ANALYSIS AND CALCULATION OF THE STEEL TANK ACCORDING TO EUROCODE AND API 650

ANALIZA I PRORAČUN ČELIČNOG REZERVOARA PREMA EVROKODU I API 650

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Summary: This paper presents a calculation of a steel vertical water tank, with a total height of 19,2 m and a diameter of 8,59 m. The construction of this tank was modelled using the ABAQUS software package, whereby a realistic picture of the stress notations in the walls of the tank was obtained. The structural load analysis was performed based on European and American standards, as well as comparison of the obtained results.

Keywords: Steel tanks, EuroCode, API 650, FEM

Rezime: U radu je prikazan proračun čeličnog vertikalnog rezervoara za vodu, ukupne visine 19,2 m i prečnika 8,59 m. Konstrukcija rezervoara je modelirana pomoću programskog paketa ABAQUS, pri čemu je dobijena realna slika naponskih stanja u zidovima rezervoara. Analiza opterećenja konstrukcije je izvršena na osnovu evropskih i američkih standarda, kao i poređenje dobijenih rezultata.

Ključne reči: Čelični rezervoar, Evrokod, API 650, MKE

1. INTRODUCTION

Tanks are very important components of industrial and agricultural facilities, because they serve to store various liquids (water, wine, petroleum, oil, etc.) The type of tank depends on geometrical and structural characteristics, capacity, material from which they are made, a place and a method of installation, characteristics of the liquid to be stored, and its application. The basic classification of the tanks is based on their position in relation to the ground, therefore they are divided into elevated and underground

1. UVOD

Rezervoari su veoma važne komponente industrijskih i poljoprivrednih objekata, jer služe za skladištenje raznih tečnosti (voda, vino, nafta, ulje itd.). Tip rezervoara zavisi od geometrijskih i konstruktivnih karakteristika, kapaciteta, materijala od koga su napravljeni, mesta i načina ugradnje, karakteristika tečnosti koja se skladišti i primene. Osnovna podela rezervoara je prema njihovom položaju u odnosu na tlo. Prema tome se dele na nadzemne i podzemne rezervoare. Najčešće se izrađuju u obliku cilindra,

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tanks. Most often, they are made in the form of a cylinder, sphere or a rectangular shape. Spherical tanks are most commonly used due to the minimal amount of steel required for their construction.
The aim of the paper is to show the following effects on the tank: the effect of liquid (water), the effect of snow, the effect of wind, the effect of temperature and the effect of a seismic action. All influences are made according to European [1,2,3,4,5,6,7,8,9,10] and American Standards [11].

2. DESCRIPTION OF THE CONSTRUCTION LOAD ANALYSIS

The analysis was carried out for a steel elevated tank with a volume of V=800 m^3 and a total height of H=19,2 m. The construction of the tank consists of curved steel plates of different thicknesses, connected to each other by welding (Figure 1). The roof of the tank is spherical in shape with sheet thickness 5 mm, with eight stiffeners made of UP 70/40. The bottom of the tank is a steel plate with a thickness of 5 mm, under which there is a reinforced concrete circular plate with a thickness of 30 cm. The material for making the tank is quality steel S235 JRG2 [12] which corresponds to the strength class according to JUS C.B0.002/1986 (C0361). The tank is supported on a reinforced concrete foundation ring with geometry w/h=30/130 cm and attached to the foundation via an M20 anchor of strength class 6,8.
The construction of the tank is modelled by a spatial calculation model in the ABAQUS [13] software package, with the actual distribution of the load on the surface of the steel sheets. The material is modelled as elastic and isotropic for all structural elements with Youngov's modulus of elasticity E=210 GPa, Poisson's coefficient v=0,3 and coefficient of linear thermal dilatation of

sfere ili pravougaonog oblika, a najveću primenu imaju sferni rezervoari zbog minimalne količine čelika potrebne za njihovu konstrukciju.
Cilj rada je prikazati sledeće uticaje na rezervoar: uticaj tečnosti (vode), uticaj snega, uticaj vetra, uticaj temperature i uticaj seizmičkog dejstva. Svi uticaji su urađeni prema evropskim standardima [1,2,3,4,5,6,7,8,9,10] i američkom standardu [11].

