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INFLUENCE OF STAGE-BY-STAGE CONSTRUCTION OF A CYLINDRICAL SHELL ON STRESS-STRAIN STATES OF AN EXISTING NEARBY SHELL IN A SOIL BODY

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Abstract: a study was carried out on influence of stage-by-stage construction of a cylindrical shell on stress-strain states of an existing nearby shell in a soil body. Additionally, a case is considered in which the stage-by-stage construction of shells was not taken into account. The obtained results were analyzed by the authors.

Keywords: construction stages, soil body, shell, finite elements, contact elements.

О ВЛИЯНИИ ПОЭТАПНО ВОЗВОДИМОЙ ЦИЛИНДРИЧЕСКОЙ ОБОЛОЧКИ НА НДС СУЩЕСТВУЮЩЕЙ БЛИЗЛЕЖАЩЕЙ ОБОЛОЧКИ И ИХ ЕДИНОГО ОКРУЖАЮЩЕГО ОСНОВАНИЯ

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Аннотация: в работе проведено исследование влияния поэтапно возводимой цилиндрической оболочки на напряженно-деформированные состояния существующей близлежащей оболочки и их единого окружающего основания. Дополнительно рассмотрен случай без учета этапности сооружения оболочек. Полученные результаты проанализированы авторами.

Ключевые слова: стадии строительства, грунтовый массив, оболочка, плоские и пространственные конечные элементы, контактные конечные элементы.

1. INTRODACTION

There is a problem of evaluating the impact of potential future construction of the cylindrical shell of a new tunnel on the stress-strain state of the cylindrical shell of an existing tunnel built earlier. Similar problems emerged when designing the first variant (with two tube tunnels) of the Lefortovo tunnel in Moscow. Calculations of such systems are known in two-dimensional formulation. For example, S. B. Kositsyn and D. B. Dolotkazin explored the effect of some features of the Lefortovo tunnel on its stress-strain state by the finite element method [4].

2. NUMERICAL ANALYSIS OF STRESS-STRAIN STATES OF CYLINDRICAL SHELLS IN A SOIL BODY

The calculation of the stress-strain state of shells was performed by the finite element method in the ANSYS Mechanical software package [2, 3, 6, 8, 11, 12].

The developed spatial computational models includes two parallel cylindrical shells and a soil body. The purpose of the study is to determine how the phased construction of a new cylindrical shell affects the stress-strain state of the existing shell built earlier. The geometric characteristics of cylindrical shells in the computational model are close to the initial data of the work [4]. The diameter of the shell D = 13.5 m, the thickness of the shell t = 0.7 m, depth of cylindrical shells Z = 25.0 m, distance between the axes of shells – *2D*. The distance between the shell and the left and right sides of the soil body is $W = 5D$. The distance between the shell and the upper side of the soil body is $H = 5D$. Both cylindrical shells consists of 32 separate rings with a width of 2.8 m.

The material of the cylindrical shell is presented by a linear-elastic model with the following characteristics: density ρ – 2300 kg/m3, elastic modulus E – 30000 MPa, Poisson's ratio μ – 0.2. The material of the soil body [9] is presented by an elastic-plastic model of Mohr–Coulomb with the following parameters: density ρ – 2000 kg/m^3, deformation modulus E_{def} – 10 MPa, Poisson's ratio μ – 0.3, cohesion C_u – 10 kPa, friction angle φ – 25°. These material models require a physically nonlinear calculation.

The soil body has constraint on the side faces and on the bottom face. The load consists of the own weight of the soil body and the cylindrical shells. In addition, there is a gap between the shell and the soil body in the computational model [7, 10], which takes into account the influence of a slurry shield during the construction of the cylindrical shell (the friction coefficient f = 0.6) [5].

The calculation was done geometrically, structurally and physically nonlinear statement.

The design case consists of 65 stages of determining the stress-strain state of the cylindrical shell and the soil body: the first (zero) stage calculates the natural state of the soil body without the shell, the next 64 stages calculate the stress-strain state of the model after activating each individual ring of shells (thirty-two stages for each shell). The change in the stress-strain state is considered for the elements of the shell installed first. This makes it possible to evaluate the impact of the construction of the second shell on the first.

The spatial computational model is shown in figure 1. The cylindrical shells are shown in figure 2.

