Bulletin of the *Transilvania* University of Braşov • Vol. 5 (54) - 2012
Series 1: Special Issue No. 1

STUDIES OF CONSOLIDATION SOLUTONS CONSIDERING FOUNDATION SOIL AND AN OPEN CAISSON WITH THE FUNCTION OF "WASTEWATER PUMPING STATION"

I. TUNS[1] **M. MĂNTULESCU**[1] **ZS. SZEKELY**[2]

Abstract: *The consolidation solutions presented in this work refer to the location of the related construction of a Water treatment plant and the walls of an open caisson as a result of foundation depth modification. The analyzed consolidation solutions have targeted the load bearing capacity of the land and the opening of the caissons wall cracks, given that it has to meet the designed function within the Water treatment plant.*

Key words: *open caisson, consolidation solutions, cracks, displacements.*

1. Introduction

The works subjected to investigations are making part of an aggregate of buildings within a Water treatment plant that was in an ample process of rehabilitation and extinction.

During the course of the works it was found the presence of an inappropriate foundation ground stratification corresponding to the Biological reactor which is composed of a series of basins, six rectangular semi recessed basins by number, as the need to change the foundation depth of the Wastewater pumping station having a reinforced concrete structure.

All of these facts have determined the need to make studies and investigations concerning identification, proposal and optimization within technical and economical aspects of the consolidation solutions according to specific performance requirements of the given destination.

1.1. General presentation of the foundation soil

The Biological reactor of the Water treatment plant is composed of six rectangular basins, with 52,70 x 80,00 m in plane dimensions and the following structural characteristics:

1. 0,50 m thick concrete slab foundation with flaring until 0,80 m at the walls
2. reinforced concrete walls embedded in the slab foundation with variable section in

[1] Department of Civil Engineering, Faculty of Civil Engineering, *Transilvania* University of Braşov
[2] Dept. of Structures, Faculty of Civil Engineering, Technical University of Cluj-Napoca

height, 0,80 m at the base and 0,30 m at the top of the wall

During the execution of the excavation works for this object the workers found at the foundation depth a layer of loose soil, the stability being well under the effective pressure that develops between the contact surfaces of foundation and foundation soil.

From a hydrological angle of view the zone is belonging to the Olt river and the Vulcanita creek.

In the soil log executed on an artificial terrace with a width of 15 m the following stratification was identified :

- 0,30 m, top soil;
- 0,30-3,50 m, refuse of industrial origin, p_{conv}=70 KPa;
- 3,50-5,00 m, loamy dust, I_c=0,5-075, e=0,70;
- Under 5,00 m, clay layer, I_c=0,75-1,0, e=0,70;

The confined ground water is met at 3,50 m under the ground.

A section regarding the soil stratification is showed in Figure 1.

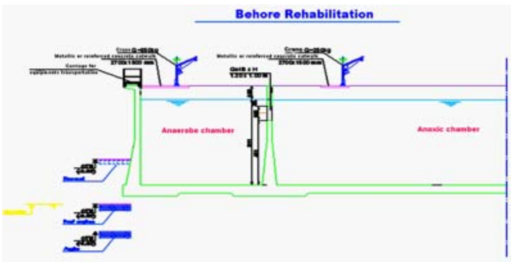

Fig. 1. *Soil stratification*

1.2. General presentation of Wastewater pumping station

The building of the Wastewater pumping station is realized of an open caisson with a square transversal section (7,00 x 7,00 m), the reinforced concrete walls having a thickness of 0,50 m.

Due to changes in the treatment plant entrance depth of the collector with a diameter of 1200 mm and given the advanced stage of construction works on the caisson, the designer has decided to adopt a constructive solution to keep the built structure and in the same time to strengthen the walls without any sectional modification. The collector enters the plant lower than the given depth with 3,50 m, which means that the 7,50 m high caisson has to be completed with a 3,50 m segment.

This major structural modification includes a modification in pressures too. The efforts that are developing bend the walls in a more stronger way, the result is the opening of the cracks in an aggressive and underwater environment. The displacements must not pass 1 mm to avoid cracks and to respect the safety characteristics of the building. Without a consolidation the walls will have displacements of 3,65 mm.