2. OPIS KONSTRUKCIJE I ANALIZA OPTEREĆENJA

Analiza je sprovedena za čelični nadzemni rezervoar zapremine V=800 m^3 i ukupne visine H=19,2 m. Konstrukcija rezervoara se sastoji od zakrivljenih čeličnih ploča različitih debljina, međusobno povezanih zavarivanjem (Slika 1). Krov rezervoara je sfernog oblika debljine lima 5 mm, sa osam ukrućenja od UP 70/40. Dno rezervoara je čelična ploča debljine 5 mm ispod koje se nalazi armiranobetonska kružna ploča debljine 30 cm. Materijal za izradu rezervoara je čelik kvaliteta S235 JRG2 [12], koji odgovara klasi čvrstoće prema JUS C.B0.002/1986 (Č0361). Rezervoar je oslonjen na temeljni armiranobetonski prsten dimenzija b/h=30/130 cm i pričvršćen na temelj preko ankera M20 klase čvrstoće 6,8.
Konstrukcija rezervoara je modelirana prostornim proračunskim modelom u programskom paketu ABAQUS [13], sa stvarnom raspodelom opterećenja po površini čeličnih limova. Materijal je modeliran kao elastičan i izotropan za sve konstruktivne elemente sa Jangovim modulom elastičnosti E=210 GPa, Poasonovim koeficijentom v=0,3 i koeficijentom linearne toplotne dilatacije materijala α_t=10^{-5} 1/℃. Analizirana su sledeća opterećenja:

the material α_t=10^{-5} 1/℃. The following loads were analysed:

- the object's own weight,
- hydrostatic pressure of the water in the tank,
- wind load for the location Bečej with basic wind speed *vb*=23 m/s and adopted II category of terrain,
- the effect of temperature on the tank,
- the effect of snow on the tank, and
- seismic impact on the tank.

- sopstvena težina objekta,
- hidrostatički pritisak vode u rezervoaru,
- opterećenje vetrom za lokaciju Bečej sa osnovnom brzinom vetra v_b=23 m/s i usvojenom II kategorijom terena,
- uticaj temperature na rezervoar,
- uticaj snega na rezervoar i
- seizmički uticaj na rezervoar.

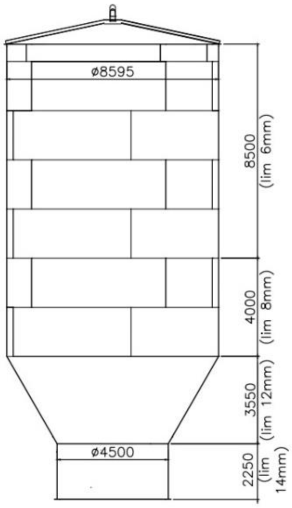


Figure 1 - Tank cross section (dimensions are given in mm)
Slika 1 - Poprečni presek rezervoara (dimenzije su date u mm)

3. CONSTRUCTION CALCULUS ABAQUS SOFTWARE PACKAGE

ABAQUS is a software package based on the Finite Element Method (FEM), intended for solving various problems related to mechanics and other fields of science. The tank model is composed of thin plates (3D shell deformable part), where all parts are modelled as thin plates rigidly attached to the surface. The model is composed of 12 parts, connected by 11 rigid connections. The lower part of the tank is clamped, which simulates the tank resting on the foundation. All parts are modelled as thin plates and S4R element is used for

3. PRORAČUN REZERVOARA U PROGRAMSKOM PAKETU ABAQUS

ABAQUS je softverski paket zasnovan na Metodi konačnih elemenata (MKE), namenjen rešavanju različitih problema vezanih za mehaniku i druge oblasti nauke. Model rezervoara je sastavljen od tankih ploča (3D shell deformable part), pri čemu su svi delovi modelirani kao tanke ploče površinski kruto vezane. Model je sastavljen od 12 delova, povezanih sa 11 krutih veza. Donji deo rezervoara je uklješten, čime je simulirano oslanjanje rezervoara na temelj. Svi delovi su modelirani kao all tank parts. They are doubly curved thin plates with 4 nodes and reduced integration. The model consists of 13502 elements with the width of the elements of 25 cm. The applied network was adopted for the reason of obtaining the best possible results.

tanke ploče i za sve delove rezervoara primenjen je S4R element. To su dvostruko zakrivljene tanke ploče sa 4 čvora i smanjenom integracijom. Model se sastoji od 13502 elementa, širine elemenata 25 cm. Primenjena mreža je usvojena iz razloga dobijanja što kvalitetnijih rezultata.

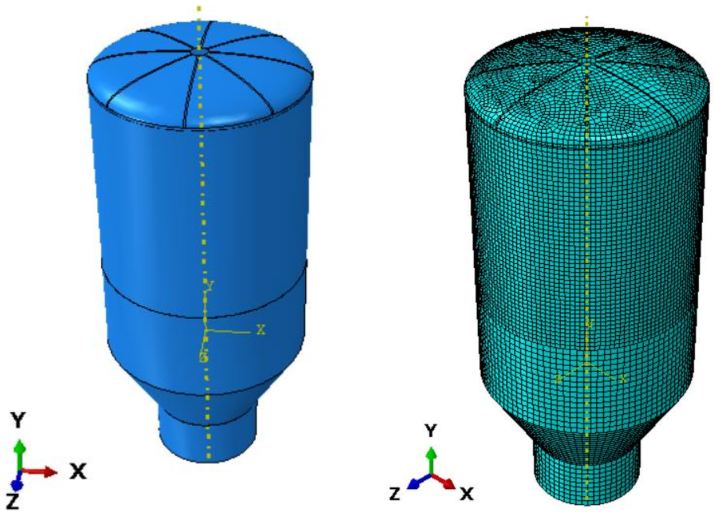


Figure 2 - 3D steel tank model [12]
Slika 2 - 3D model čeličnog rezervoara [12]

Influence on the tank due to the effect of constant load

The self-weight of the structure is entered by the calculation model.

