# Ensuring Stability of Boards of Deep Ditches in Seismic Regions

## Assurer la stabilité des fossés profonds dans les régions sismiques

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ABSTRACT: Questions of ensuring stability of boards of ditches up to 24 meters in depth are considered at subway construction in Almaty. Difficulties cause such factors as density of building of the territory, heterogeneity of an engineering-geological structure and the increased seismicity of the territory. Results of laboratory and field researches on specification of strength and deformation parameters of soil are given. For a case of a superficial driving of the subway it is set an example fixing of boards when developing a ditch up to 25 meters in depth. For fixing of slopes the combined scheme in which excavation of a ditch is accepted both without fastening, and with fastening of boards of a ditch in the form of retaining walls and vertical racks in the form of piles is accepted. Stability of a protection is provided with inclined soil anchors. Bearing ability of anchors at static and seismic loadings was defined by field tests and laboratory researches of models of a slope in a tray.

RÉSUMÉ : On examine les questions de la stabilité des bords des fouilles par la profondeur jusqu'à 25 mètres à la construction du métropolitain à Almaty. La complexité de l'exécution de la construction est provoquée par tels facteurs comme la densité de la construction du territoire, la non homogénéité de la structure géotechnique et une haute sismicité du territoire. On amène les résultats des études de laboratoire et champêtres selon la précision прочностных et деформационных des paramètres du sol. Pour le cas du fonçage superficiel du métro on montre l'exemple de la fixation des bords à l'élaboration de la fouille par la profondeur jusqu'à 25 mètres. Pour la fixation des pentes on accepte le schéma cumulé, dans qui l'élaboration de la fouille est acceptée sans fixation, ainsi qu'avec la fixation des bords de la fouille en forme des murs de support et les comptoirs verticaux en forme des pilots. La stabilité de la barrière est assurée par les ancres inclinés dans le sol. La capacité portant des ancres aux charges statiques et sismiques était définie par les essais champêtres et les essais de laboratoire des modèles de la pente dans l'éventaire.

KEYWORDS: underground, seismicity, soil, durability, deformation, ditch, anchor.

## 1 INTRODUCTION

Modern construction of the densely populated cities demands intensive development of underground space which is necessary for development of engineering support, a solution of the problem of autoparkings, underground public transport, creation of the additional areas, etc. But the solution of these questions is most complicated. Existing buildings, are expensive and engineering communications interfere with a construction of new underground constructions. The intensive development of the city resulted Almaty (Kazakhstan) in need of improvement of its infrastructure. About 10 large automobile outcomes on internal and ring highways were constructed. However it only partially solved transport problems. Automobile jams remained a big problem. In 2011 in Almaty the first line of the subway was started. The main part is located at a depth of 60-35 meters. It is constructed in the underground way and it is located only in the central part of the city. Again under construction second line covers new areas. Density of building of the territory here not so big. Therefore for economy construction of a new branch is planned in the open way.

## 2 GEOLOGICALSTRUCTUREOFTHETERRITORY

The territory of construction is located on the inclined foothill plain, a strip along a northern slope of ridge Zailiysky Ala Tau. Within the line of the subway the accumulative type of a relief is widespread. In the geomorphologic relation the site is located within the foothill loop formed as a result of merge of cones of carrying out of the mountain rivers. Surface flat, with a bias from mountains to the plain. The surface is crossed by a river valley Big Almatinka with depth of cutting of 5-6 m. Boards cool, from a surface are put by loams, is deeper – boulder and pebble soil with sandy, loamy and sandy filler. Prolyuvialny deposits of verkhnechetvertichny age ($apQ_{III}$) take part in a geological litologichesky structure of a section allyuvialno rom physic-geological processes there is an insignificant plane washout, high seismicity [SNIP RK 2006].

