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Trial Loads Method check of Valea Runcu intake desander

Ioan Ciortea [1] Teodor Eugen Man [1] Maria Kozora[2] Laurenţiu Maier[2]

Abstract: The paper describes the structural design check of Valea Runcu intake desander with trial loads method, which is part of „Amenajare potenţial hidroenergetic râu Săpânţa, jud. Maramures , Romania" project. The project has been accomplished by SC ISPE SA, Timisoara Subsidiary, hydrotechnical staff. The project faze has been construction detailing, in collaboration with Stdio Frosio, the sole benneficiary being SC ESPE Energia SA. In this paper the stress distribution through the transversal beams was checked and the bending moments reduction at the bottom of the wall holding the right river bank. For design optimisation purposes the stress values have been mediated. The trial loads method was applied to try and eliminate stress concentration due to the shell and liniar elements modeling. This way the bending moments obtained from the design calculations (plate theory and trial loads method) are close, there are no stress concentrations for the trial loads method computations and the reinforcement areas were calculated for elastic rigid supports. The conclusion is that the trial loads method can be used to design or check reinforced concrete tank like structures with relative small errors, the advantage of using this method being avoiding stress concentration and convergence loss when using linear elements like beams and columns, stress distribution only includes linear elements and the corrections (for example base slab - wall intersections) can easily be achieved by using node constraints.

1. INTRODUCTION

Valea Runcu intake and its sill are part of „Amenajare potenţial hidroenergetic râu Săpânţa, jud. Maramures" project. The construction detailing has been achieved by SC ISPE SA, Timisoara Subsidiary and the hydrotechnical staff. The documents were based on a task imposed by Studio Frosio, the investment beneficiary being SC ESPE Energia SA.

2. DESANDER DESIGN COMPUTATION

The desander is a reinforced concrete raft like structure, with 24.42 x 6.50 m horizontal dimensions and 3.20 m internal height. On the structural side, the desander has two longside channels separated by a wall, both the separating and external walls having sills. The wall supporting the right river bank has been heightened to facilitate an access road, so for a better stress distribution transversal beams were added to stiffen both channels. The beams are also the support for the prefabricated tiles which cover the two channels [1]. The desander, plane and section are presented in figures 1 and 2.

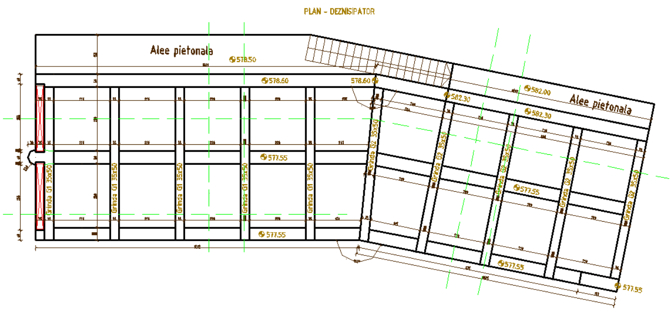

Figure 1. Desander overview

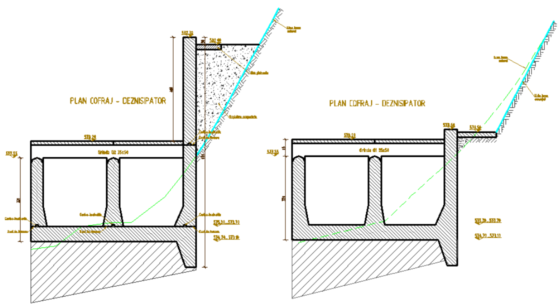

Figure 2. Sections

The foundation of the structure has been on the bedrock through C8/10 concrete filling, about 4 m from the ground surface. The filling height is variable through the length of the structure.

The structural model was base on shell elements with rigid edge intersections. The foundation layer was a Winkler type soil with the rigidity of 60000 kN/m3. The issue with this model were the horizontal forces trough the transversal beams, due to the loading of the wall supporting the right bank, transmitted to the other two channels' walls, which lead to stress concentration at the intersection of linear and bidimensional elements. The loads that have been taken into consideration are:

- Soil load p_a=70.75 kN/m^2;
- Additional load p_v=32.66 kN/m^2;
- Hydrostatic pressure;
- The weight of the prefabricated roof;
- Snow.

1 Politehnica Universiy of Timisoar
2 S.C. ISPE S.A. – Timişoara, bld. Gh. Lazăr nr. 18-20, Timişoara

Bending moments diagrams are shown in figure 3. We can see bending moments peaks at the begings and ends of the transversal beams which can generate failure stresses in the concrete. Due to the fact that the beams are fixed at the edge of the wall increasing reinforcement areas was not practical.