Influence the tank due to the effect of water

According to EN 1991-1-4 [2] the loads due to liquids are calculated taking into account all types of liquids that are expected to be stored in the tank, the geometry of the tank and the maximum possible depth of the liquid in the tank. The characteristic pressure values *p* is:

Uticaj na rezervoar usled dejstva stalnog opterećenja

Sopstvena težina konstrukcije uneta je proračunskim modelom.

Uticaj na rezervoar usled dejstva vode

Prema EN 1991-1-4 [2], opterećenja usled tečnosti računaju se uz uzimanje u obzir svih vrsta tečnosti čije se skladištenje predviđa u rezervoaru, geometrije rezervoara i maksimalne moguće dubine tečnosti u rezervoaru. Karakteristična vrednost pritiska *p* je:

$$p(z) = \gamma z, \quad (1)$$

with:
$\gamma = 10\,\mathrm{kN/m^3}$ - unit weight of liquid,
z - depth of fluid.

gde su:
$\gamma = 10\,\mathrm{kN/m^3}$ - zapreminska težina tečnosti, z - dubina tečnosti.

Influence on the tank to the effect wind load according to EN [4]

According to [4], the wind load is simulated as a distributed pressure around the enclosure of shroud. That pressure varies along the height and scope of shroud.

Uticaj na rezervoar usled dejstva vetra prema EN [4]

Opterećenje vetrom prema [4] simulirano je kao raspodeljeni pritisak po obodu plašta. Taj pritisak varira duž visine i obima plašta.

Table 1 - Basic characteristics of a steel tank for wind calculation
Tabela 1 - Osnovne karakteristike čeličnog rezervoara za proračun vetra

Height of the tank wall / Visina zida rezervoara	$z = 18{,}3\ \mathrm{m}$
Diametar of the tank / Prečnik rezervoara	$D = 8{,}58\ \mathrm{m}$
Elevation of the construction / Nadmorska visina na kojoj se nalazi objekta	$H_n = 81{,}0\ \mathrm{m}$
Fundamental wind speed / Fundamentalna brzina vetra	$V_{b0} = 23{,}0 \frac{\mathrm{m}}{\mathrm{s}}$
Coefficient of direction / Koeficijent pravca	$C_{dir} = 1{,}0$
Coefficient of seasonal influence / Koeficijent sezonskog delovanja	$\mathrm{C_{season}} = 1{,}0$
Coefficient of topography / Koeficijent topografije	$C_{0(z)} = 1$
Category of terrain / Kategorija terena	$K_t = \mathrm{II}$
Length of roughness / Dužina hrapavosti	$z_0 = 0{,}05$
Minimal height / Minimalna visina	$z_{min} = 2\ \mathrm{m}$
Maximal height / Maksimalna visina	$z_{max} = 200\ \mathrm{m}$
Turbulence coefficient / Koeficijent turbulencije	$K_I = 1$
Air density / Gustina vazduha	$\rho = 1{,}25\ \mathrm{kg/m^3}$

Basic wind speed: / Osnovna brzina vetra:

$$V_b = C_{dir} \cdot C_{season} \cdot V_{b0} = 23\,\mathrm{m/s} \tag{2}$$

Coefficient of terrain: / Koeficijent terena:

$$k_r = 0{,}19 \cdot \left(\frac{z_0}{z_{0,\mathrm{II}}}\right)^{0{,}07} = 0{,}19 \cdot \left(\frac{0{,}05}{0{,}05}\right)^{0{,}07} = 0{,}19 \tag{3}$$

Roughness coefficient: / Koeficijent hrapavosti:

$$C_{r(z)} = k_r \cdot \ln\left(\frac{z}{z_0}\right) \text{ za } z_{min} \le z \le z_{max} \tag{4}$$

$$C_{r(z)} = 0{,}19 \cdot \ln\left(\frac{18{,}3}{0{,}05}\right) = 1{,}1215 \ \text{ za } 2{,}0\ \mathrm{m} \le 18{,}3\ \mathrm{m} \le 200\ \mathrm{m}$$

Average wind speed: / Srednja brzina vetra:

$$V_{m(z)} = C_{r(z)} \cdot C_{0(z)} \cdot V_b = 25{,}79451\ \mathrm{m/s} \tag{5}$$