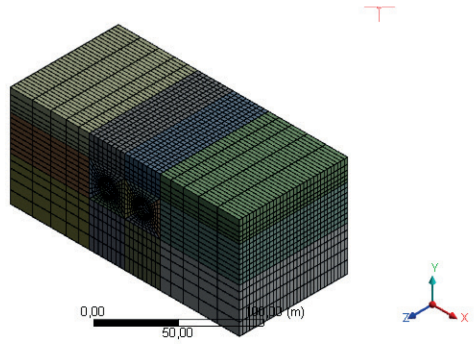

Figure 1. Spatial computational model in ANSYS Mechanical

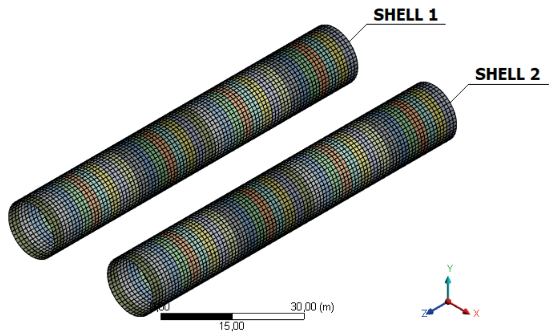

Figure 2. View of cylindrical shells

The equivalent stresses curves according to the IV strength theory (von Mises) [1] of the cylindrical shell rings are shown in figures 3 – 11. Vertical green lines on the graphs separate the stages of construction of the first and second shells.

Table 1 shows the values of the stress increase caused by the construction of the second shell, and their percentage share for the considered rings of the first shell.

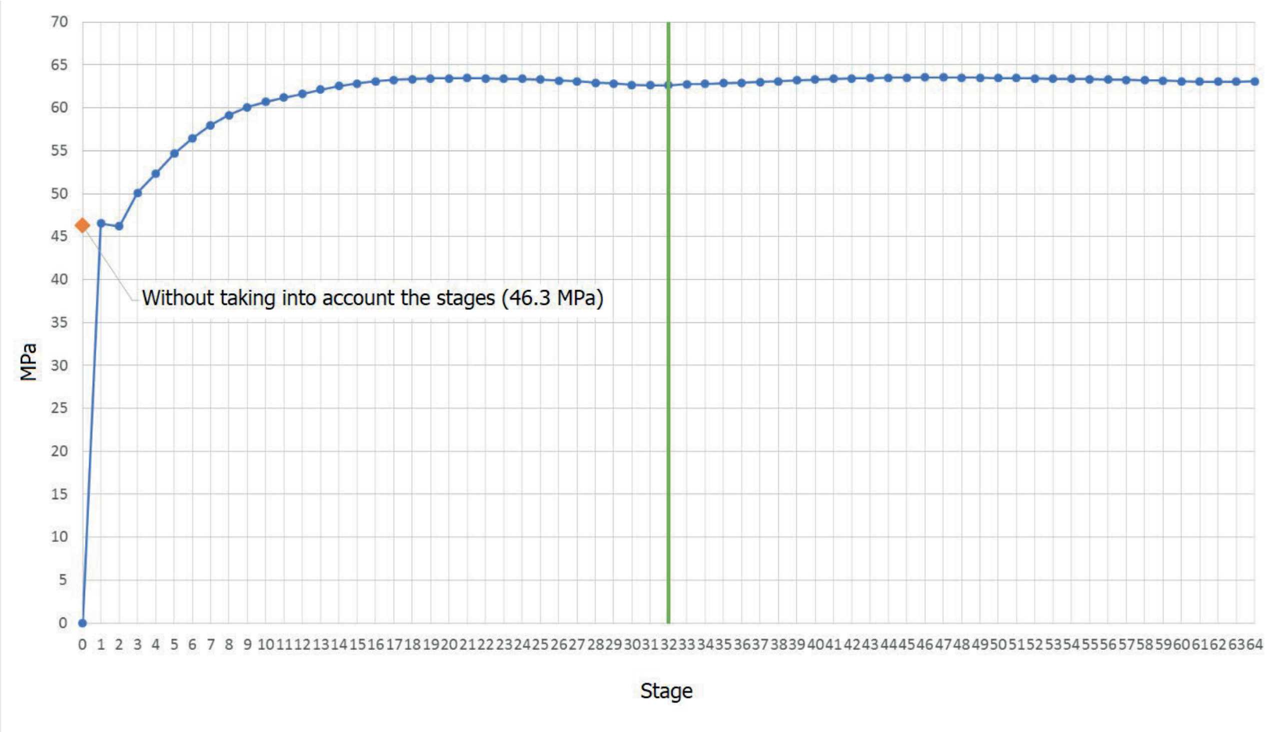

Figure 3. *The maximum equivalent stresses according to the IV strength theory (von Mises) of 01 ring of the first shell*

