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DEVELOPMENT OF THE COMPUTER PROGRAM OF CALCULATION OF CONCRETE BORED PILES IN SOIL GROUND OF ASTANA CITY

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ABSTRACT: The current calculating theories of massive constructions are based on the simplified models without consideration of factors settlement as nonhomogeneous environments interaction, the interacting environments nonlinearity or considering them separately and conditionally. Therefore, equivalent numerical model designing of bored piles interaction with the soil mass and designing of a nonlinear technique of numerical calculation of similar systems on its basis is a modern and relevant task, which is an effective tool for a number of relevant geotechnical tasks solutions. The calculation of reinforced concrete bored pile with the real diagrams of a pile material deformation and surrounding rock massif has been presented in the article. The computer program allows receiving the strain-stress state of a pile and the surrounded massif as one heterogeneous body. New calculation approaches of the reinforced concrete bored pile can be used in the standards modernization when transferring from the regulatory framework of Kazakhstan to Euro code according to the reform concept.

Keywords: Pile, soil, Program, Calculation

1. INTRODUCTION

There are cardinal changes in the regulatory base in the construction industry in the Republic of Kazakhstan now.

The numerical methods of researches are a powerful research tool. Today they are widely used and still improved.

Equivalent numerical model designing of bored piles interaction with the soil mass and designing of a nonlinear technique of numerical calculation of similar systems on its basis is a modern and relevant task, which is an effective tool for a number of relevant geotechnical tasks solutions [1-3].

The nonlinear behavior of construction and earth foundation is described by various models, which are based on different hypotheses in practical calculation methods of similar systems.

The complaints interaction is considered approximately by means of the friction theory, the coupling theory, etc. Therein, the interaction consideration questions of two deformable mediums remain undetermined. The fundamental idea of the given technique of numerical researches involves one equivalent model formation of real nonhomogeneous deformable mediums: a reinforced concrete cylindrical shell (a buried construction) and a surrounding soil massif. The considered system "buried construction-soil" is accepted as one nonhomogeneous body. It is characterized by various properties in various points. The contact of two bodies is considered ideal, every medium is characterized by its deformation diagram and by relevant physical and geometrical relationships [4-6].

2. THE OBJECT CHARACTERIZATION

Accelerated socio-economic development of Kazakhstan in the early 21st century has caused an urgent need for professionals with a high level of technical, managerial and leadership competencies, so a project of creating the Intellectual schools had been launched. The construction site (Nazarbayev Intellectual School) is located in the capital of the Republic of Kazakhstan Astana city, on the left bank of the Yesil River (see Figure 1). The city's territory is located on the Kazakh shield and does not have tectonic movements, therefore its territory is not considered as seismic.

Fig.1 Nazarbayev Intellectual School

The building sites in the territory of Astana city are taken as the research objects characterizing typical engineering-geological conditions of this region. According to the soil investigation (see Table 1) on the construction site, the following soil formation has been a settlement.

Table 1-Soil investigation

Geological engineering element	Intercept cohesion, кPa	The angle of internal friction, °	Modulus of deformation on saturation, MPa	Soil density, g/cm^3
Water loam	3.5	16.3	6,19	2,03
Loam aQ_{II-IV}	16.2	17	7	1.99
Gravel sand aQ_{II-IV}	1	38	21	2,00
Clay soil	22	17	13.0	2,09

The project provided for static tests on three bored piles: C6-30 №293, 453, 750 on the depth 5.4m (see Figure 2).