Turbulence intensity: Koeficijent turbulencije:

$$I_{v(z)} = \frac{K_I}{C_{0(z)} \cdot \ln(\frac{z}{z_0})} \text{ za } z_{min} \leq z \leq z_{max} \tag{6}$$

$$I_{v(z)} = \frac{1}{1 \cdot \ln(\frac{18,3}{0,05})} = 0,169416 \text{ za } 2,0 \text{ m} \leq 18,3 \text{ m} \leq 200 \text{ m}$$

Impact wind pressure: Udarni pritisak vetra:

$$q_{p(z)} = \left(1 + 7 \cdot I_{v(z)}\right) \cdot \frac{1}{2} \cdot \rho \cdot V_{m(z)}^2 \tag{7}$$

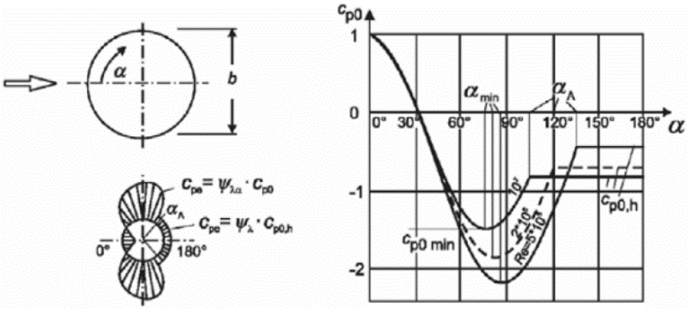


Figure 3 - Wind pressure distribution, for spheres with different Reynolds numbers [4]
Slika 3 - Raspodela pritisaka od vetra, za sfere sa različitim Reynolds-ovim brojevima [4]

Table 2 - Impact wind pressure
Tabela 2 - Udarni pritisak vetra

z [m]	$C_{r(z)}$	$V_{m(z)}$	$I_{v(z)}$	$q_{p(z)} \left[\frac{\text{kN}}{\text{m}}\right]$
2,25	0,7233	16,6351	0,2627	0,4910
4,00	0,8326	19,1495	0,2282	0,5953
5,80	0,9032	20,7732	0,2104	0,6669
7,8	0,9595	22,0679	0,1980	0,7263
9,8	1,0028	23,0654	0,1895	0,7735
11,8	1,0381	23,8769	0,1830	0,8128
13,8	1,0679	24,5612	0,1779	0,8466
15,8	1,0936	25,1526	0,1737	0,8763
17,8	1,1162	25,6734	0,1702	0,9028
18,3	1,1215	25,7945	0,1694	0,9090

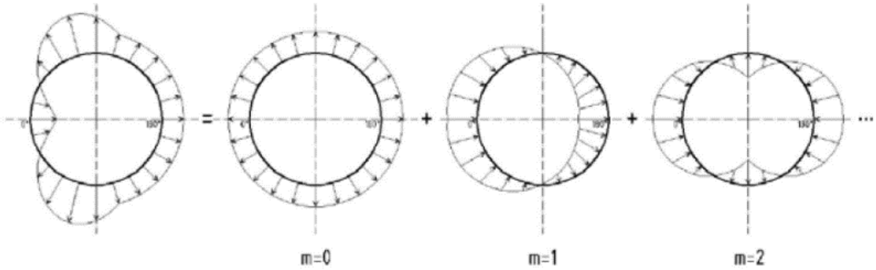


Figure 4 - Distribution of wind load on the tank shell [4]
Slika 4 - Raspodela opterećenja vetra po plaštu rezervoara [4]

Influence on the tank due to seismic load according to EN [9,10]

Uticaji na rezervoaru usled dejstva seizmike prema EN [9,10]

Vertical component of seismic action:

Vertikalna komponenta seizmičkog dejstva:

$$p_{vr}(\varsigma, t) = \rho \cdot H \cdot (1 - \varsigma) \cdot A_v(t) \quad (8)$$

Impulse natural vibration period:

Impulsni prirodni period vibracija:

$$T_{imp} = C_i \cdot \frac{H \cdot \sqrt{\rho}}{\sqrt{\frac{s}{R}} \cdot \sqrt{E}} = 0{,}0521 \text{ s} \quad (9)$$

Design acceleration for type A soil:

Projektno ubrzanje za tlo tipa A:

$$a_{vg} = 0{,}9 \cdot a_g = 0{,}531 \frac{\text{m}}{\text{s}^2} \quad (10)$$

Lower period limit in the area with constant spectral acceleration: $T_B(S)$=0,05. Upper period limit in the area with constant spectral acceleration: $T_C(S)$=0,15. The value of the period that defines the beginning of the spectral region with a constant shift response in the spectrum: $T_D(S)$=1,00 [9].