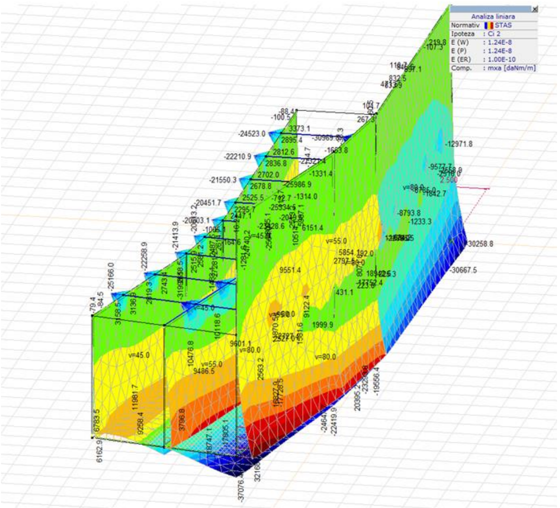

Figure 3. Bending moments diagrams

The reinforcement intensities have been calculated as so, and for the stress distribution and redistribution check the trial loads method was used.

3. TRIAL LOADS METHOD CHECK OF TE DESANDER

3.1. METHOD DESCRIPTION

The trial loads method was elaborated by F.A. Nötzli and used for concrete arch dams [4] [5]. In principle, a wall or plate element can be made out of linear vertical and horizontal elements that form a net like structure (figure 4).

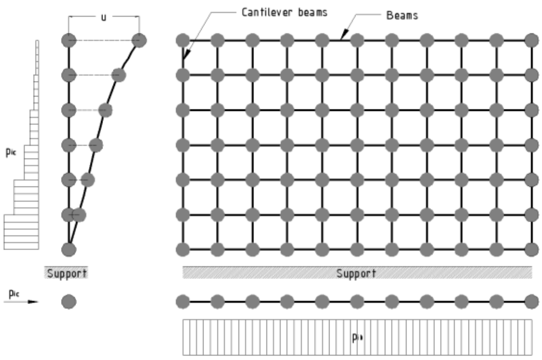

Figure 4. Linear vertical and horizontal elements

Figure 4 shows the structural model of a wall using linear elements. The external loads are distributed to the horizontal and vertical elements assuring the continuity of the structure - the nodal displacements of the elements taken separately must pe equal. The reactions nd the equilibrium forces are obtained by imposing equal displacements therefore resulting an overall displacementf of the system.

In cas of arch dams, the body is constructed of cantilever beams and horizontal arches, while the external loads are applied to either the beams or the arches separately. Both the arches and the cantilever beam are computed separately, while their supports may or may not take into consideration soil deformations. The main disadvantage of using this method is the time necesary for the computation of each load case and the equilibrium forces.

These days, using finite element analysis software, the structural model can be modeled as a whole, the only variable being the external loads' values. Basically there is no need for for computing the structural elements separately, but taking into consideration only different load cases. Figure 5 shows such a model for modeling a wall.

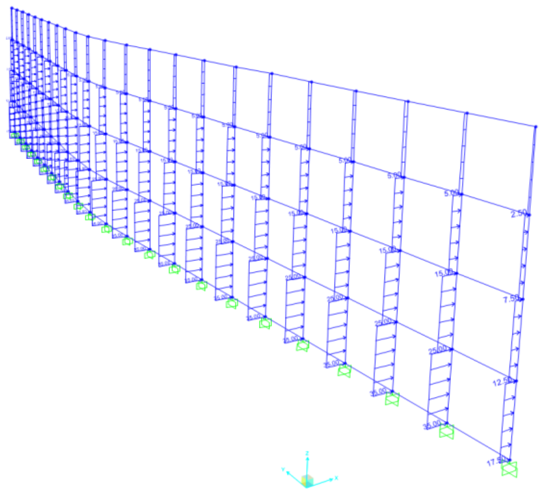

Figure 5. Concrete wall made from linear elements

To achieve structure continuity, the nodal displacements of both elements taken separately must be the same. The external load has one value, while correction factors can be added to each group of elements using load cases.

In the example shown in figure 5 the load is distributed by 40% to the horizontal elements, while the vertical elements are loaded with 60% of the total load. The results are considered to be satisfactory when the error is aproximately 1% in case of relative simple structures.