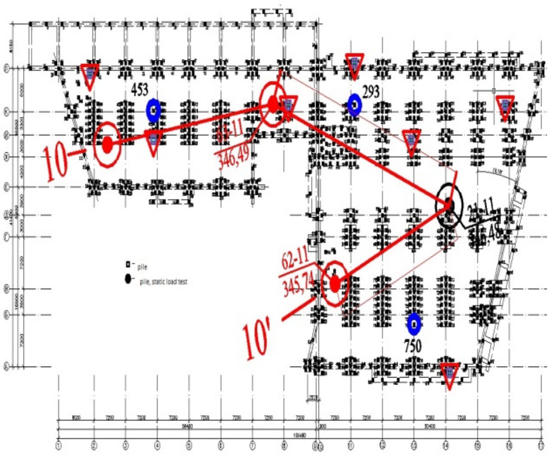


Fig.2 Pile plan field

Static load test carried out for driving piles after the “rest” and for driven piles after achievements of the concrete strength more than 80%. For static load tests the following equipment is used: hydraulic jack DU-100P - 100 t., manometer MTP-160, caving in-measurers of the type 6PAO.

Load platform with systems of beams and loads with a total weight equal to 70 t., installed on the same platform, loaded the pile. The resulting maximum load is 64.28 t. This is load similar to the total weight of the platform. Therefore, this weight not only pressed the pile but also raised the platform. Therefore, 2 should divide the experimental value.

Value displacement with the applied load is 3.76 mm.

The object is a monolithic reinforced concrete structure - a driving pile of 0.3x0.3 m size with driving depth 5.4 m, arranged in non-uniform layered soil at a mark of 344,100 m.

For the calculation, a pile with a square section is replaced with a circular section with a diameter of 0.34 m with an approximate cross-sectional area of 0.090745 m^2.

The characteristic of concrete is E = 30000 MPa, volumetric weight $\gamma = 2.5$ t / m^3.

Design load on the pile P = 64.28 t.

Table 2, Figures 3-5 presents results of static pile test.

The first record was performed just after putting the loading, then consequently 4 records with an interval of 15 minutes, 2 records with an interval of 30 minutes and further for every hour until the conditional stabilization of pile settlement. For the criterion of conditional stabilization of pile, the settlement was taken when the speed of settlement of piles on the given stage of loading did not exceed 0.1 mm during the last 1-2 hours of observations. Reloading (unloading) conducted half stages of the loading [7-8].

Table 2 Results of static load test

Pile number	№ 293	№ 453	№ 750
Embedded depth, (m)	7.00	9.25	10.25
Driving depth, (m)	5.4	5.4	5.4
Settlement, (mm)	5.65	7.53	14.69
Applied load, (kN)	642.8	642.8	642.8
Max.load, (kN)	1200	1200	1200

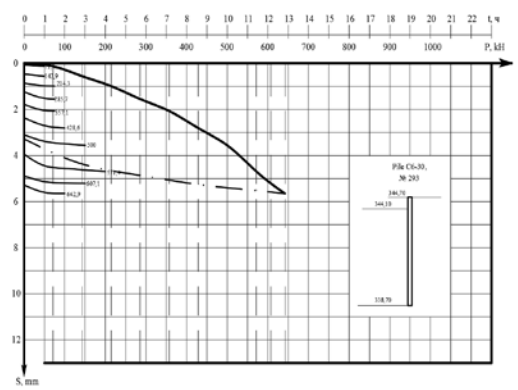


Fig.3 Correlation between settlement S and load P, the results of field static test on pile293

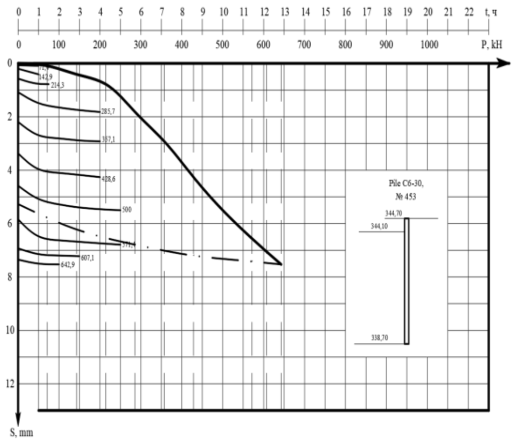


Fig.4 Correlation between settlement S and load P, the results of field static test on pile453

