4-700         | 0.97 | 0.91 | 0.82 | 0.74 | 0.69 | 0.65 | 0.63 | 0.51 | 0.51 | 0.61 | 0.61 | 0    | 0    | 0    | 0    | 0    |
| 6-560         | 0.97 | 0.91 | 0.82 | 0.75 | 0.7  | 0.68 | 0.66 | 0.66 | 0.67 | 0.69 | 0.7  | 0.73 | 0.75 | 0.77 | 0.79 | 0.79 |

| relative depth | calculated values of correction factors for: | correction factors $\alpha = 0.562$ | SIGMA 1 | Vertical 2 |
|---------------|---------------------------------------------|--------------------------------------|-------|----------|
|               | 0.2V | 0.6V | 1.0V | 1.4V | 1.8V | 2.2V | 2.6V | 3.0V | 3.4V | 3.8V | 4.2V | 4.6V | 5.0B | 5.4V | 5.8V | 6.2V |
| 1-250         | 0.99 | 0.97 | 0.94 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| 2-500         | 0.99 | 0.97 | 0.94 | 0.91 | 0.89 | 0.87 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| 3-750         | 0.99 | 0.97 | 0.94 | 0.91 | 0.89 | 0.87 | 0.82 | 0.84 | 0.84 | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| 4-700         | 0.99 | 0.97 | 0.94 | 0.91 | 0.89 | 0.87 | 0.84 | 0.85 | 0.84 | 0.84 | 0.84 | 0.83 | 0    | 0    | 0    | 0    |
| 6-560         | 0.99 | 0.97 | 0.94 | 0.91 | 0.9  | 0.89 | 0.87 | 0.87 | 0.87 | 0.86 | 0.87 | 0.87 | 0.87 | 0.88 | 0.88 | 0.88 |

| relative depth | calculated values of correction factors for: | correction factors $\alpha = 1.778$ |
|---------------|---------------------------------------------|--------------------------------------|
|               | 0.2V | 0.6V | 1.0V | 1.4V | 1.8V | 2.2V | 2.6V | 3.0V | 3.4V | 3.8V | 4.2V | 4.6V | 5.0V | 5.4V | 5.8V | 6.2V |
| 1-250         | 1.01 | 1.02 | 1.04 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| 2-500         | 1.01 | 1.02 | 1.04 | 1.07 | 1.08 | 1.1  | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| 3-750         | 1.01 | 1.02 | 1.04 | 1.06 | 1.09 | 1.1  | 1.12 | 1.13 | 1.14 | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| 4-700         | 1.01 | 1.02 | 1.04 | 1.07 | 1.08 | 1.1  | 1.12 | 1.13 | 1.13 | 1.14 | 1.15 | 1.15 | 0    | 0    | 0    | 0    |
| 6-560         | 1.01 | 1.02 | 1.04 | 1.06 | 1.09 | 1.1  | 1.11 | 1.12 | 1.13 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 |

| relative depth | calculated values of correction factors for: | correction factors $\alpha = 4.500$ |
|---------------|---------------------------------------------|--------------------------------------|
|               | 0.2V | 0.6V | 1.0V | 1.4V | 1.8V | 2.2V | 2.6V | 3.0V | 3.4V | 3.8V | 4.2V | 4.6V | 5.0V | 5.4V | 5.8V | 6.2V |
| 1-250         | 1.02 | 1.04 | 1.09 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| 2-500         | 1.02 | 1.04 | 1.09 | 1.14 | 1.14 | 1.2  | 1.25 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| 3-750         | 1.02 | 1.04 | 1.09 | 1.15 | 1.21 | 1.25 | 1.28 | 1.31 | 1.33 | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| 4-700         | 1.02 | 1.04 | 1.09 | 1.15 | 1.2  | 1.25 | 1.29 | 1.32 | 1.34 | 1.35 | 1.37 | 1.37 | 0    | 0    | 0    | 0    |
| 6-560         | 1.02 | 1.04 | 1.09 | 1.14 | 1.19 | 1.23 | 1.27 | 1.29 | 1.31 | 1.31 | 1.33 | 1.32 | 1.32 | 1.32 | 1.32 | 1.32 |
4. Conclusion

It should be noted that the soils of the Barnaul territory, for example, have a pronounced anisotropy of filtration and compressibility, which have a significant impact on the bearing capacity and deformability of the bases.

It was also established that in cases where the base has a deformation anisotropy index $\alpha < 1$, the values of the calculated base soil resistance $R$ increase, which leads to a decrease in the size of the foundations base and to obtain a known economic effect. So, when $\alpha > 1$ requires an increase in the size of the sole compared with those established in SR 22.13330.2016. Set of rules. Foundations of buildings and structures [1]. Studies show that applying the isotropic model for calculating soil bases leads to the real picture of the foundations.

The influence of deformation anisotropy on the predicted sediments’ value with a weakly expressed anisotropy of ordinary soils is estimated to reach 10-40% from the calculated settlement of the foundation, located on an isotropic base. The obtained data can be used in the calculations of deformation bases during the superstructure of buildings and structures, taking into account that anisotropic soils anisotropy index $\alpha < 1$ is calculated according to the SR method 22.13330.2016. Set of rules. The foundations of buildings and structures [1], which do not take into account anisotropy, lead to overestimated precipitation values, as well as with such methods of reinforcing foundations as broadening of the foundation, clips arrangement, shirts, extensions, etc. For soils with $\alpha > 1$ anisotropy indices, the traditional calculation gives a decrease in sediment value. If we take into account such soils of great deformation anisotropy influence, since soils have a layered or columnar texture, it is unacceptable to neglect this fact during reconstruction. The deformation anisotropy must be considered, converting columnar foundations into strip foundations, as well as transferring foundations to piles, because all of the above is true for the calculation of pile foundations and their deformation bases. It is also necessary to take into account the deformation anisotropy, calculating the settlement of foundations during a new building construction near an existing one, because, an increase in the estimated settlement due to deformation anisotropy can be unacceptably large, considering uneven of adjacent foundations’ settlement for weak base soils.

The described methodology application for calculating the foundation sediment is advisable, taking into account the influence of neighboring foundations, as well as for calculating the settlement of the final thickness layer.

Thus, the proposed improved practical method for calculating soil bases from deformations makes it possible to more accurately and reasonably calculate the foundations’ settlement with their real properties [14, 15]. The given tables of correction factors for the influence of soil anisotropy can be recommended for calculating foundation sediments taking into account deformation anisotropy according to BN 22.13330.2016 “Foundations of buildings and structures. The updated edition of BNR 2.02.01-83” [1] and the proposed practical method for deformation anisotropy accounting can also be recommended for the implementation in the design practice of foundations for buildings under construction, reconstructed and restored.

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