Advantages and disadvantages of the trial loads method:

a). Advantages

- Elimination of the concentrated stresses in beam - plate intersections where loss of convergence may appear;
- Seing the load distribution
- The possibility of design optimisation with virtual loads diagrams

b). Disadvantages

- The structural model can be complicated to develop;
- The need for different mass distribution;
- Errors in dynamic response of structure;
- Stiffness errors may occur.

3.2. STRUCTURAL AND CALCULUS MODEL

For the design check of the desander previously presented the model shown in figure 6 was used, constructed of vertical elements (cantilever beams) and horizontal elements (beams). The mesh dimensions are 1 x 1 m for ease of load distribution.

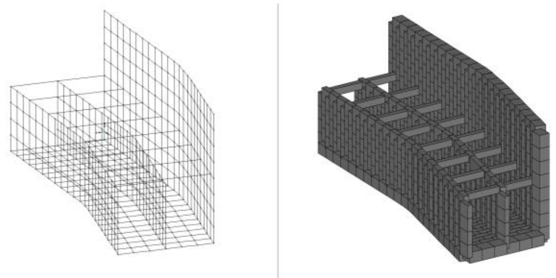

Figure 6. Structural model

Soil interaction consisted in nodal springs, the overal rigidity factor being 60000 kN/m3. The design calculus included several values for the base rigidity [2] [3], with small differences in the end.
Load distribution was as shown in figure 7. The load values are uniformigly distributed over each element's lenght, each type of element having its own load case. This way there is a separated load case for each element type, although the analysis is carried out on the whole model (figures 7 and 8). Note that the main interest is the wall supporting the right bank where the load values are semnificative.

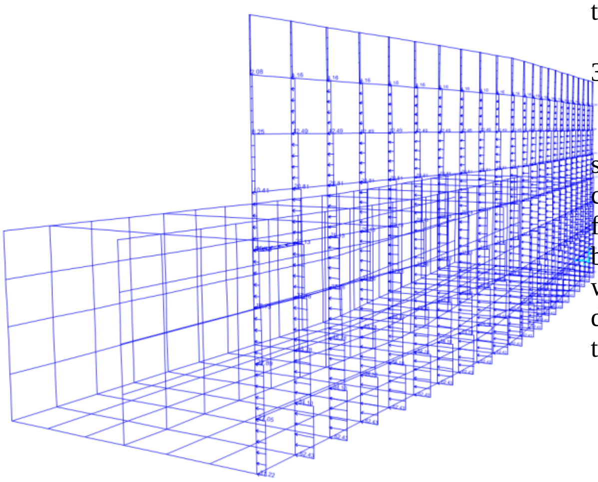

Figure 7. Cantilever beams loading

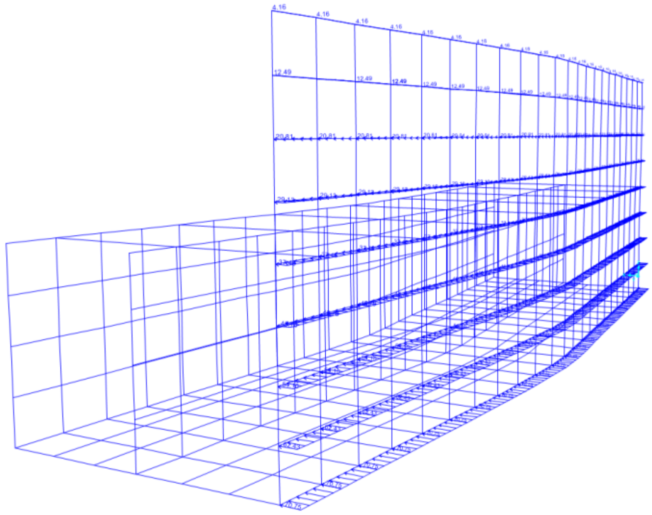

Figure 8. Beams loading

After the static analysis run there are two sets of values for the six displacements of each node (3 displacements and 3 rotations). In thos case the error values were between 6‰ and 4%, the smallest being along the transverse direction where the external loads are significant. The distribution factors are 0.55 for the vertical elements and 0.45 for the horizontal ones, which means that 55% of the total load is being distributed to the verticcal elements while the horizontal ones take over 45% of the same toatl load. The calculation of these coefficients was done with use of tables compairing the sets of displacement values until the error was considered acceptable for this structure. The joints are considered to be rigid and the analysis was linear static.