The majored efforts resulted as a sum of the following actions:

1. Increased earth pressure
2. Increased water pressure

The reasons why the consolidation takes place:

1. Economical – it costs more if the caisson is demolished and built again than a consolidation for the existing structure
2. Time management

2. Description of consolidation works

The presented studies and investigations in the work contain major branch components:

1. The consolidation of the foundation soil
2. The structural consolidation of an open caisson

2.1. The consolidation of the foundation soil

The consolidation works consist of realizing a ballast cushion by laying out and compaction by successive layers, 20-

60 cm in height. These layers are compacted several times successfully with a steam roller.

Loose filling of waste, which is the base layer is replaced with the ballast cushion because foundations you can not be realized on aggressive, inhomogeneous lands, whose aggressive behavior can not be determined, the reactive pressures being under the value of 80 KN / m^2. By simply using super heavy rams, the compacted surface would reach higher resistance but uniform compaction can not be achieved.

Following the consolidation operations, it will result a pressure of 350 kN/m^2 admissible to those developed, much lower as value. The ballast cushion fillings will be made as prescribed in the following according to the granularity of the material [1], [2] (Table 1):

Material characteristics Table 1

Charact.	Symbol	MU	Blocks
Dry vol. weight	γ_d	kN/m^3	21,5
Optimum compaction moisture	ω_{opt}	%	4-6
Degree of tamping	I_d	-	-

The simulations and calculations are made in a specific software for building structures. This software is the AxisVM, which helped to define all the efforts in different layers of the foundation soil.

First of all we determined all the efforts on the foundation basis obtaining the following maximum values on the diagram (Fig. 2, Table 2):

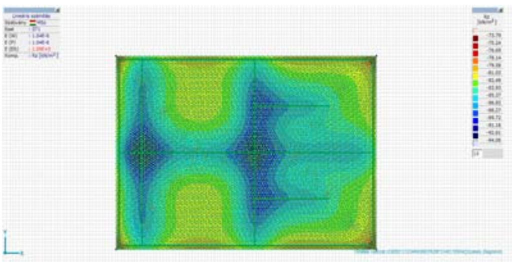

Fig. 2. *Pressure diagram*

Reactions [linear, ST1] Table 2

Nod	Surface	R_z [kN/m^2]
1109	1750. shell	**-94.00**

As a second step, it were determined all the pressures between the second and third soil layer in order to see that the lower layers are resisting well to the consolidation processes (Fig. 3, Table 3).

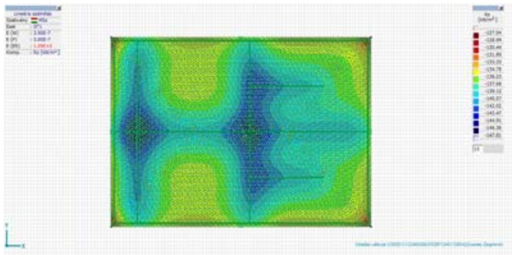

Fig. 3. *Pressure diagram*

Reactions [linear, ST1] Table 3

Nod	Surface	R_z [kN/m^2]
1109	1750. shell	**-147.75**

- $P_{adm} > P_{ef}$; 2,88 daN/cm^2 > 1,47 daN/cm^2.

The same procedure is followed in determining the efforts between the third and the fourth soil layers (Fig. 4, Table 4).

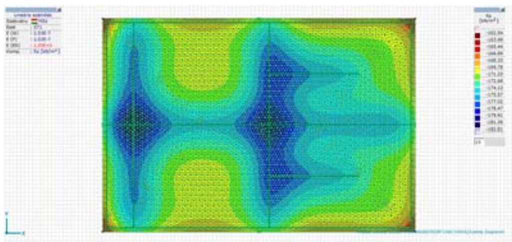

Fig. 4. *Pressure diagram*

Reactions [linear, ST1] Table 4

Nod	Surface	R_z [kN/m^2]
1109	1750. shell	**-182.75**

2.2. The structural consolidation of the caisson

The main changes which determined the consolidation of the caisson were the followings:

- Failed depth given by the designer for the collector which enters the Water treatment plant
- The depth difference was 3,50 m
- Partial realization of the caisson, when the failure was found, the caisson was 75 % finished
- Keeping in touch with the initial working schedule

The software that were used in the calculations are Abacus Simulia for the composite solution of consolidation and AxisVM for the traditional consolidations [4].

First we simulate effective displacements on the caisson with the initial transversal section characteristics but with a different height of 11,00 m instead of the initial 7,50 m (Fig. 5, Table 5).