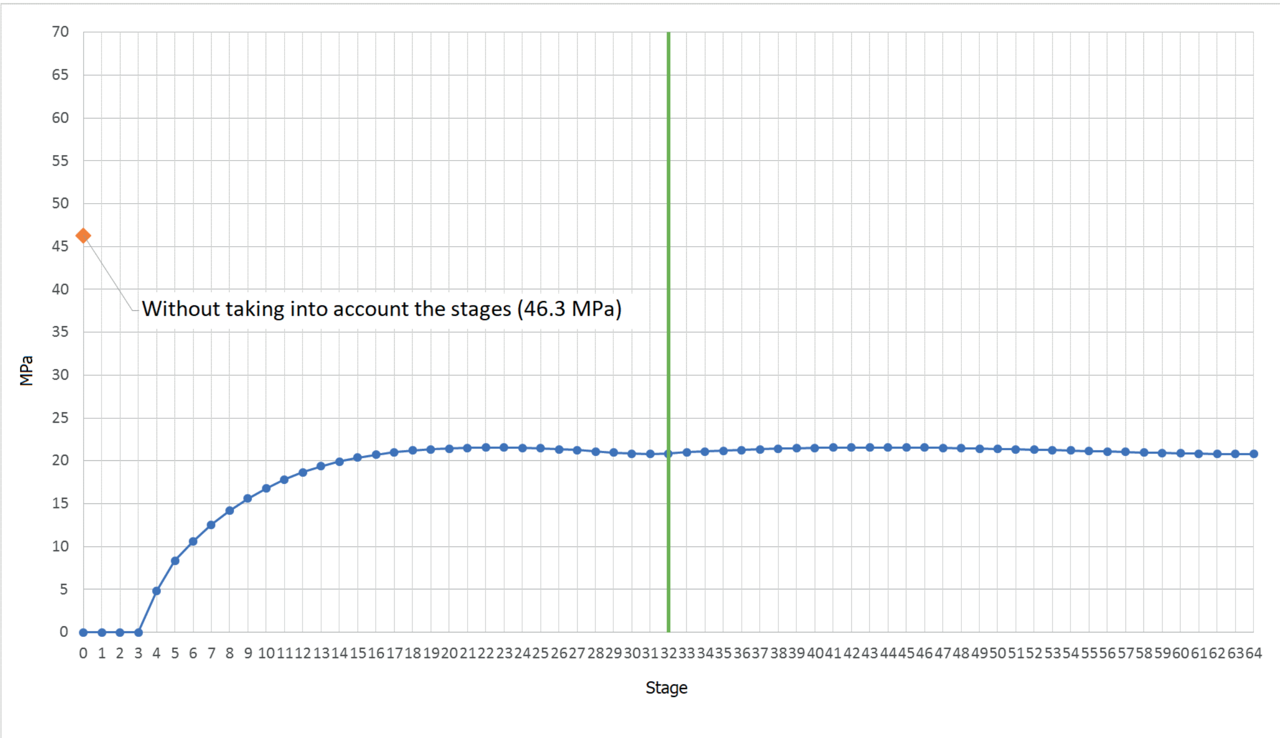

Figure 4. *The maximum equivalent stresses according to the IV strength theory (von Mises) of 04 ring of the first shell*

