Bases and foundations of buildings at reconstruction

Alexey Glushkov¹ and Vyacheslav Glushko

Volga State University of Technology, Lenin sq., b. 3, 424000, Yoshkar-Ola, Russia

E-mail: ¹glushkovav@volgatech.net

Abstract. The problems of increasing the pressures on soils, compressed by the load from the exploited structures when superstructuring heighten additional floors with increasing the load without strengthening basis and foundations are considered. The successful experience of strengthening without reinforcing the foundations and artificial hardening of the soil shows that the pressure on the basis can be increased even for \( p > R \). Despite the wide native experience of reconstruction, there are no regional or departmental norms or rules at design of the bases and the foundations of the reconstructed buildings nowadays. To determine the reserves of the bearing capacity of the soils, due to the underestimated requirements of the norms, it seems reasonable to analyse the previously used methods for designing the bases and use modern nonlinear state models in the calculations. For this, it is necessary to reliably and correctly determine the physic-mechanical and deformation properties of the undisturbed structure in the substrate. Calculation for two limit states in that case can be reduced to the common calculation allowing to define the stress-strain state at any settlement and, on the contrary, the deformed state at any loadings up to destroying. The use of the numerical modelling with the application of elasto-plastic tasks at the reconstruction of buildings and constructions excludes the need of extremely laborious works on artificial hardening of soil in the basis and the strengthening of the existing foundations.

1. Introduction

In the Russian normative documents on design of foundations of buildings and constructions there are no concrete and detailed recommendations for destination of permissible pressure upon soil bases of the existing foundations [12]. Successful experience of superstructures without foundation strengthening and artificial hardening of soil foundations shows that pressure upon soil bases can be increased even at \( p > R \); where \( p \) – the average foundation beds pressure, \( R \) – rated soil resistance [14].

Despite the wide native experience of reconstruction, there are no regional or departmental norms or rules at design of the bases and the foundations of the reconstructed buildings nowadays [1, 9].

Experience of reconstruction of civil, industrial and public buildings in a number of cities in the country showed, that the increase in loads is possible without hardening of soil basement and strengthening the foundation, if we use reserves of the bearing capacity of soil [2, 6].

Norms and design methods of the basement and foundations which were taken for the buildings reconstruction, provided considerably smaller loadings than their actual bearing capacity allowed [8]. Soil bases are condensed and gain new properties during the long upkeep of the construction under the influence of loading upon the foundation [13]. When reserves of the increase in the bearing capacity of the basis become insufficient, it is necessary to carry out strengthening or replacement of the existing foundations.

To find out the reserves of the bearing capacity of the soil basis, caused by the underestimated requirements of norms, it is advisable to analyse the design methods of the bases applied earlier and to
use modern nonlinear models of the bases in calculations [15]. For this purpose it is necessary to define authentically and correctly physic and mechanical, and also deformation properties of soil of undisturbed structure in the basis [4].

2. Investigation survey

The offered way of the assessment of the stress-strain state of the basis with the use of nonlinear methods of calculation allows to exclude labour input of necessary works on artificial hardening of soil of the basis or to increase the sizes of the foundations [7].

As the actual pressure upon soil of the basis is more than the settlement resistance of soil, it is possible to use nonlinear methods of calculation taking into account the formation of zones of plastic deformations in the basis for the safe upkeep of the building [3].

The method of calculation of the basis of the reconstructed buildings has to be conducted taking into account the design features (receptivity of the building to uneven settlements) and to be based on the principle of calculation of the bases for two groups of limit states (on the bearing capacity and deformations) [11].

For this purpose it is necessary to investigate the condition of the foundation bases of the reconstructed building and to reveal the following regularities:

– change of pressure upon soil of the basis after reconstruction;
– the completeness of usage in calculations of strengthening and deformation properties of soil of the basis;
– the essence (structural feature) of the processes happening in the soil of the basis in case of their long upkeep;
– the actual compaction of soil in the basis of the reconstructed building;
– the prediction of the building deformations after the reconstruction, their part from maximum allowable values.

Using of elastoplastic solutions for the stress-strain state assessment of the foundation of the reconstructed building indicates feasibility of their application in practice of design and construction. It also gives a chance to conduct the calculation of the foundations, based on maximum allowable deformations of buildings and constructions.

Most thoroughly, the behaviour of soil under loading in the existing building with the simultaneous development of elastic and plastic areas describes the elastoplastic model of the basis [16].

The excess \( p > R \) indicates the need of accounting of simultaneous existence of elastic and plastic deformations and nonlinear dependence between stress and deformations.

Calculation for two limit states in that case can be reduced to the common calculation allowing to define the stress-strain state at any settlement and, on the contrary, the deformed state at any loadings up to destroying.

3. Experimentals

3.1. The reconstructed building No. 1

3.1.1. Design features. One-storey building No. 1 of the canteen of “Elektroavtomatika” was built in the 1960s. It has the sizes in design of 53.4×18.0 m (fig. 1). As for design features the building represents the three-vaulted building with the outside bearing brick walls of 510 mm thick. The basic design elements are longitudinal bearing walls and brick columns, combined reinforced concrete in the longitudinal direction and combined reinforced concrete hollow plates of a covering in the cross direction.
The foundations of outside and inside walls are done strip, the width of the foundation bed is $b=1.2$ m, the depth is $h=3.7$ m.