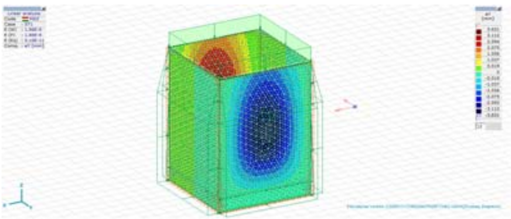

Fig. 5. *Displacement diagram*

Displacement diagram Table 5

Nod	e_y [mm]	f_x [rad]	f_y [rad]	f_z [rad]
6723	**3.631**	0.00001	0	0.00004

In order to reduce these displacements it was analyzed three different solutions of consolidations:

- Two reinforced concrete frames placed in cross form.
- A reinforced concrete frame with one column and cross beams.
- Composite material applied on the inner surface of the walls.

a. The first consolidation solution

The consolidation structure is made of two reinforced concrete frames consisting of 4 columns and 4 beams. These frames are forming a cross in plan, in order to reduce displacements. The height of the frames is 7,50 m, which covers the main zones where displacements have the biggest values. The columns sectional dimensions are 0,50 x 0,50 m, the beams having 0,40 x 0,60 m as sectional dimensions.

It can be observed that the displacements are reducing substantially, the biggest displacements being situated at the top of the caisson e_X=1,659 mm. In the bottom half zone of the structure the displacements are almost zero (Fig. 6, Table 6).

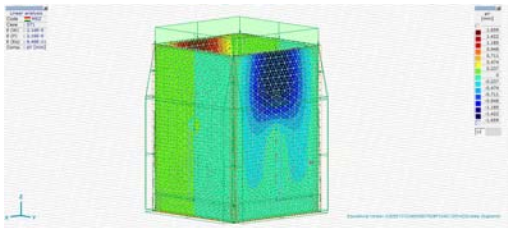

Fig. 6. *Displacement diagram*

Displacement diagram Table 6

Nod	e_x [mm]	f_x [rad]	f_y [rad]	f_z [rad]
4486	**1.659**	0	0.00004	0

b. The second consolidation solution

The consolidation system is one special with one column in the middle intersection and four beams with four feets to ensure a better and bigger supporting surface (Fig. 7).

The height of the consolidation structure is the same like in the first consolidation situation.

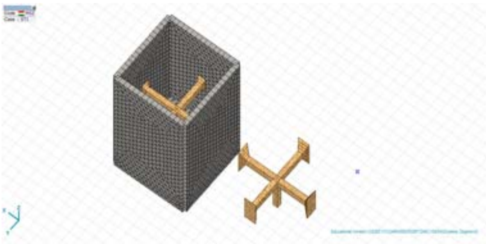

Fig. 7. *Consolidation solution*

It can be observed that the displacements are reducing substantially, the biggest displacements being situated at the top of the caisson e_X=1,784 mm. In the bottom half zone of the structure the displacements are approximately the same ones like at the top of the caisson (Fig. 8, Table 7).

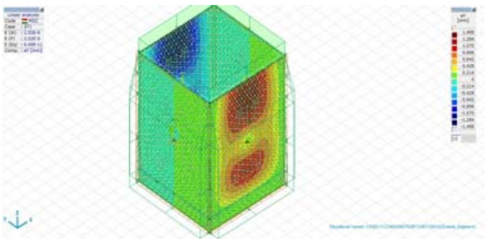

Fig. 8. *Displacement diagram*

Displacement table Table 7

Nod	e_x [mm]	e_z [mm]
1690	**-1.784**	-0.462

c. Third consolidation solution

Fibre reinforced polymer composites are used on a large scale in the rehabilitation of structures or structural elements, especially in the case of buildings when traditional solutions are found deficient.

Applying this support material includes the application of special epoxy resins. The final thickness of 3 cm will be reached with 6 layers bonded to each other [5].

The work between the layers is considered ideal, there is a perfect contact between the composite materials that were used. The purpose of the application is to reduce the bending of the walls in an efficient and uniformly distributed form.

The composite layer will cover the entire inner surface of the caisson's walls from the slab foundation to the top of the wall.

For the simulation it was used the following mechanical properties of the composite material (Table 8, Fig. 9).

Mechanical properties [8] Table 8

E_{12}	E_{23}	E_{13}	G_{12}	G_{23}	G_{13}
147 GPa	10,3 GPa	10,3 GPa	7 GPa	3,7 GPa	7 GPa
ν_{12}	ν_{23}	ν_{13}			
0,27	0,54	0,27			

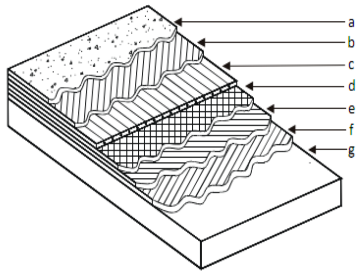

Fig. 9. *Composite structure*

Where:
a. protective coating; b. resin layer; c. composite polymer; d. resin layer; e. lute; f. primer; g. reinforced concrete; [6].