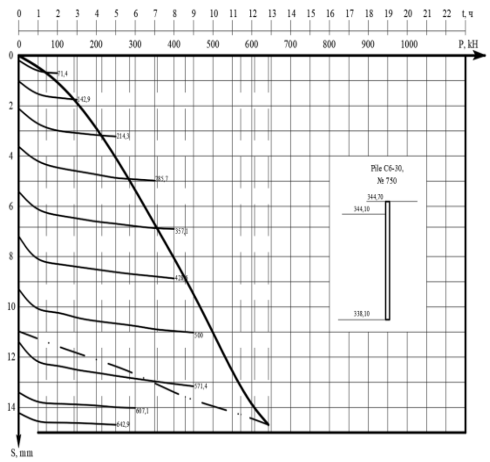


Fig.5 Correlation between settlement S and load P, the results of field static test on pile750

3. NONLINEAR THEORY CREATION AND CALCULATION COMPUTER PROGRAM

The problem solution of a finding of stress-strain state of the reinforced concrete driving pile in a heterogeneous base was done in several publications [9-12]. Figure 6 shows the design scheme with an indication of variation limits of materials types. The design scheme presented that 1 m of pile contacted with geotechnical element number 3.

Figure 7 shows the table with numerical values of materials characteristics according to the color of a names background. It is provided with the fixing ways to the ground in the picture below. Figure 7 specifies the existence of displacement restraint. The table in Figure 8 shows step splitting intervals on the radius and depth where the difference grid knots at the intersection will be located.

The area is divided by parallel lines with the various steps on the radius and depth.

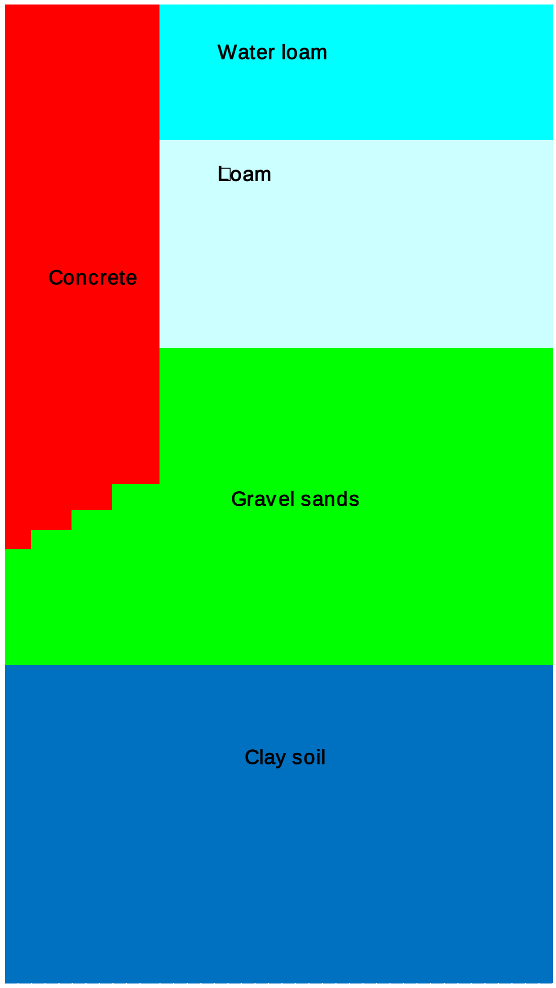


Fig. 6 The design scheme of the concrete driving pile in layered heterogeneous soil

Calculate Material	Modulus of elasticity, MPa	Density, MN/m^3	Poisson's coefficient	Limit deformation angle of internal friction, Gradian	Limit strength, unit cohesion, Mpa
	E	γ	ν	ε	σ
Concrete	30000	0,025	0,3	0,02	17,6
Water loam	47,17	0,02	0,4	19,3	0,0277
Loam	77,5	0,02	0,33	19,3	0,0277
Gravel sands	175	0,02	0,22	38	0,001
Clay soil	65,41	0,02	0,35	25	0,037
		Moves			
Fixing the ends		U	W	Cause	
Top				Surface	
Bottom			1	Non-compressible soil	
Inside		1		Centre	
Outside		1		Untouched soil	

Fig.7 Calculation data of material properties

The calculation computer program of the strain-stress distribution around the bored pile, settlement in the nonhomogeneous layered base, is written in an algorithmic language of Visual Basic.