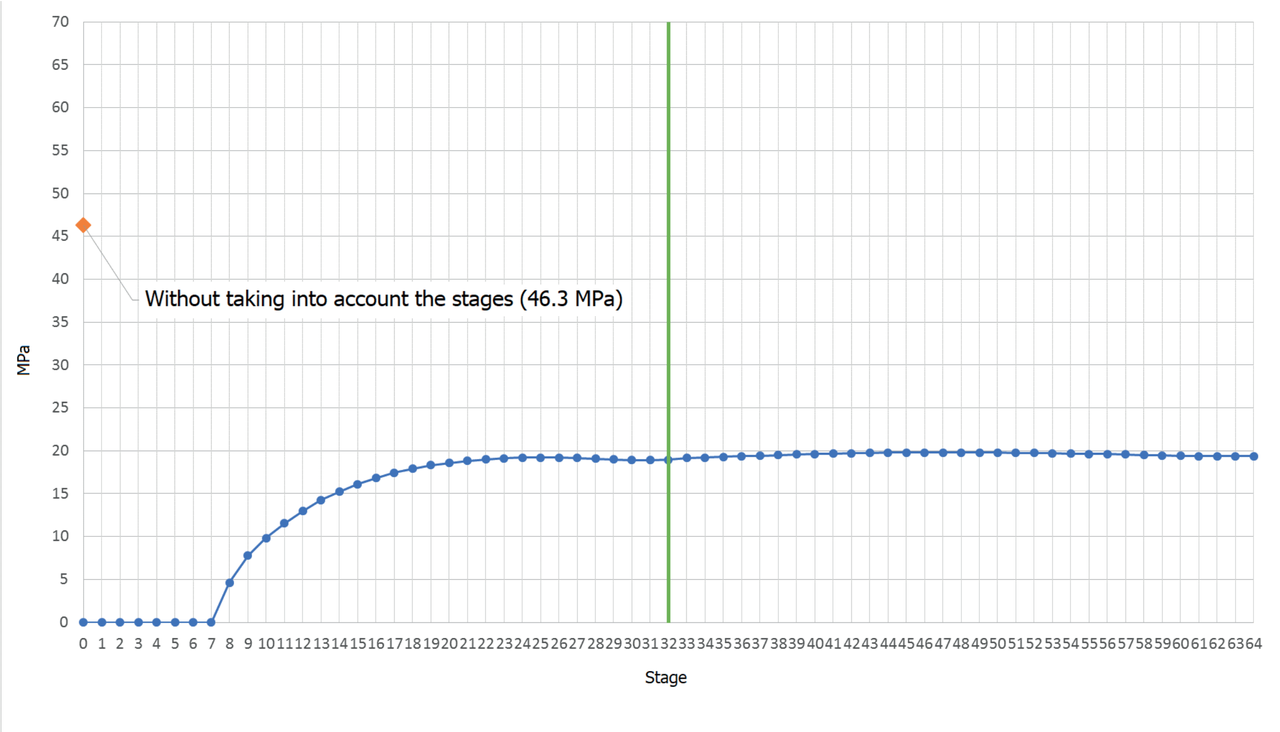

Figure 5. *The maximum equivalent stresses according to the IV strength theory (von Mises) of 08 ring of the first shell*

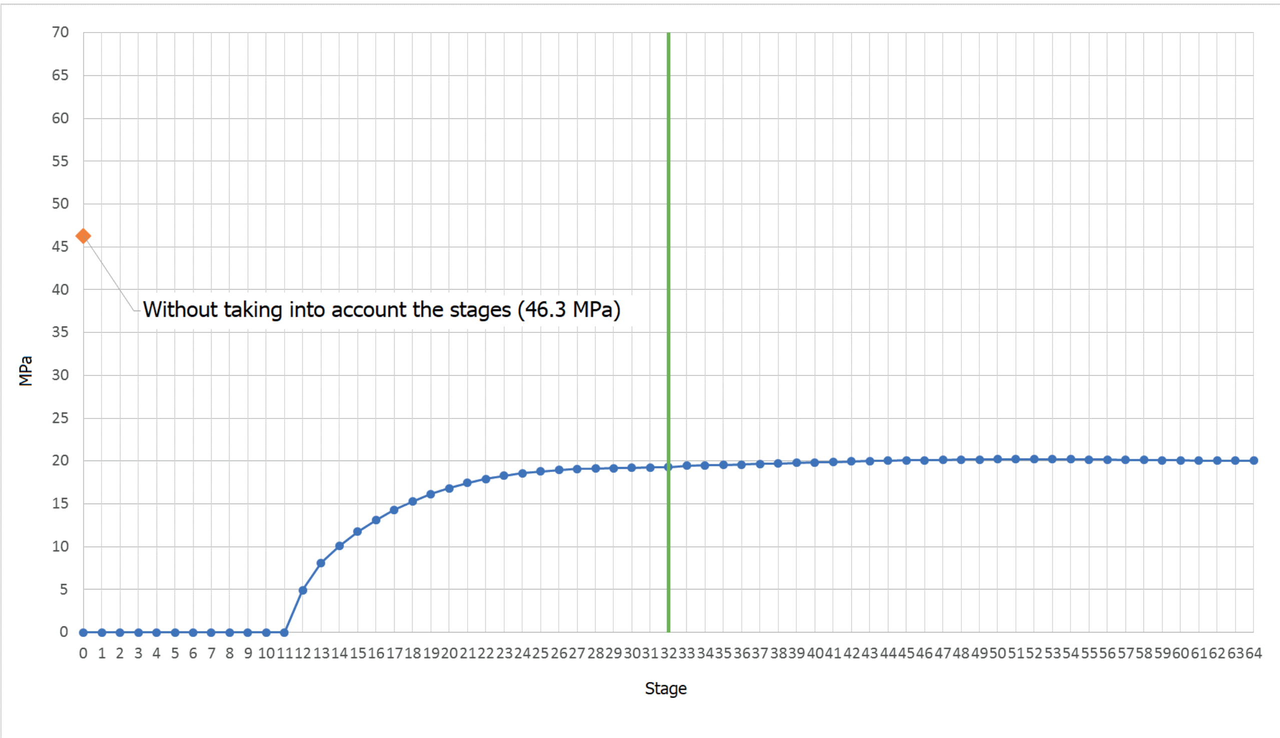

Figure 6. *The maximum equivalent stresses according to the IV strength theory (von Mises) of 12 ring of the first shell*