It can be observed that the displacements are reducing substantially, the biggest displacements being situated at the top of the caisson e_X=0,9335 mm. The biggest difference in comparison with the traditional consolidation solutions is that when have a uniform distribution of the efforts (Fig. 10, 11).

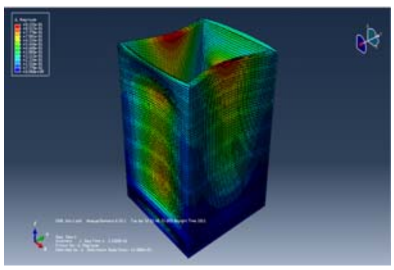

Fig. 10. *Displacement diagram*

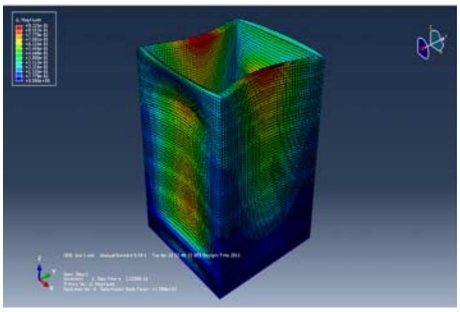

Fig. 11. *Sectional displacement diagram*

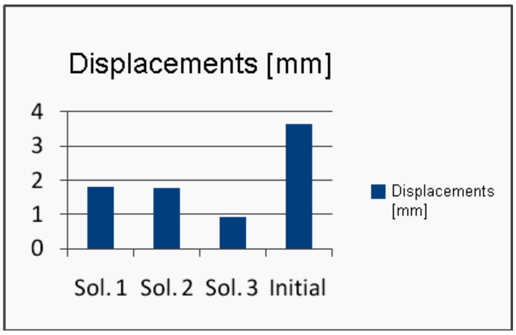

Fig. 12. *Displacement chart*

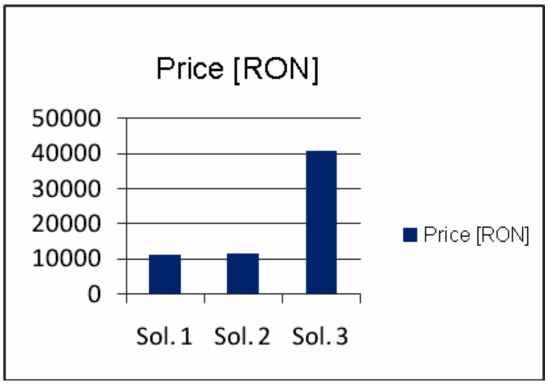

Fig. 13. *Cost chart*

3. Conclusions

a. The classical solutions with a reinforced concrete frames are cheaper than the third solution with composite materials.

b. The first structure ensures a greater weight than the other solutions.

c. The period of time is equal for all the consolidation solutions.

d. The most small displacements are reached with the third consolidation solution.

e. The weight of the structure isn't too much modificated with the third solution.

f. Consolidation with reinforced concrete structures occupies valuable space inside the caisson.

g. Composite consolidation doesn't occupy a small volume in the caisson.

h. The composite material assures a better distribution of efforts in the caisson's walls.

i. To avoid the collector's gaps composite material should be cut and properly fixed to prevent its detachment.

j. Consolidation with composites involves hiring specialized companies in this work.

Graphic, the conclusions resulted are showed in Figures 12,13.

References

1. *Îmbunătățirea terenurilor slabe în vederea fundării directe – M. Păunescu*
2. *Sisteme de consolidare a construcțiilor cu materiale compozite* – Bogdan Bahnariu
3. *Consolidarea și întreținerea construcțiilor* - C. Nistor
4. *Mechanical Properties of Composite Material* - Dr. Hani Aziz Ameen
5. *** C 29 – 85 - *Îmbunătățirea terenului de fundare prin procedee mecanice*
6. *** NP 112-2004 *Normativ pentru proiectarea structurilor de fundare directă.*
7. *** *Manual AxisVM.*
8. *** *Manual Abaqus Simulia.*