3.3. RESULTS

Following the statical analysis of the model the stress distribution of the wall was studied, for the load case generated by the soil load and the added load from the acces road. Next the bending moments can be seen for the intersection of the base slab and the wall. Figures 9 an 10 show the bending moments diagrams for both the plate an beams model as for the trial loads method simplification.

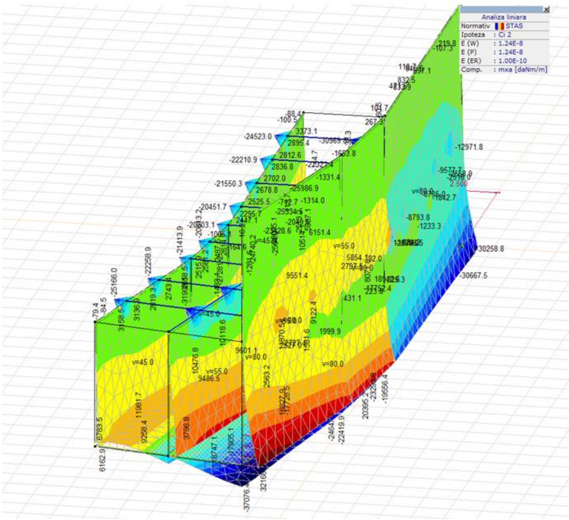

Figure 9. Strain diagram – plates

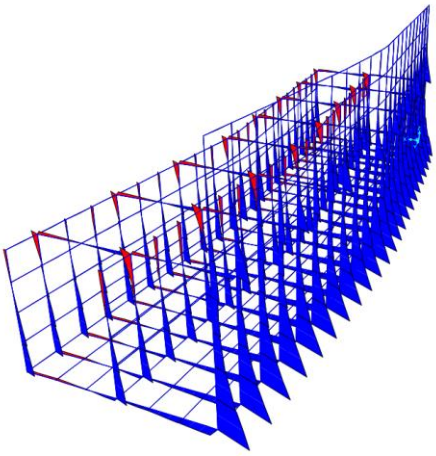

Figure 10. Bending moments diagrams - Trial loads method

The maximum values of the bending moments close to the slab - wall joint are shown in the table below.

Table 1. Bending moments

	Shell elements		**Trial loads method**	
	Slab	**Wall**	**Slab**	**Wall**
M [kNm]	370.8	321.7	357.07	335.55

Small difference can be observed between the two models (about 4%) making little difference in reinforcement areas calculation. The design calculation take into consideration all acting loads, as for the trial loads method the analysis steps are the same.

4. CONCLUSIONS

The trial loads method is used to remove the stress concentration due to the limits of the shell - beam model. Considering that the end results (for both plate theory and trial loads method) are very close and the stress concentrations do not appear in the trial loads method model, we can say that these do not affect the overall stress distribution in the structure. This way the stress peaks were ignored, reinforcement areas were calculated for the fixed joints.

Trial loads method can be used for design and checks of raft concrete like structures with relative small errors. The main advantage of using this method is avoiding loss of convergence and stress concentration when using beam or column elements, the stress flow being through linear elements. Certain corrections can easily be done (for example the base slab - wall joint) using constraints on linear segments. In this paper the stress distribution through transversal beams was evaluated and also reducing the bending moments at the bottom of the wall supporting the right river bank.

In some cases, for optimization, there can be taken into consideration constructive measures - like haunches or different sections of some elements. For the case presented before, the design stresses can be uniformed by mediating the values as shown in figure 11.

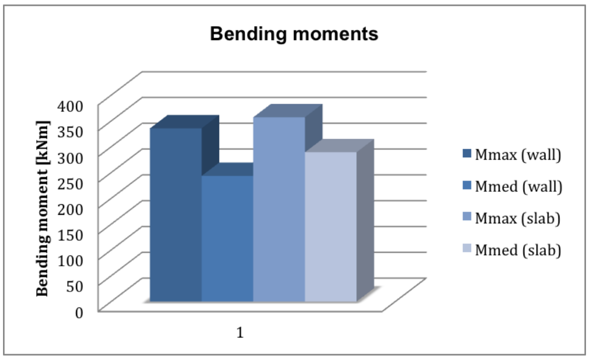

Figure 11. Mediated values

The main disadvantage of this method is the complicated model when dealing with loads acting on multiple directions, which means that the correction factor can be very difficult to determine. Because they are determined by multiple iterations the process can be tedious it lacks practicality. Although the method can be used for non linear analysis, all the displacements and torsions must be take into consideration alongside the overall behavior and the vibration modes of the structure.

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