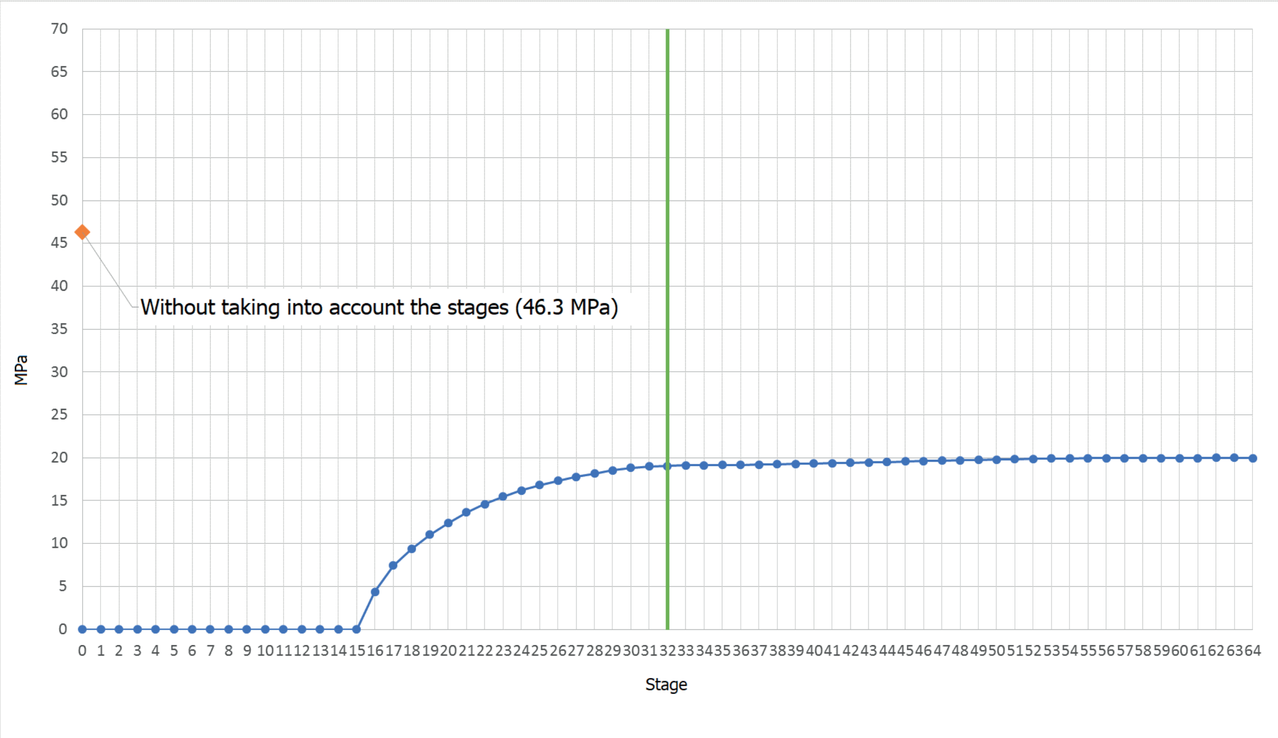

Figure 7. The maximum equivalent stresses according to the IV strength theory (von Mises) of 16 ring of the first shell