On a site of a line of underground up to the investigated depth of 24,0 m it is allocated 5 engineering - geological elements. GL-1-a bulk ground - capacity of a layer of 0,2-2,7 m. GL-2 - a soil - vegetative layer, loam with roots of plants. Capacity of a layer of 0,2 m. GL-3 - loam of brown grey color, a firm consistence, macro porous, subsiding soils, with particles of calcium as veins, sometimes with inclusion of gravel and a fine pebble up to 5 %. Capacity of a layer of 0,2-2,6 m. The angle of internal friction is equal 19 °, cohesion intercept 33 kPa, the module of deformation of 7,4 MPa.GL-4 - gravel a ground with a loamy and sandy filler in amount up to 20-30 %, with inclusion of boulders in the size up to 300mm up to 15 %. Capacity of a layer of 0,3-0,4 m. The angle of internal friction is equal-36°, cohesion intercept-27 kPa, the module of deformation of 68 MPa. GL-5 - gravel a ground with a sandy filler up to 20-25 %. Presence of fractions: boulders - up to 12,5-29,0 %, with depth the amount of boulders is increased up to 30,2-34,0 %, a pebble of 27,8-63,2 %, gravel - 5,5-22,8 %. Fragments are well processed by water and have no sharp corners. Opened capacity of a layer of 9,8-34,0 m. The angle of internal friction is equal 41°, cohesion intercept 36 kPa, the module of deformation of 75 MPa.

## 3. SPECIAL RESEARCHES OF PROPERTIES OF SOIL

Experience of design on gravel soil shows that usually as the basic data characterizing properties of soil, values of strength characteristics only filler are used generally. Influence of large fractions thus aren't considered. It leads to use of the underestimated values of mechanical characteristics and uneconomical design decisions.

Now researches on bearing ability soil gravel, and also on influence of the sizes of fractions is a lot of (L.A.Avakjan 1981, V.I.Feodorov 1973). Researchers are conducted on shift devices and in field conditions. However similar researches are very labor-consuming because of the big extent of rocky separateness and volumes of tests, need of use of large-scale devices.

In laboratory of the Kazakh Leading Architectural and Construction Academy (the city of Almaty, Kazakhstan) are conducted researches on definition of influence of diameter of fraction and percentage of inclusions on indicators of durability of soil. Researches were conducted on special option of the one-plane device of a design of the Moscow Engineering Construction Institute (Figure 1) (V.A.Khomyakov 2007), and also in an experimental tray with different structures of soil mixes.

The area of a sample of the shift device is equal 100 cm$^2$, sample height 8,1cm. Tests are dried with different compositions of soil with filler fractions from 2 to 20 mm. Tests are carried out on compositions of soil with the maintenance of large fractions 25, 50, 75 percent. At test on the shift device resistance to shift of soil was determined by the kinematic scheme after preliminary consolidation of samples by vertical loading before conditional stabilization. Horizontal deformation was put and the shifting effort was registered. Percentage of large fractions and filler in mixes was established by results of definition of grain structure. Results of tests were subjected to statistical processing.

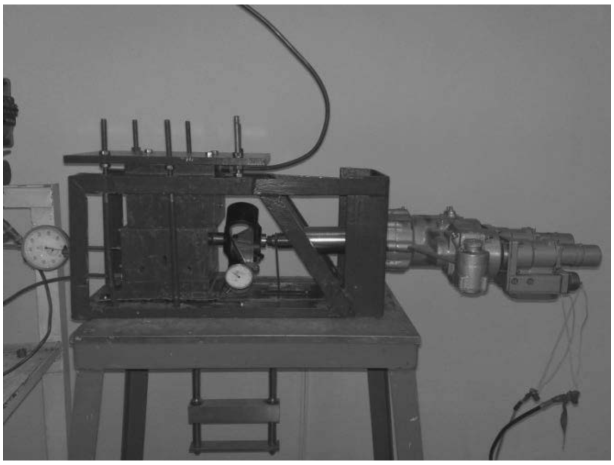

Figure 1. The general view of the shift device

In Table 1 results of tests of influence of inclusions on durability gravel of a ground for tests other authors (L.A.Avakjan 1981,V.I.Feodorov 1973) and KazGACA are given.

Research of influence of filler on properties of a ground has shown, that at increase of number of plasticity of clay filler of value of a corner of internal friction are reduced, and specific coupling grow (V.I.Feodorov 1973). The increase of the maintenance of a sandy filler up to 25 % raises value of a corner of internal friction and lowers value of specific coupling ( V.I.Feodorov 1973,V.A.Khomyakov 2007).