Donja granica perioda u oblasti sa konstantnim spektralnim ubrzanjem: $T_B(S)$=0,05. Gornja granica perioda u oblasti sa konstantnim spektralnim ubrzanjem: $T_C(S)$=0,15. Vrednost perioda koja definiše početak oblasti spektra sa konstantnim odgovorom pomeranja u spektru: $T_D(S)$=1,00 [9].

$$T_B \leq T \leq T_C \text{ , } S_{ve}(T) = a_g \cdot S \cdot \eta \cdot 3 \quad (11)$$
$$0{,}05 \leq 0{,}0521 \leq 0{,}15 \text{ , } S_{ve}(T) = 0{,}531 \cdot 1 \cdot 1{,}35 \cdot 3 = 2{,}15055 \frac{\text{m}}{\text{s}^2}$$

Table 3 - Vertical component of seismic action
Tabela 3 - Vertikalna komponenta seizmičkog dejstva

Point/Tačka	z [m]	$\varsigma = \frac{z}{R}$	$p_{vr}(\varsigma, t)$ $\left[\frac{\mathrm{kN}}{\mathrm{m}^2}\right]$
1	2,25	0,1229	34,5163
2	4,00	0,2186	30,7529
3	5,80	0,3169	26,8819
4	7,80	0,4262	22,5808
5	9,80	0,5355	18,2797
6	11,8	0,6448	13,9786
7	13,8	0,7541	9,6775
8	15,8	0,8634	5,3764
9	17,8	0,9727	1,0753
10	18,3	0,9836	0,6452

Pressure of the radial deformation of the tank wall:

Pritisak radijalne deformacije zida rezervoara:

$$p_{vf}(\varsigma, t) = 0{,}815 \cdot f(\gamma) \cdot \rho \cdot H \cdot \cos(\frac{\pi}{2}\varsigma) \cdot A_{vf}(t) \tag{12}$$

$$f(\gamma) = 1{,}078 + 0{,}247 \cdot \ln(\gamma) \text{ za } 0{,}8 \leq \gamma < 4 \tag{13}$$

$$\gamma = \frac{H}{R} = \frac{18{,}3}{4{,}29} = 2{,}133 \tag{14}$$

$$f(\gamma) = 1{,}078 + 0{,}247 \cdot \ln(2{,}133) = 1{,}265$$

Acceleration of the response of a simple oscillator with a frequency corresponding to the fundamental frequency: $A_{vf}(t)$=2,1055 m/s^2 [9].

Ubrzanje odgovora jednostavnog oscilatora sa frekvencijom koja odgovara osnovnoj frekvenciji: $A_{vf}(t)$=2,1055 m/s^2 [9].

Table 4 - Pressure of the radial deformation of the tank wall
Tabela 4 - Pritisak radijalne deformacije zida rezervoara

Point/Tačka	z [m]	$\varsigma = \frac{z}{R}$	$p_{vf}(\varsigma, t)$ $\left[\frac{\mathrm{kN}}{\mathrm{m}^2}\right]$
1	2,25	0,1229	39,8197
2	4,00	0,2186	38,2060
3	5,80	0,3169	35,6489
4	7,80	0,4262	31,8150
5	9,80	0,5355	27,0457
6	11,8	0,6448	21,4813
7	13,8	0,7541	15,2854
8	15,8	0,8634	8,6401
9	17,8	0,9727	1,7408
10	18,3	0,9836	1,0447

Table 5 - Joint action of hydrodynamic and radial deformation pressure
Tabela 5 - Zajedničko delovanje hidrodinamičkog i pritiska radijalne deformacije

Point/Tačka	z [m]	$p_{vr}(\varsigma,t)$ $\left[\frac{\mathrm{kN}}{\mathrm{m}^2}\right]$	$p_{vf}(\varsigma,t)$ $\left[\frac{\mathrm{kN}}{\mathrm{m}^2}\right]$	p_v $\left[\frac{\mathrm{kN}}{\mathrm{m}^2}\right]$
1	2,25	34,5163	39,8197	74,3361
2	4,00	30,7529	38,2060	68,9588
3	5,80	26,8819	35,6489	62,5301
4	7,80	22,5808	31,8150	54,3957
5	9,80	18,2797	27,0457	45,3253
6	11,8	13,9786	21,4813	35,4599
7	13,8	9,6775	15,2854	24,9629
8	15,8	5,3764	8,6401	14,0165
9	17,8	1,0753	1,7408	2,8161
10	18,3	0,6452	1,0447	1,6897

Influence on the tank due to wind load according to API 650

API 650 [11] wind load is simulated as a distributed pressure of 0,86 kPa around the shell and distribution of pressure of 1,44 kPa on the tank roof.

Influence on the tank due to seismic load according to API 650

Seismic influence includes the time during which changes in water movement occur, in which case one part of the liquid along the walls and bottom is firmly attached to the tank, and the other part, due to the effect of oscillations, moves independently. The first part of the fluid is called the impulsive mass, and the second part of the fluid is called the convective mass. Both components cause pressure [11].