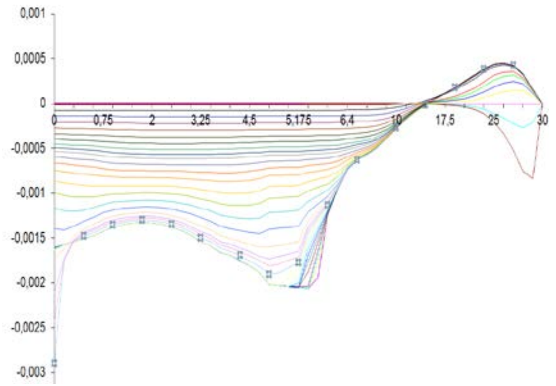
The program, at first scans, Figure 6 and defines borders of materials filling and reads out its characteristics from the table in Figure 8. By means of the table, which is shown in Figure 8, the area is divided into various fragments and the above-created characteristics are a settlement to these rectangular fragments, called difference grid cells.

Radius	Vertical strength on the bottom	Vertical strength on the top	Shear strength on the bottom	Shear strength on the top	Depth	Lateral internally pressure	Lateral internally shear strength	Lateral external pressure	Lateral external shear strength
0	0	10	0	0	0	0	0	0	0
0,009	0	7,08	0	0	0,125	0	0	0	0
0,017	0	7,08	0	0	0,25	0	0	0	0
0,026	0	7,08	0	0	0,375	0	0	0	0
0,034	0	7,08	0	0	0,5	0	0	0	0
0,051	0	7,08	0	0	0,75	0	0	0	0
0,068	0	7,08	0	0	1	0	0	0	0
0,085	0	7,08	0	0	1,25	0	0	0	0
0,102	0	7,08	0	0	1,5	0	0	0	0
0,119	0	7,08	0	0	1,75	0	0	0	0
0,136	0	7,08	0	0	2	0	0	0	0
0,153	0	7,08	0	0	2,25	0	0	0	0
0,17	0	7,08	0	0	2,5	0	0	0	0
0,187	0	0	0	0	2,75	0	0	0	0
0,204	0	0	0	0	3	0	0	0	0
0,238	0	0	0	0	3,25	0	0	0	0
0,306	0	0	0	0	3,4	0	0	0	0
0,408	0	0	0	0	3,75	0	0	0	0
0,544	0	0	0	0	4	0	0	0	0
0,714	0	0	0	0	4,25	0	0	0	0
0,952	0	0	0	0	4,5	0	0	0	0
1,19	0	0	0	0	4,75	0	0	0	0
1,462	0	0	0	0	5,1	0	0	0	0
1,768	0	0	0	0	5,125	0	0	0	0
2	0	0	0	0	5,15	0	0	0	0
2,325	0	0	0	0	5,175	0	0	0	0
2,78	0	0	0	0	5,4	0	0	0	0
3,416	0	0	0	0	5,525	0	0	0	0
4,307	0	0	0	0	5,65	0	0	0	0
5,555	0	0	0	0	5,9	0	0	0	0
7,302	0	0	0	0	6,4	0	0	0	0
9,748	0	0	0	0	6,9	0	0	0	0
13,171	0	0	0	0	7,4	0	0	0	0
14,2	0	0	0	0	8	0	0	0	0
15,1	0	0	0	0	8,8	0	0	0	0
16	0	0	0	0	10	0	0	0	0
16,8	0	0	0	0	11,5	0	0	0	0
17,6	0	0	0	0	13	0	0	0	0
18,4	0	0	0	0	14,5	0	0	0	0
19,2	0	0	0	0	16	0	0	0	0
20	0	0	0	0	17,5	0	0	0	0
					19	0	0	0	0
					20,5	0	0	0	0
					22	0	0	0	0
					23,5	0	0	0	0
					25	0	0	0	0
					26	0	0	0	0
					27	0	0	0	0
					28	0	0	0	0
					29	0	0	0	0
					30	0	0	0	0