It is necessary to note, that results of definition of a corner of internal friction and specific coupling for artificial mixes tested DalNIICA (L.A.Avakjan1981) and in laboratory KazGASA on shift devices of the different sizes appeared comparable, and confirm, that increase of the maintenance of large fractions more than 25 %, irrespective of a kind of a filler, results in increase of durability of the basis.

For obtaining fuller data on properties of soil, in laboratories of KazGACA on the special tray, imitating seismic impacts on the soil massif, tests on stability of boards of the ditches put by loams (Figure 2) were carried out.

The tray represents a rectangle 1200 mm long, 200 mm wide and 800 mm high. The tray is in the middle divided into two parts by a partition. Forward wall of a tray transparent of plexiglas, back and lateral walls wooden also are strengthened by metal. Mobility of the stand is provided by means of four axes with wheels on ball-bearings. Seismic loading is put by action of the squeezed spring. Parameters of influence are registered special control measuring equipment.

Table 1. Influence of a filler on durability of the characteristic of a ground

| The name of a ground and the size of fractions | The size of fraction of a filler or consistence | The characteristic of a ground | The maintenance gravel of a ground, % | | | | |
|---|---|---|---|---|---|---|---|
| | | | 25 | 35 | 50 | 70 | 75 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Gravel a ground (fractions from 10-20 mm) | 0,25÷2 mm | c, кPa | 1 | - | 45 | - | 1 |
| | | φ, ° | 48 | - | 52 | - | 63 |
| Gravel a ground (fractions from 5-10 mm) | 0,25÷2 mm | c, кPa | 1 | - | 1 | - | 1 |
| | | φ, ° | 42 | - | 42 | - | 60 |
| Gravel a ground (fractions from 2- 5 mm) | 0,25÷2 mm | c, кPa | 2 | - | 21 | - | 34 |
| | | φ, ° | 41 | - | 44 | - | 52 |
| Sandy loam | plastic consistence0<$J_L$ ≤0,75 | c, кPa | 11 | 10 | 7 | 5 | - |
| | | φ, ° | 38 | 42 | 45 | 47 | - |
| Loam | semi-firm consistence0<$J_L$ ≤0,25 | c, кPa | 41 | 35 | 27 | 20 | - |
| | | φ, ° | 27 | 34 | 39 | 45 | - |
| Clay | semi-firm consistence0<$J_L$ ≤0,25 | c, кPa | 50 | 43 | 34 | 25 | - |
| | | φ, ° | 18 | 24 | 33 | 41 | - |

The note - the maintenance of diameter gravel of inclusions (%) is established by results of definition of grain structure. Thus particles are larger 2mm carry to inclusions, particles less 2mm - to a filler.

In laboratory researches the soil model which structure consists of three components was used: sand – 80%, grated small polyfoam – 10%, veretenny oil – 10%. Density of model of soil -1450 kg/m$^3$. According to the characteristics the model of soil is similar to macro porosity loam. External loading modeling weight a number of the located building, it was put by the weight of a set of weights. Weights are installed on a rectangular platform of 200x200 mm. Test objective was determination of stability of boards without actions for fixing of soil when developing ditches. To determine the maximum height of a slope with which stability is provided with a corner of a natural slope. Stability increase in case of strengthening of a slope of a ditch by soil anchors. Anchor was modeled by a metal wire with seal to the massif. Anchor was established in two ranks, the retaining wall is modeled by a wooden plate.

As a result of tests it is received that application of anchors on increases stability of a slope many. Sensors of movements received values of horizontal and vertical deformations of a board of a ditch. Soil movements in natural state was much more movements of the slope fixed by soil anchors.


1- Scale of compression of a spring; 2 - Basic castors; 3 Spring; 4-Temporary partition in the middle of the stand; 5 - Transparent plexiglas; 6 - Directing rails.

Figure 2. The general view of an experimental tray.

## 4. APPLICATION OF THE RECEIVED RESULTS IN PRACTICE

At construction of underground by an open way by primary goal is to provide stability of walls of foundation ditches. Constraint of conditions of a platform does not allow to provide a corner of a natural slope for slopes of a foundation ditch. Development of foundation ditches should be carried out under condition of fastening walls from destruction. Supporting design should provide reliable work of all adjoining buildings and constructions.