Uticaji na rezervoaru usled dejstva vetra prema API 650

Opterećenje vetrom prema API 650 [11] simulirano je kao raspodeljeni pritisak od 0,86 kPa po obodu plašta i raspodeljeni pritisak od 1,44 kPa na krov rezervoara.

Uticaji na rezervoaru usled dejstva seizmike prema API 650

Seizmički uticaj uključuje vreme kroz koje se dešavaju promene kretanja vode. U tom slučaju, jedan deo tečnosti duž zidova i dna je čvrsto vezan za rezervoar, a drugi deo se, usled dejstva oscilacija, kreće samostalno. Prvi deo tečnosti se naziva impulsivna masa, a drugi deo tečnosti konvektivna masa. Obe komponente izazivaju pritisak [11].

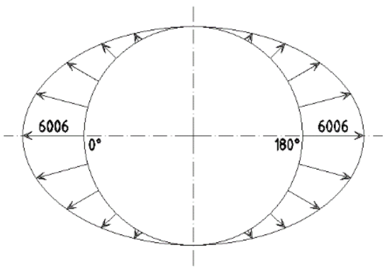


Figure 5 - Load distribution due to the effect of seismic [11]
Slika 5 - Raspodela opterećenja usled dejstva seizmike [11]

Diagrams of stress

Influence on the tank due to constant load

Dijagrami napona

Uticaji na rezervoaru usled dejstva stalnog opterećenja

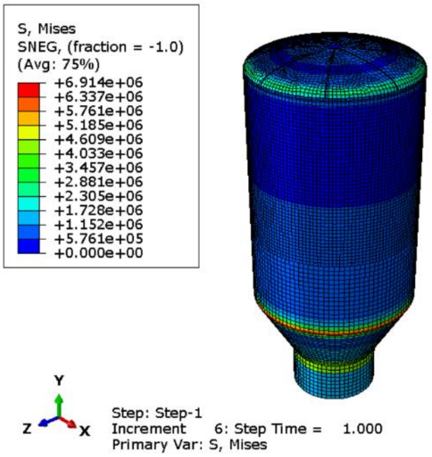


Figure 6 - Stress in the tank due to the effect of self weight [Pa]
Slika 6 - Naponi u rezervoaru usled dejstva sopstvene težine i tečnosti [Pa]

Influence on the tank due to water

Uticaji na rezervoaru usled dejstva vode

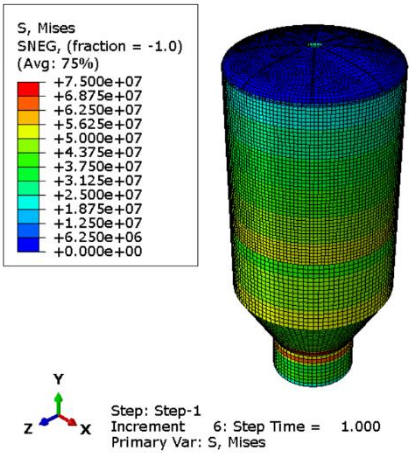


Figure 7 - Stress in the tank due to the effect of water [Pa]
Slika 7 - Naponi u rezervoaru usled dejstva vode [Pa]

Influence on the tank due to temperatures

Uticaji na rezervoaru usled dejstva temperature

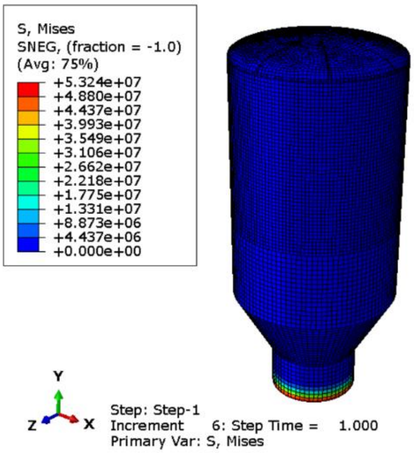
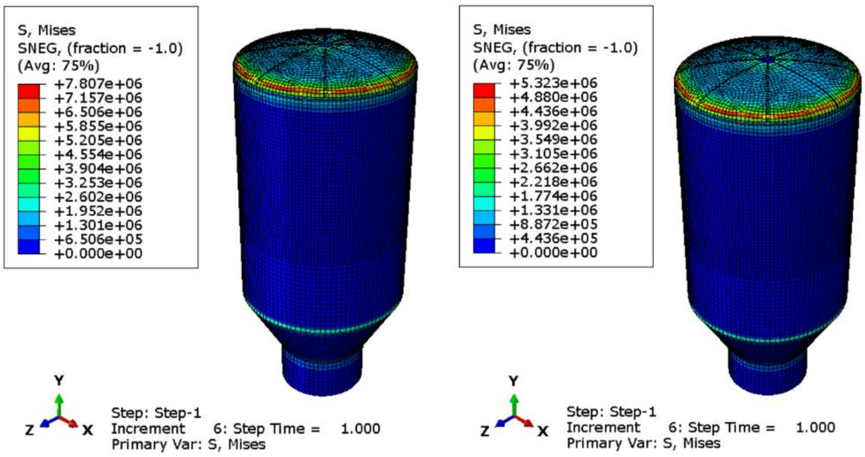