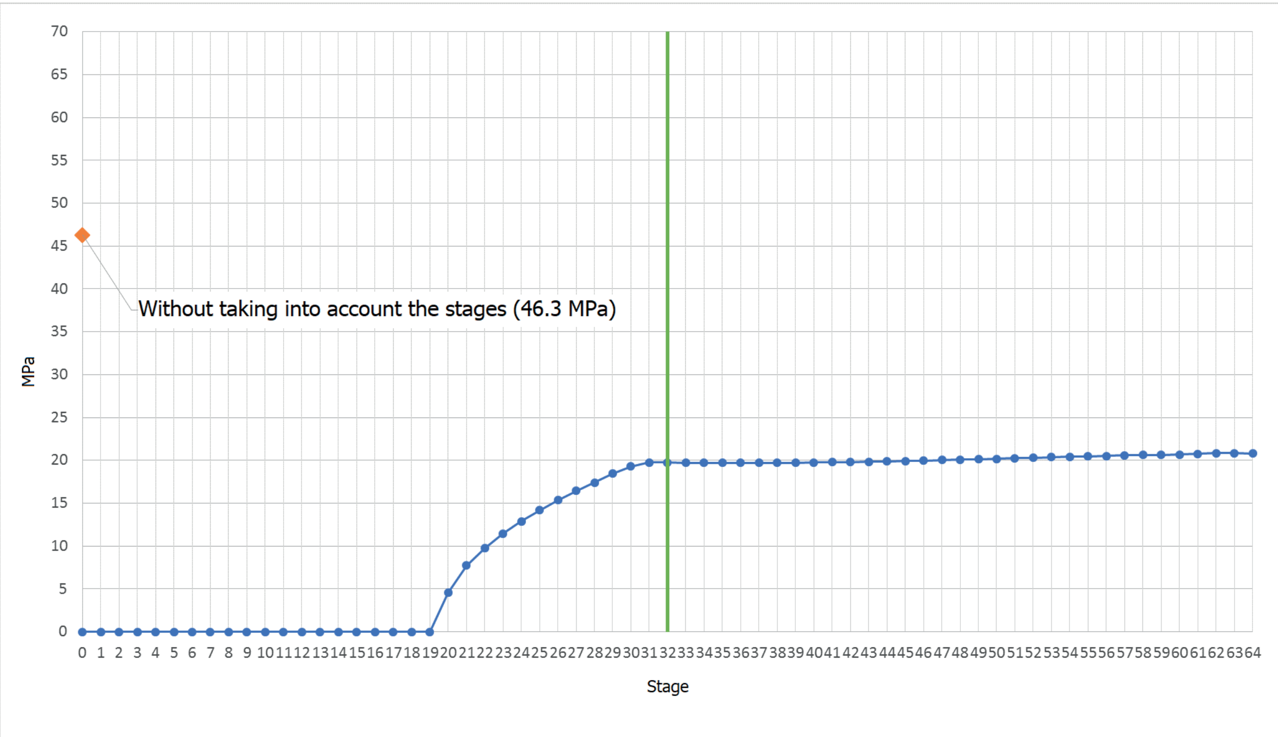

Figure 8. The maximum equivalent stresses according to the IV strength theory (von Mises) of 20 ring of the first shell

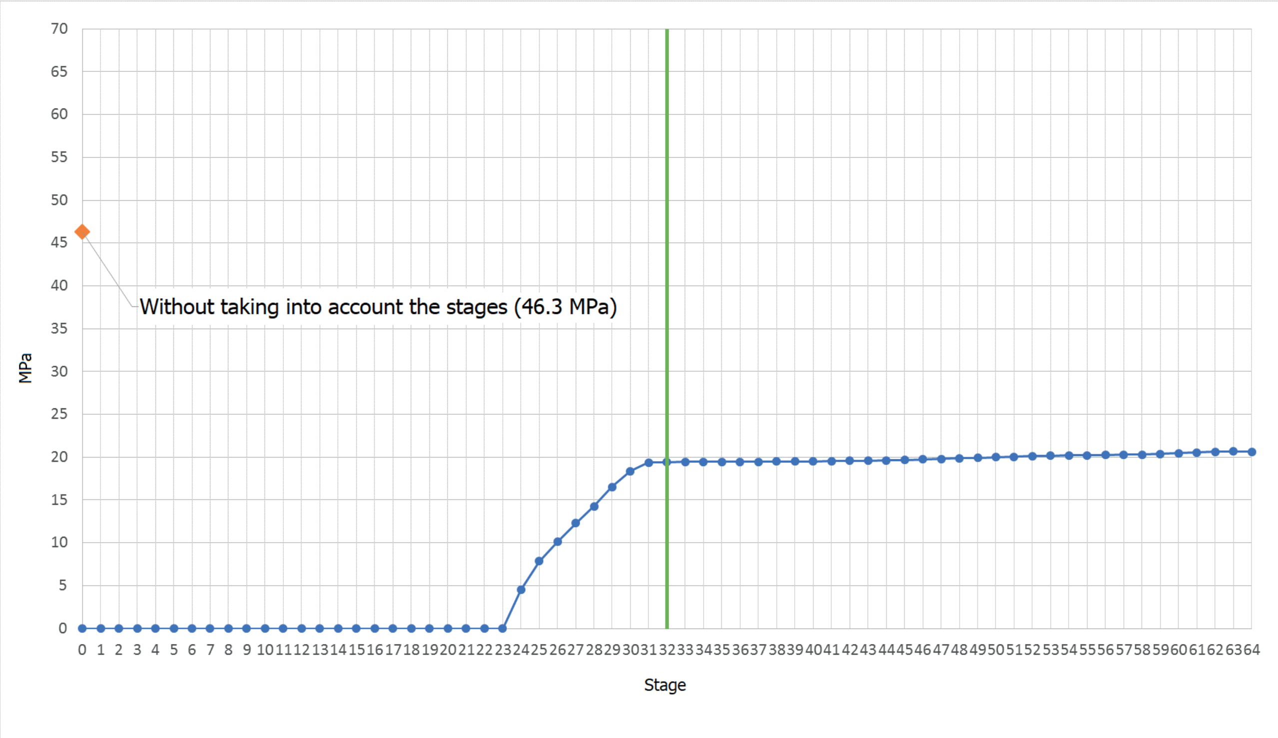

Figure 9. The maximum equivalent stresses according to the IV strength theory (von Mises) of 24 ring of the first shell

