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# INCREASING OF SEISMIC RESPONSIBILITY OF STEEL TANKS FOR "CCR" IN NPP "KOZLODUY"

**Lyubomir Zdravkov[1],**

***Key words*:** *steel tank, seismic influence, coefficient of responsibility, column, vertical brace, foundation*

***Scientific field*:** *building structures*

Specialized Division „РАО и ОЯГ", part of NPP „Kozloduy", manages many facilities which store radioactive wastes. There are 2 tanks between them for liquid radioactive concentrate, subject of the article. They are steel and have main body where radioactive wastes are kept, and 4 columns. These facilities are manufactured in 1992 year in the USA. Their first test on site of NPP "Kozloduy" dates on 2001, when they were filled with ХОВ and with 24 hour retention by 20 $^0$C.

The above mentioned 2 tanks are delivered without design calculations which could clarify design loads and combinations and main principles of measurement of steel sections.

## 1. Introduction

The above mentioned two steel tanks for liquid radioactive concentrate were delivered without design documentation clarifying calculated loading status and rules for measurements (check) of steel sections. Several production schemes are available but they are insufficient. In that reason That their owner wanted to check how they could be used without failure under condition of the site of NPP "Kozloduy".

## 2. Characteristic of tanks and site

### 2.1 Main data for the tanks and location

The tanks are situated in the NPP "Kozloduy" – Bulgaria. They are made by "HPS Industries" Inc., Suwanee, GA 30174, USA in 1992. They were delivered by company "Westinghouse". They were mounted by company "Енергомонтаж – АЕК" АД. Their first examination was done in 2001 when they were filled with ХОВ for 24 hours at temperature 20 $^o$C.

The facilities are used by Specialized Division „РАО и ОЯГ".

### 2.2 Data for tanks' geometry and condition of their exploitation

The tanks RW-TK-03 and RW-TK-04 for liquid radioactive concentrate are facilities with vertical cylindrical shell and cone bottom, where the product is tapped. The shell is supported by four steel columns W6x16 which are welded to it in horizontal joint between cylinder and cone. The columns are pin connected to the foundation plate.

Nominal capacity – V = 12 m$^3$;

[1] Lyubomir Angelov Zdravkov, PhD, Civil Engineer, UACG, Sofia 1046, №1 "Hristo Smirnensky" str., floor. 7 office 733, e-mail: zdravkov_fce@uacg.bg

Height from the bottom to covering sheets – 5359 mm;
Height from the bottom to the joint between cone and cylindrical part of the tank– 2159 mm;
Minimum height from the bottom to the cone part – 1118 mm;
Outside diameter of the shell – $D$ = 2134 mm;
Specific weight of the stored product - $\rho$ = 1,39 t/m$^3$ ;
Internal pressure - Atmosphere;
Work temperature - 5 ÷ 80 $^0$C.

The tanks are under roof in closed premises with limited access. That is way they shall not be loaded by wind or snow.

The facilities efforts influence to the common for the whole concrete foundation plate with thickness 1,40 m. In the tanks area it is reinforced by net of crossed steel bars N25/20/20 cm and by net of crossed bars N12/20/20 cm.

### 2.3 Climate conditions of the site in the NPP "Kozloduy" [2]

The conditions of the site in the NPP "Kozloduy" are:
- temperature – 20 ÷ 36 $^0$C ;
- maximum of wind loading – $w_m$ = 0,53 kN/m$^2$;
- snow – $s_n$ = 2,0 kN/m$^2$;
- seismic zone for Kozloduy sity – VII, $k_c$ = 0,1 [1]

Seismic characteristic of NPP "Kozloduy" are valid for all building and facilities and are represented by the response spectrum for zero level. The maximum of acceleration for short periods $T \approx 0$ s are as follows:
- 0,2.g for horizontal component;
- 0,1.g for vertical component.

From the above mentioned possible loads upon the tanks only the seismic accelerations calculated for the site are important.