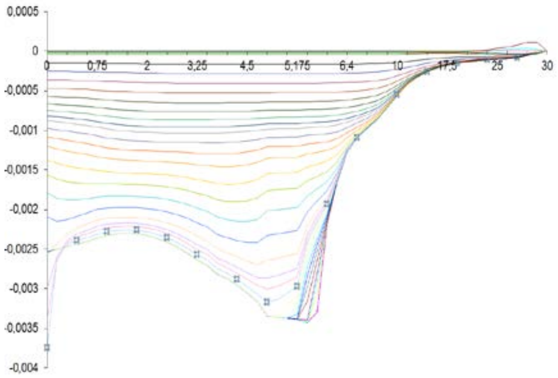
Fig.8 Table of the description of the geometry and loads

The variation and different approach of differential equations solution allow making the algebraic equations of symmetric structure which are effectively solved by Cholesky method [5].

The Figures 9-16 show the strain-stress distribution around the driven pile, settlement in the nonhomogeneous layered base. Figure 9 b) show that such movements of a soil surface are coordinated by sophisticated observations and show the adequacy of the mathematical model of the current task.



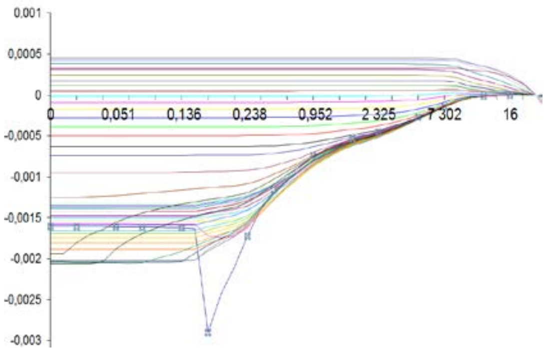
a)



b)

a) linear, b) no linear

Fig.9 Diagram of vertical displacements W on z



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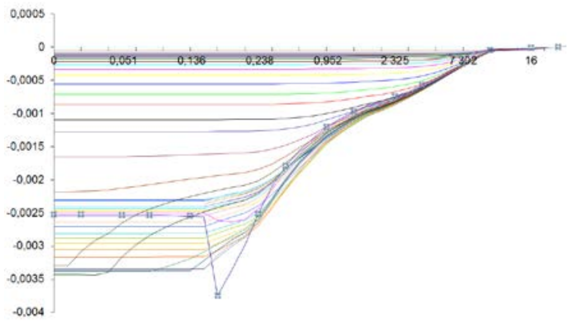
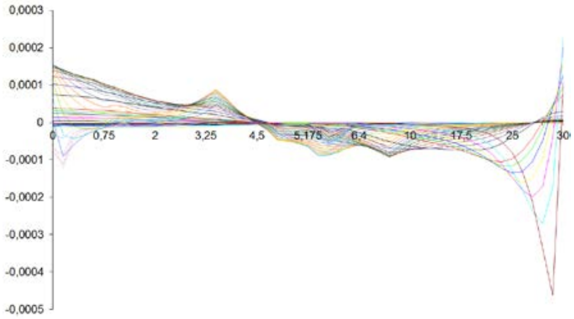


b)