Figure 8 - Stress in the tank due to the effect of temperature [Pa]
Slika 8 - Naponi u rezervoaru usled dejstva temperature [Pa]

Influence on the tank due to snow

Uticaji na rezervoaru usled dejstva snega

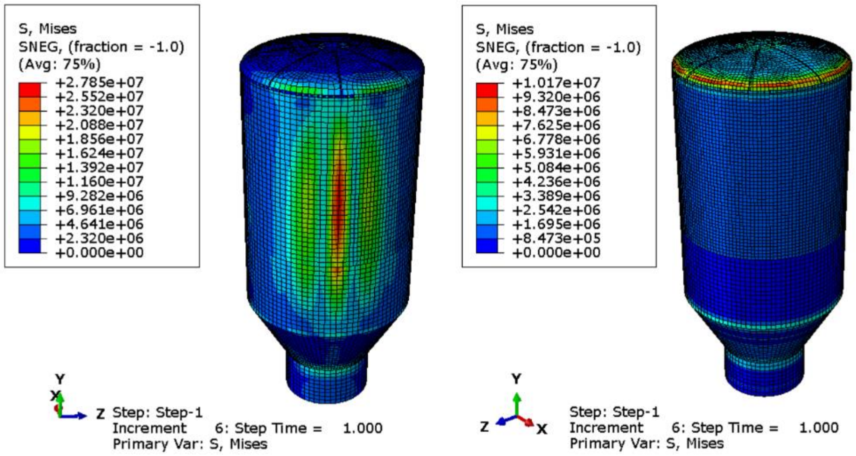


a) EuroCode b) API 650

Figure 9 - Stress in the tank due to the effect of snow [Pa]
Slika 9 - Naponi u rezervoaru usled dejstva snega [Pa]

Influence on the tank due to wind

Uticaji na rezervoaru usled dejstva vetra



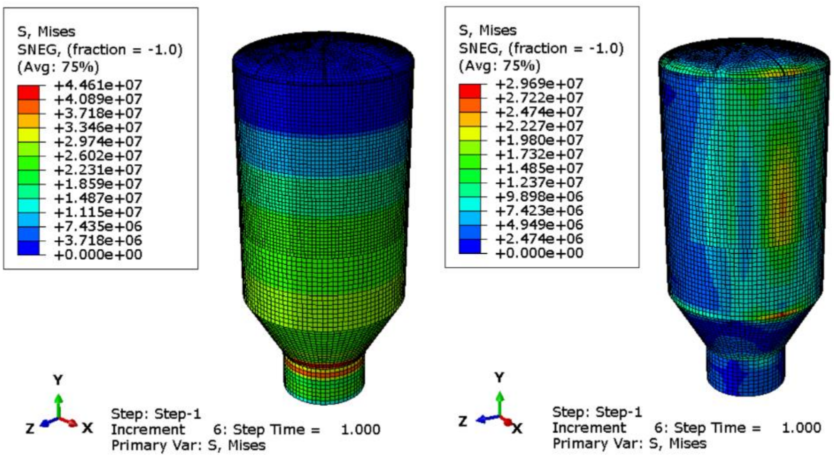
a) EuroCode b) API 650

Figure 10 - Stress in the tank due to the effect of wind [Pa]

Slika 10 - Naponi u rezervoaru usled dejstva vetra [Pa]

Influence on the tank due to seismic

Uticaji na rezervoaru usled dejstva seizmike



a) EuroCode b) API 650

Figure 11 - Stress in the tank due to the effect of seismic [Pa]

Slika 11 - Naponi u rezervoaru usled dejstva seizmike [Pa]

4. ANALYSIS OF THE OBTAINED RESULTS

The presented diagrams were obtained after conducting a static analysis of a steel tank for water storage for some load cases. Table 5 shows the obtained results according to different influences, and tables 6 and 7 show the combination of loads for the limit of carrying capacity with the corresponding coefficients. According to the Eurocode, the authoritative load combination of 188,0269 MPa was obtained, and according to API 650, the authoritative load combination of 112,136 MPa was obtained.

4. ANALIZA DOBIJENIH REZULTATA

Prikazani dijagrami dobijeni su nakon sprovedene statičke analize čeličnog rezervoara za skladištenje vode, za neke slučajeve opterećenja. U tabeli 5 prikazani su dobijeni rezultati prema različitim uticajima, a tabele 6 i 7 daju prikaz kombinacije opterećenja za granično stanje nosivosti sa odgovarajućim koeficijentima. Prema Evrokodu dobijena je merodavna kombinacija opterećenja od 188,0269 MPa, a prema API 650 dobijena je merodavna kombinacija opterećenja od 112,136 MPa.