### 2.4 Used materials

For the tanks' shell and cone bottom it was used an alloy steel 304 according to the ASTM with the following characteristics, according to the available report from the examinations:
- tensile strength – $R_{u,n}$ = 603 MPa;
- yield strength – $R_{y,n}$ = 339 MPa.

The material used for four columns was not described in the available tanks schemes. After cutting a sample from them and examinations on the sample it was found that the column steel corresponds to the A36 according to ASTM.

## 3. Tanks examinations

Due to the particular character of the stored materials and operation mode of the facilities it is not permitted elements of steel construction to work in plastic stage. As a result there are not plastic zones for energy dissipation. That is the reason to accept that coefficient of reaction of the construction shall be ***R* = 1,0**.

The tank's effort resulted by the seismic acceleration of the earth basement is calculated according to the:

$$E_{ik} = C.R.k_c.\beta_i(T).\eta_{i,k}.Q_k\,, \qquad (1)$$

where:
$C$ = 1,0 coefficient of importance of facility;
$R$ = 1,0 – coefficient of reaction of the construction;
$k_c$ – coefficient of seismic acceleration calculated for the site of NPP "Kozloduy";
$\beta_i$ (T) – dynamic coefficient chosen by response spectrum curves for NPP "Kozloduy" , by 5% modal damping (fig. 1);
$\eta_{i,k}$ – coefficient for allocation of the calculated seismic loading;
$Q_k$ – sum of the loadings (mass) of the examined facilities which includes:

- Dead weight of steel construction which includes main body + supporting structure;
- Weight of the stored product when the maximum level of filling is reached.

Coefficient of overloading for the two types of loads – $k$ = 1,0.

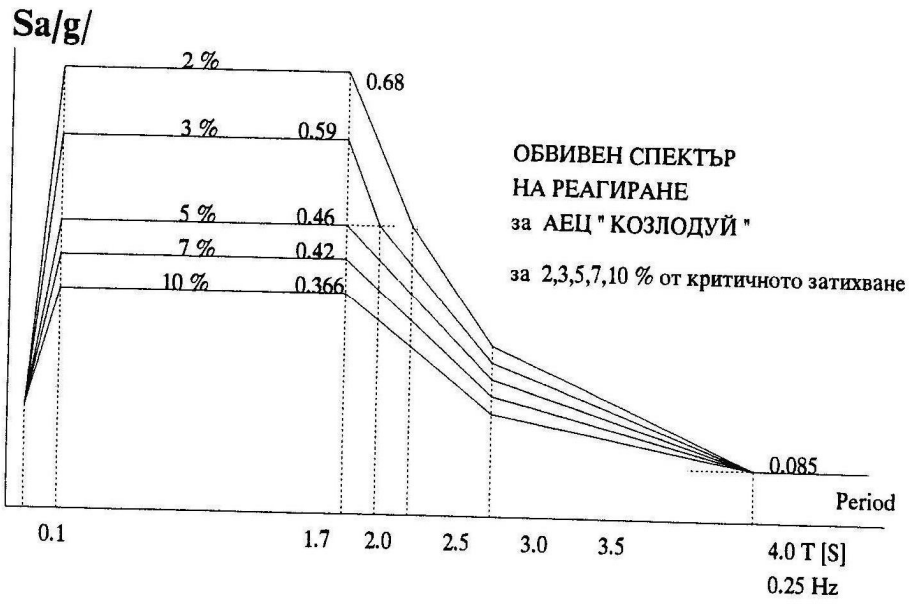


fig. 1 Response spectrum for the site of NPP "Kozloduy"

Due to the considerable correlation *H*/*D* and small dimension of the facility for liquid storage, the liquid radioactive concentrate is assumed as stiff not deformable body which moves together /with the same frequency/ with the steel construction. The waves forming in the upper layers of stored liquid are not considered which is favourable for safety.

Several three dimensioned models of steel tanks are created with the software SAP2000 v.10. The aim was to make the models as close as possible to the reality. Columns were accepted as FRAME elements with their real geometrical parameters. In order to take into account the fixing of the columns in the cylindrical parts, in the design model they penetrate in it and reach their real height. Steel sheets of the cylindrical and cone parts are accepted as SHELL elements with their real thickness. In joint between cylindrical and cone parts as well as in the area of contact of columns and cylindrical part, the net of shell elements is denser.