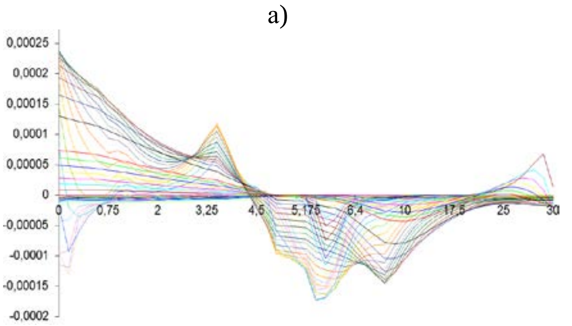
a) linear, b) no linear

Fig.10 Diagram of vertical displacements W on r

The value of the maximum vertical displacements of the tip of the piles is W = 3.4 mm. It is equal to the experimental value 3.76 mm. The difference is 9% (see Figure 10 b).



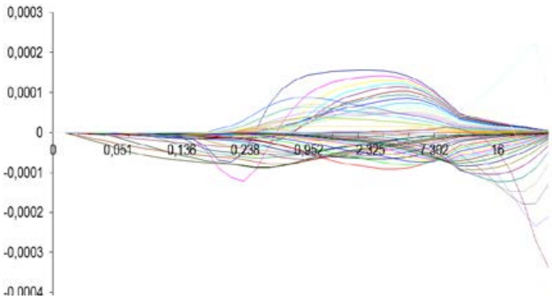
a)



b)

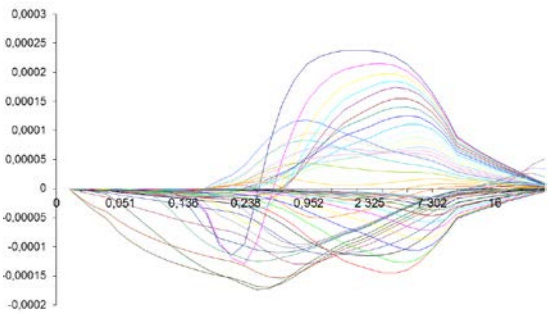
a) linear, b) no linear

Fig.11 Diagram of radial displacements U on z



a)

Figures 11-13 show that deformation occurs near the surface of the piles changed in the diagram of radial displacements U.

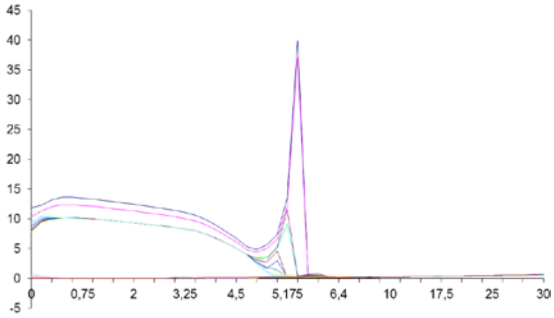


b)

a) linear, b) no linear

Fig.12 Diagram of radial displacements U on r

A significant decrease of value and attenuation of the discontinuous changes in the radial displacements presented nonlinear determination in comparative analyses with linear determination.



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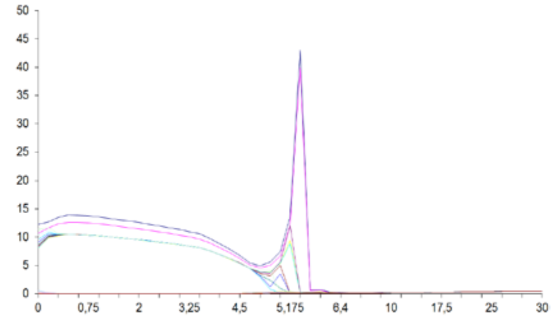


b)

a) linear, b) no linear

Fig.13 Diagram of vertical stress σ_z

Diagram 14 presented an uneven distribution of stresses on the surface of the application (concentration of stresses near the center), although they are evenly distributed.

The vertical load causes increased some non-linear stresses near the bottom, associated with the action of the own weight of the pile.

Figure 15 show the concentration of tensile stresses up to 6 MPa vertically near the center of the piles on the radial stress σ_θ plots passing to compressive stresses. At the tip of the pile, the stress value increased up to 20 MPa.