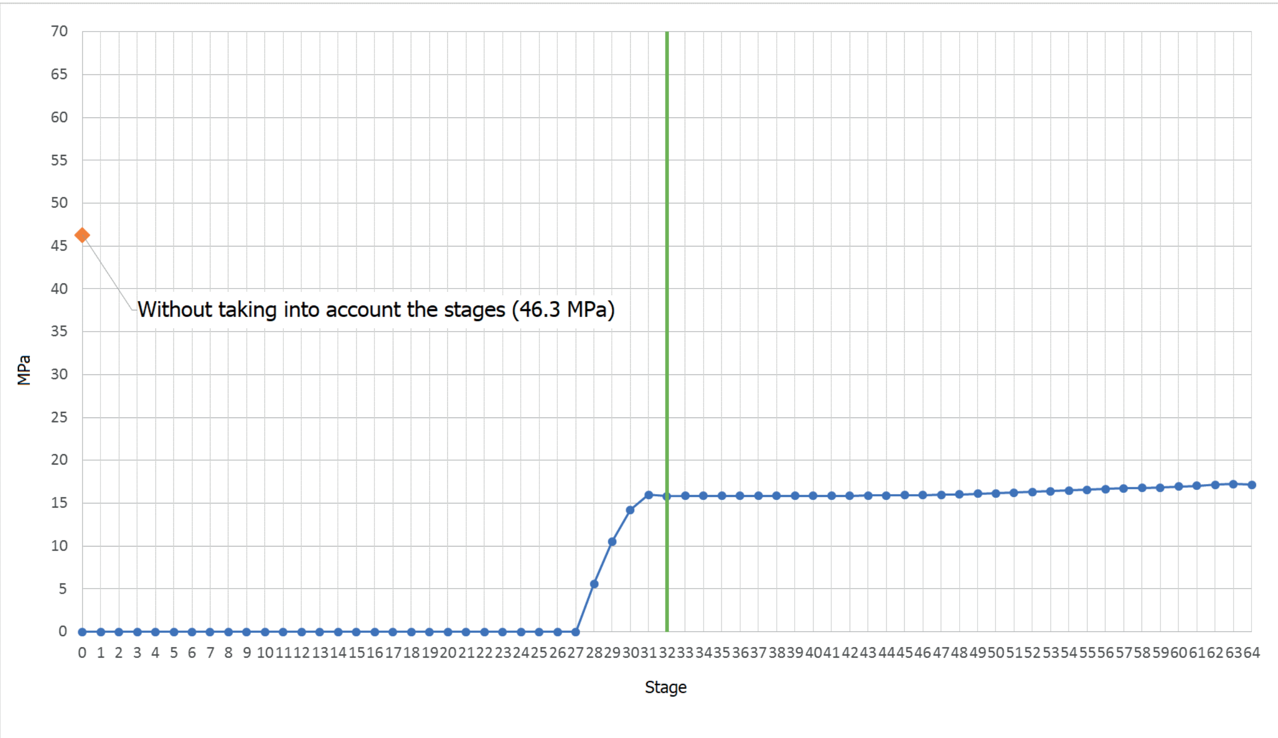

Figure 10. The maximum equivalent stresses according to the IV strength theory (von Mises) of 28 ring of the first shell