Table 6 - Comprasion of the obtaned results
Tabela 6 - Poređenje dobijenih rezultata prema različitim uticajima

Influence/Uticaj	EuroCode	API 650
	Stress/Napon [MPa]	Stress/Napon [MPa]
Wind/Vetar	27,85	10,17
Snow/Sneg	7,81	5,32
Seismic/Seizmika	44,61	29,69

Table 7 - Load combinations for the limit state of load capacity, with corresponding coefficients according to Eurocode [1]
Tabela 7 - Kombinacije opterećenja za granično stanje nosivosti, sa odgovarajućim koeficijentima prema Evrokodu [1]

Combined load / Kombinacija opterećenja	Description of the combination/ Opis kombinacije	Stress/ Napon [MPa]
1	Self weight/Stalno opterećenje (*G*) + liquid/tečnost (*F*) + wind/vetar (*W*)	144,4054
	$\gamma_{G,j}G + \gamma_{Q,1}\psi_{0,i}F + \gamma_{Q,i}\psi_{0,2}W$	
2	Self weight /Stalno opterećenje (*G*) + liquid/tečnost (*F*) + snow/sneg (*S*)	126,3667
	$\gamma_{G,j}G + \gamma_{Q,1}\psi_{0,i}F + \gamma_{Q,i}\psi_{0,2}S$	
3	Self weight /Stalno opterećenje (*G*) + wind/vetar (*W*)	32,6704
	$\gamma_{G,j}G + \gamma_{Q,i}\psi_{0,i}W$	
4	Self weight /Stalno opterećenje (*G*) + temperature/temperatura (*T*) + liquid/tečnost (*F*)	**188,0269**
	$\gamma_{G,j}G + \gamma_{Q,1}\psi_{0,i}T + \gamma_{Q,i}\psi_{0,2}F$	
5	Self weight /Stalno opterećenje (*G*) + liquid/tečnost (*F*) + seismic /seizmika (A_{Ed})	104,764
	$G + T + A_{Ed}$	

Table 8 - Load combinations for the limit state of load capacity, with corresponding coefficients according to API 650 [11]
Tabela 8 - Kombinacije opterećenja za granično stanje nosivosti, sa odgovarajućim koeficijentima prema API 650 [11]

Combined load / Kombinacija opterećenja	Description of the combination/ Opis kombinacije	Stress/Napon [MPa]
1	Self weight/Stalno opterećenje (D_L) + internal pressure/unutrašnji pritisak (P_i)	81,914
	$D_L + Pi$	
2	Self weight/Stalno opterećenje (D_L) + wind/vetar (W) + internal pressure/unutrašnji pritisak (P_i)	47,084
	$D_L + W + 0{,}4P_i$	
3	Self weight/Stalno opterećenje (D_L) + wind/vetar (W) + external pressure/spoljašnji pritisak (P_e)	52,396
	$D_L + W + 0{,}4P_e$	
4	Self weight/Stalno opterećenje (D_L) + liquid/tečnost (F) + seismic/seizmika (S) + snow/sneg (S_b) + internal pressure/unutrašnji pritisak (P_i)	**112,136**
	$D_L + F + S + 0{,}1S_b + 0{,}4P_i$	

Where are: $\gamma_{G,j}$ =1.1 - partial coefficient for constant effect, $\gamma_{Q,1} = 1.5$ - partial coefficient for variable effect, $\psi_{0,i}$ - coefficient for value of variable effect for combinations [1].

Gde su: $\gamma_{G,j} = 1{,}1$ - parcijalni koeficijent za stalno dejstvo, $\gamma_{Q,1} = 1{,}5$ - parcijalni koeficijent za promenljivo dejstvo, $\psi_{0,i}$ - koeficijent za vrednost promenljivog dejstva za kombinacije [1].

5. CONCLUSION

The paper presents the analysis and calculation of a steel tank according to the European standard and API 650. With the obtained dimensions of the elements, the tank was modelled in the ABAQUS software package. Emphasis is placed on the compared results according to the specified standards. Due to the application of different standards, the difference in the obtained results is expected. It primarily occurs due to the different influence of wind, snow and seismicity, but also the applied coefficients in calculation situations.

5. ZAKLJUČAK

U radu je prikazana analiza i proračun čeličnog rezervoara prema različitim standardima. Sa dobijenim dimenzijama elemenata rezervoar je modeliran u softverskom paketu ABAQUS. Akcenat je stavljen na poređene rezultata prema evropskom standardu i API 650. Zbog primene različitih standarda, razlika u dobijenim rezultatima je očekivana. Prvenstveno se javlja zbog različitog uticaja vetra, snega i seizmike, ali i primenjenih koeficijenata u proračunskim situacijama.

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