In order to report the possible loss of stability of thin cylindrical shell, during the examination it was taken into account not linear behaviour of structure. The lack of convergence of the FEA would show that the steel sheets elements lose their stability.

The tanks RW-TK-03 and RW-TK-04 have been examined for the following combination of the loads:

- Main load combination

  It includes dead weight of steel structure and the weight of the stored in the tanks liquid.

  The coefficient for overloading are calculated according to the [2] and $k > 1{,}0$.
- Particular load combination

  It includes dead weight of steel structure and weight of the stored liquid when the maximum liquid level is reached, and the inertial forces caused by earthquake.

  The coefficient for overloading are calculated according to the [2] and $k = 1{,}0$.

After the examination the particular load combination was assumed as valid and for this purpose steel structure must be reinforced and checked.

Specialized Division „РАО и ОЯГ" requested the development and comparison of two possible variants for facility reinforcement. After that the investor compared them and chose one of them.

**Variant 1**

This reinforcement suggestion offers to add four new steel columns IPE160 to already existing four steel columns W6x16 according to the scheme fig.2. Vertical "X" – shaped braces from double angle sections L50x5 shall be developed. These vertical braces function as stiff disks in their plane.

The existing and new mounted columns have pin connections to the foundation. The joints of new columns to the foundation are provided by anchors "HILTI".

It is reported elasticity fixing of the columns to the facility' body.

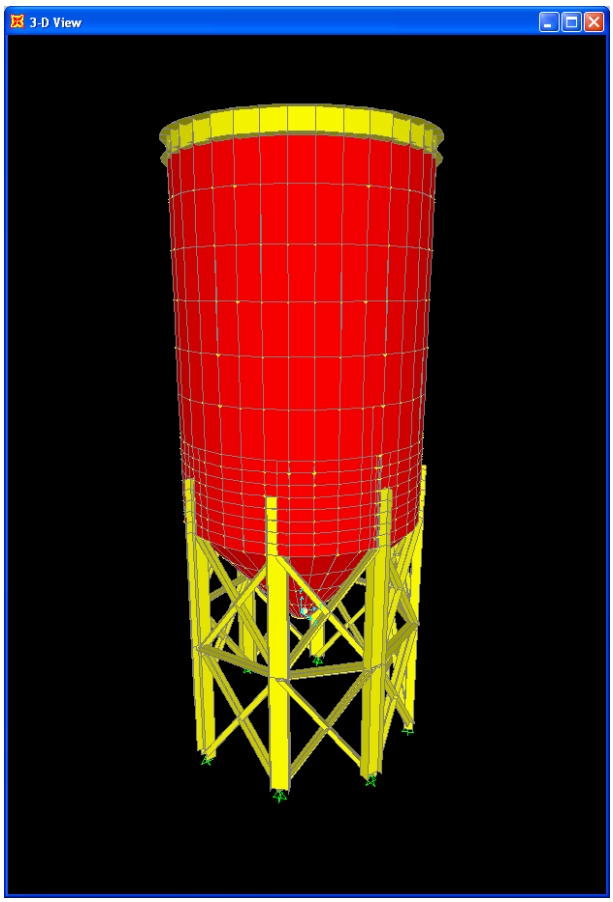


fig. 2 Reinforcement of the steel structure with additional columns and steel braces.

Steel sections required for the reinforcement according to the Variant 1 are shown in Table 1:

**TABLE 1**

| № | Element | Section | Length, mm | Steel | Pcs. | Weight, kg | |
|---|---|---|---|---|---|---|---|
| | | | | | | one | total |
| 1 | Columns | IPE 160 | 2280 | S235J0 | 4 | 36,1 | 144,4 |
| 2 | X - braces | 2L50x5 | 6245 | S235J0 | 8 | 47,1 | 376,8 |
| 3 | Base plates | -16x180 | 250 | S235J0 | 4 | 5,7 | 22,8 |
| 4 | Plates | | | S235J0 | 10% | 38 | 38 |
| 5 | Anchors "HILTI" | M24x170/48 | 170 | klass 5.8 | 16 | | |
| | | | | | | Total: | **582** |

**Variant 2**

According to this variant of reinforcement additional four new steel columns with section HEA 360 shall be put under the shell' body. There are not vertical X-braces between the columns, according to the scheme on fig. 3.