Analyzing geological conditions to become obvious, that the basic thickness of a fixed file is generated GL-4 and GL-5, that is gravel of a ground. Results of researches show that the parameters of durability determined by researches by a standard technique do not reflect to the full a nature of resistibility gravel of a ground. For GL-4 it is possible to recommend a corner of friction of 48 degrees, for GL-5 up to 50 degrees.

By results of calculations with use of experimentally established mechanical properties of soils and programs Lira 9.6 and PLAXIS the optimal variant of fastening of walls of a foundation ditch (Figure 3) is chosen. The used settlement programs are based on application of a method of final elements for modeling earth geological conditions and the accepted constructive decisions of fastening of boards of foundation ditches. Settlement seismicity of a site made 9 points on scale MSK-1964. Seismic loading is enclosed in calculations kvazistatical by away. The three-storied circuit is accepted. Height of circles are accordingly 9m, 9m and 6m. The basic bearing elements of a protection are vertical racks as piles. Diameter of piles is accepted 168 mm. The pile inside is completely filled by concrete. Stability of racks is provided with inclined earth anchors such as "Titan". For each circle the step of arrangement of vertical racks both required quantity and length of anchors are picked up, (M.I.Gorbunov-Posadov 1985, L.N Ginzburg. 1979).

On the circuit (Figure 3), it is visible that for fastening the top circle is required two lines of anchors, length of 12 and 10 meters. Section of anchors was as a pipe with external and internal diameter 30 mm and 11mm accordingly. For fastening the second circle it is required already three lines of such anchors. Steady position of the third circle is provided only five lines of anchors. The required section of anchors was increased up to 40mmexternal and 20mminternal diameter.

Control check is executed with use of program PLAXIS

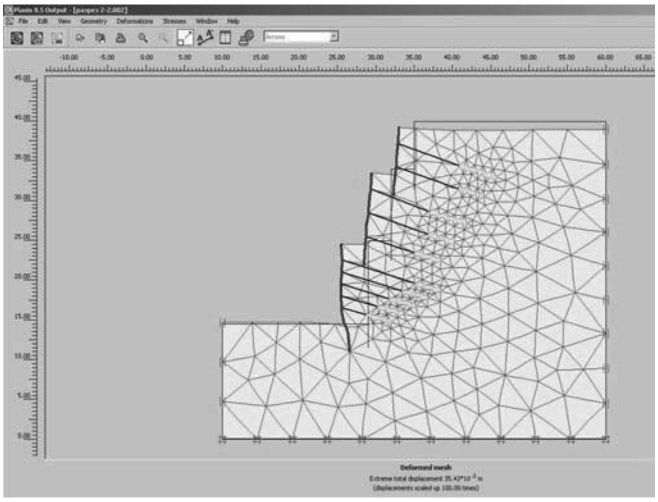


Figure 3. The Deformed circuit of the fixed slope in program PLAXIS

## 5. CONCLUSIONS

1 At excavation of deep ditches of the most optimum the scheme of excavation and soil fixing by circles is. With a height of circle more than 6 meters fixing of soil is an indispensable condition, irrespective of a type of soil in which they are constructed. Fixing in difficult geological conditions and in seismically active areas is especially important.
2 Laboratory researches in a tray showed efficiency of application of soil anchors for ensuring stability of a slope of a ditch. Tests are carried out on a mix modeling properties of clay soil in a natural not water-saturated state.
3 If ditches it is dug out in pebble soil, for fixing of boards of ditches up to 9 meters high it is possible to use tube concrete or ferroconcrete piles with a diameter from 150 mm. It is expedient to pile to arrange in two ranks, having connected them on top a ferroconcrete plate. Stability of vertical racks is provided with soil anchors. Anchor length, and also length and diameter of an anchor it is necessary to select only for calculation.
4 In a case when ditches are arranged in weak clay or water-saturated soil use for fastening of walls of a ditch of only soil anchors insufficiently. From experience it is visible that reliable work of fastening of a ditch requires application of struts and other horizontal communications.

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