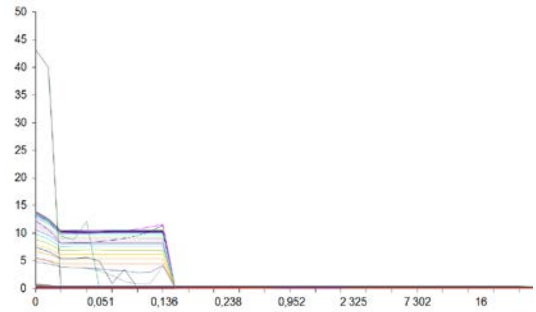
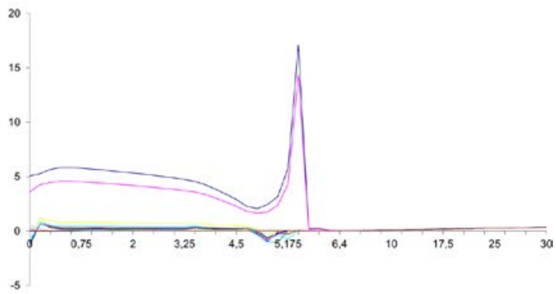


Fig.14 Change diagram of no linear vertical stress σ_z

Diagram 16 shows that shear stress increased from the center to the periphery, spreads vertically within the outer surface of the piles at the points of contact with the base. Values are negligible and splashes are not observed.



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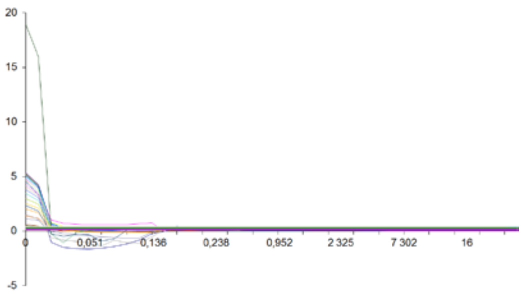

b)

a) no linear, b) linear

Fig.15 Diagram of radial stress σ_θ

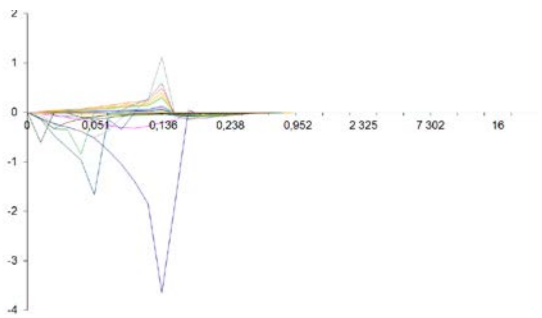

Fig.16 Change diagram of shear stress τ_{rz}

4. RESULTS

The study resulted in the following:

1. It can be seen, on the displacement profile, according to the figures that the value of the maximum vertical displacements of the tip of the piles is W = 3.4 mm. It is equal to the experimental value 3.76 mm. The difference is 9%.

The results show that computer program results agree with the results of the static test.

2. The obtained results of the calculation are agreed with the known decisions and demonstrate the adequacy of the developed mathematical model to the original problem;

3. The analysis of the obtained results confirms a possibility of the developed technique use for a solution of a wide range of relevant geotechnical tasks.

5. CONCLUSION

The calculation computer program of the driven pile with the real diagrams of material deformation of a pile and surrounding rocks massif has been created.

The computer program allows receiving the stress deformed state of a pile and the surrounded massif as one nonhomogeneous body, having Prandtl's diagram for concrete and Botkin's diagram for different types of soil. A new method for solving problems of pile foundations is presented as an alternative to the design of pile foundations according to the requirements of the Kazakhstan standards SNIP 5.01-03-2002 “Pile foundations” [13]. This program can be used in the harmonized standard. The Modernization of the normative base allows completing usage of advanced technology in existing construction condition.

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