New columns are fixed to the foundation plate through chemical anchors "HILTI".

Steel sections required for reinforcement of the tanks according to the Variant 2 are shown on Table 2:

**TABLE 2**

| № | Element | Section | Length, mm | Steel | Pcs. | Weight, kg | |
|---|---|---|---|---|---|---|---|
| | | | | | | one | total |
| 1 | Columns | HEA 360 | 2280 | S235J0 | 4 | 255,4 | 1021,6 |
| 3 | Base plates | -25x400 | 570 | S235J0 | 4 | 44,8 | 179,2 |
| 4 | Plates | -12x420 | 420 | S235J0 | 4 | 16,7 | 66,8 |
| 5 | Anchors "HILTI" | M27x240/60 | 170 | klass 5.8 | 16 | | |
| | | | | | | Total: | **1267,6** |

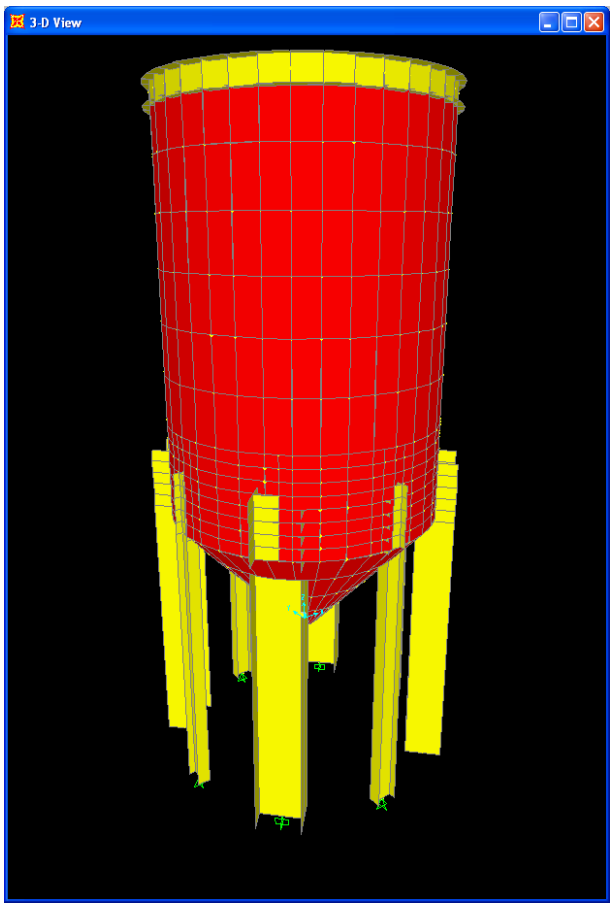

fig. 3 Reinforcement of the main structure with additional columns.

It must be taken into consideration that the tanks are supported by thick, bar reinforced, foundation plate but the research upon the foundation plate was not done for both Variants.

Having in mind that the steel structure is not geometrically linear the solution is convergent for both Variants – the thin shell of the tank shall not lose stability.

The Investor, Specialized Division „РАО и ОЯГ", leaded by technological and mounting reasons chose heavier Variant 2.

## 4. Conclusions after the research

4.1 Maximum seismic accelerations for NPP "Kozloduy" site, determined according to microseismic zones are two times bigger than maximum seismic accelerations for Kozloduy city, situated at about 3 km distance from NPP, determined according to [1]

4.2 Some of the facilities operating in the NPP were not measured to resist expected earthquake.

4.3 Leaded by technological reasons the Investor can chose heavier and more expensive engineer solution.

Literature

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