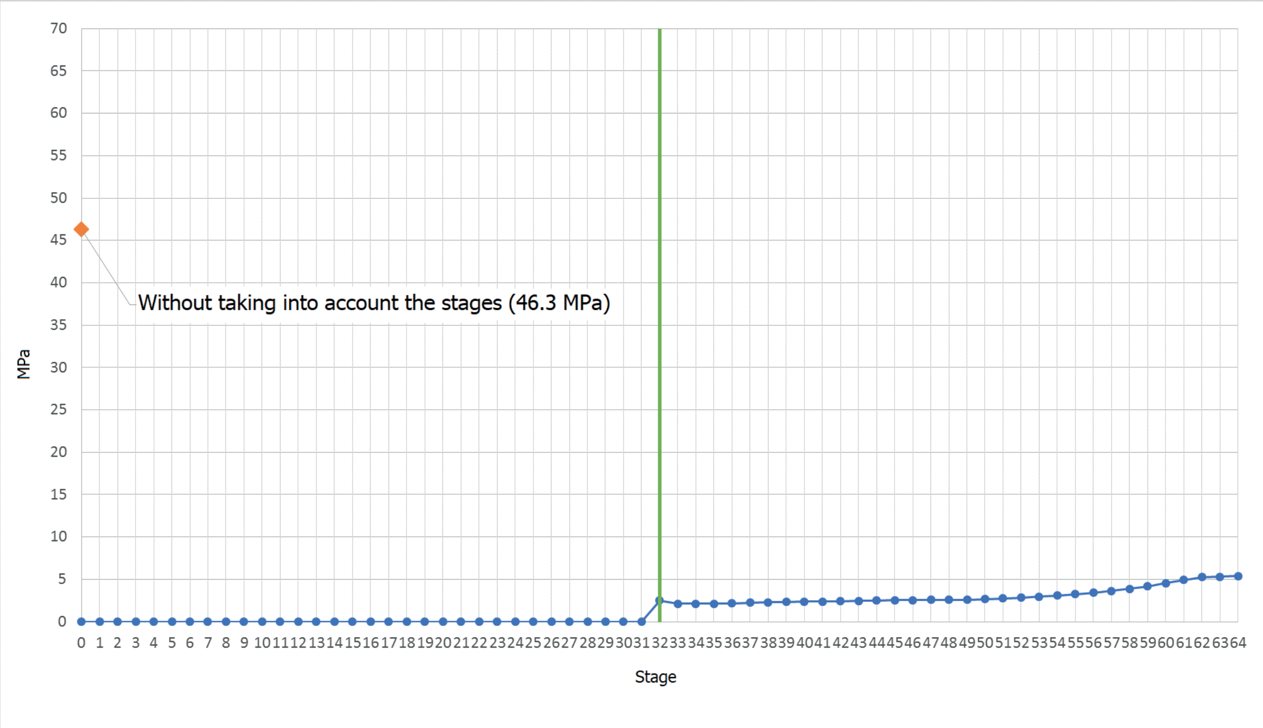

Figure 11. The maximum equivalent stresses according to the IV strength theory (von Mises) of 32 ring of the first shell

Table 1. The increase in the equivalent stresses according to the IV strength theory (von Mises) in the considered rings of the first shell

Shell ring	Increase in equivalent stresses, MPa	%
1	0.08	0.1
4	0.04	0.2
8	0.59	3.1
12	0.91	4.7
16	0.94	4.9
20	1.11	5.6
24	1.26	6.5
28	1.25	7.8
32	2.89	116.8

The results show that the construction of the second shell has little impact on the existing shell. The increase in equivalent stresses is 116.8 % only in the last ring. This is due to the fact that the last ring is underloaded more than the others during the construction of the first shell. However, this ring takes a new load equally with the others during the construction of the second shell. The stresses increase does not exceed 7.8 % in rings from 1 to 28. The maximum equivalent stresses in the shells are 46.3 MPa in the calculations without taking into account the construction stages. Table 2 shows the stresses in the first shell from the calculated cases, taking into account and without taking into account the stages of construction, as well as the difference of these stresses as a percentage. Higher stresses were obtained in all the shell rings without taking into account the construction stages, except for the first one.

Table 2. The maximum equivalent stresses according to the IV strength theory (von Mises) for the calculated cases with and without taking into account the stages

Shell ring	Maximum equivalent stresses, MPa		The difference of the maximum equivalent stresses, %
	Without taking into account the stages	With taking into account the stages	
1	46.3	63.5	37 %
4	46.3	21.6	– 53 %
8	46.3	19.8	– 57 %
12	46.3	20.2	– 56 %
16	46.3	20.0	– 57 %
20	46.3	20.8	– 55 %
24	46.3	20.7	– 55 %
28	46.3	17.2	– 63 %
32	46.3	5.4	– 88 %

3. CONCLUSION

The authors consider the features of the stress-strain state of a system consisting of two parallel cylindrical shells and a soil body. In this paper it is shown how the phased construction of a new cylindrical shell affects the existing nearby shell. The results obtained showed that this effect is insignificant. The stress increase for all the considered rings of the first shell does not exceed 7.8 %, except for the last ring, where the stress increase is 116.8 %.

Additionally, the stress-strain state of the first shell is compared with and without taking into account the stages of construction. The comparison showed that it is necessary to take into account the stages of construction of cylindrical shells in such tasks.

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