On the outside bearing brick walls of the building there are numerous through cracks with a width of disclosure of $\delta=2\pm10$ mm – the result of irregular deformations of the basis.

### 3.1.2. Geological conditions.
In the geological structure of the platform there are modern technogenical (tQIV) sediments with the capacity of 0.4-1.6 m spread by the quaternary alluvial (aQ) deposits presented by clay from turgid to clayey clay consistence with the capacity of the 4.5-6.0 m. From the depth of 4.9-7.6 m sand of average fineness and average density (dQ) is found.

To specify the characteristics of soil in the basis there was conducted a complex of field surveys with the use of the probe-penetrometre, the offset impeller, stamp tests, geophysical methods, and laboratory tests of monoliths of soil. Under the foundation beds lies clay with $I_p=0.17$; $I_L=0.87$; $e=0.740$; $\varphi=4^\circ$; $C=16$ kPa; $E=5.0$ MPa with low strength and deformation characteristics ($R=100$ kPa).

As the result of the conducted researches it is established that on the outside and inside walls of the building of the dining room, the average pressure on the existing foundation beds exceeds the value of settlement of soil resistance ($p>R$). The extent use of the bearing capacity of soil in the basis before reconstruction makes $p/R = 1.52$.

The reconstruction of the building of the dining room into the shopping centre assumes a superstructure of two additional floors, with the height of the floor $h_{st}=4.5$ m with monolithic reinforced concrete overlappings and brick walls, with the payload of $P_t=4$ kPa. It will lead to increase in the pressure on the existing foundation beds by 1.7 times, the proportion of $p/R$ will make 2.5.

Let us calculate the stress-strain state of the foundation of the reconstructed building taking into account a superstructure of two floors in elasto-plastic state.

### 3.1.3. Analytics.
The analytical method allows to determine a vertical component of the limit state resistance of the basis of the strip foundation by a formula:

$$n_u = b^* \left\{ q + \left(1 + \pi - \alpha + \cos \alpha \right) \cdot C_1 \right\},$$

where $b^*$ – is the specified width of the foundation bed; $q$ –is the loading of the basis from the soil uplift; $C_1$ – is the specific cohesion of soil; $\alpha$ – is a corner, rad:

$$\alpha = \arcsin \left[ F_h / (b^* \cdot C_1) \right],$$

where $F_h$ – is a horizontal component of loading.
At $F_b = 0$ the formula (1) becomes:

$$n_u = b' \{q + 5.14 - C_1\}. \quad (3)$$

3.1.4. Results of calculations. The reconstruction of the building of the dining room into the shopping centre is done without strengthening of the existing foundations and the basis. To increase the stiffness of the construction and decrease unevenness of settlements on outside walls, two reinforced concrete belts on the bottom of the overlapping of the 2 and 3 floors are used.

3.2. The reconstructed building No. 2

3.2.1. Design features. The reconstruction of the three-story building of the policlinic of the Ministry of Internal Affairs in Yoshkar-Ola (fig. 2) planned a superstructure of two additional floors. The existing building has the sizes $53.2 \times 12.0 \, \text{m}$, the height of the floor $h_{st} = 3.3 \, \text{m}$ with the longitudinal outside and inside bearing brick walls and combined with reinforced concrete overlappings. The foundations of the building are constructed from the driven prismatic piles 4.0 m and 5.0 m long, a section of $30 \times 30 \, \text{cm}$ with reinforced concrete capping. The design load of the pile is 300 kN.

3.2.2. Geological conditions. In the geological structure of the platform there are quaternary alluvial and dealluvial deposits blocked by modern technogenic soil: soft clay (adQ) up to the depth of 4.5 m is spread by sands of average fineness (adQ) up to the depth of 5.3 m; lower there is soft loam (adQ) up to 7.1 m; grey sand of average fineness and average density finishes the section of deposits opened up to 18 m.

![Figure 2. Frontispiece of the building No.2 after the reconstruction](image)

3.2.3. Calculation results.

![Figure 3. Dependence of the wall settlements before and after reconstruction](image)
Figure 4. The calculation results of the vertical displacements $U_z$ of the policlinic building for platform no. 2

Figure 5. The calculation results of the horizontal displacements $U_z$ of the policlinic building for platform no. 2

Figure 6. The calculation results of the points of plastic deformations of the policlinic building for platform no. 2

The use of the numerical modelling with the application of elasto-plastic tasks at the reconstruction of buildings and constructions excludes the need of extremely laborious works on artificial hardening of soil in the basis and the strengthening of the existing foundations (fig. 3-6) [5, 10].
4. Conclusions
The unevenness foundation settlements of the building mainly arises during the reconstruction connected with the superstructure of additional floors. Reinforced concrete belts in the bearing brick walls at the bottom level of the overlapping of the heighten 4 and 5 floors are provided to reduce the unevenness of settlements and to increase the spatial stiffness of the policlinic building.

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