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Evaluation of design procedure of conical tanks in ECP 201-2012 under earthquakes loads

Dr. Gamal Mahmoud Hussin[1], Dr. Amgad Ahmed Talaat[2], Dr. Nasr Eid Nasr[2] and Eng. Ahmed Amr Fouad Rashed[3]

1. Associate professor, Structural Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt
2. Assistant professor, Structural Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt
3. Structural Engineer

ملخص البحث:

في هذا البحث يتم تقييم طريقة الكود المصري للاحمال رقم 201 لسنة 2012 في تحليل الخزانات المخروطية تحت تأثير أحمال الزلازل حيث ان الكود المصري 201 لا يحتوي علي طريقة خاصة لهذا الشكل من الخزانات كما انه ينص علي استخدام طريقة تقريبية لتحليل مثل هذه الخزانات عن طريق تحويلها لخزانات اسطواني مكافئة.

تم عمل تحليل ثلاثي الابعاد باستخدام طريقة العناصر المحددة باستخدام طريقة اضافة الكتلة لتمثيل التاثير الديناميكي للسائل داخل الخزان.

تم عمل مقارنة بين نتائج كلا الطريقتين باستخدام طيف التجاوب المرن وقد أظهرت تلك المقارنة ان طريقة الكود المصري 201 لسنة 2012 تقوم بتقدير اقل من الحقيقي للقوي علي تلك الخزانات تحت تأثير أحمال الزلازل.

Abstract

This paper aims to evaluate current dynamic analysis procedure used in Egyptian code of loads (ECP 201-2012) for conical shape containers. As ECP 201 doesn't include a special procedure for any tank rather than rectangular or circular shape of the tank container, the code assume an approximate cylindrical shape based on the volume and geometry characteristics of the conical shape container. Added mass approach is followed in the 3D FEM using mechanical properties of a previous study on conical shape tanks. Response spectrum method is used to compare between ECP 201 results and FEM results under earthquakes loads. This comparison indicates that ECP 201 technique undervalued the dynamic response of conical shape containers under earthquakes loads.

- ***KEYWORDS*:** conical tanks; fluid-structure interaction; dynamic analysis; seismic response.

• Introduction

Tanks are important in many activities like storage of fluids and liquids; also they are used in water supply structures. So, tanks should be designed in a proper manner to keep them safe against failure under earthquakes effect. The dynamic response of a conical tank is different from the behavior of a cylindrical tank.

In ECP 201-2012 clause no.10-6-1-3, if the tank container is not rectangular or circular shape, an approximate cylindrical shape may be utilized.

El Damatty and Sweedan (2006) developed a mechanical model that is used in this paper to get the mechanical properties of the FEM for any conical shape ground tank.

The aim of this paper is to compare between method used in ECP 201 results and FEM results under earthquakes loads for a set of studied tanks.

• ECP 201-2012 method

ECP 201 method is summarized in the following steps:

1- Estimate the shape of the equivalent tank:

1.1 $hw_{eq} = V / (\pi * R_T^2)$ (1)

Where V is the conical container volume, and Rt is the radius at the top of liquid surface

2- Get the mechanical parameters for that cylinder tank.

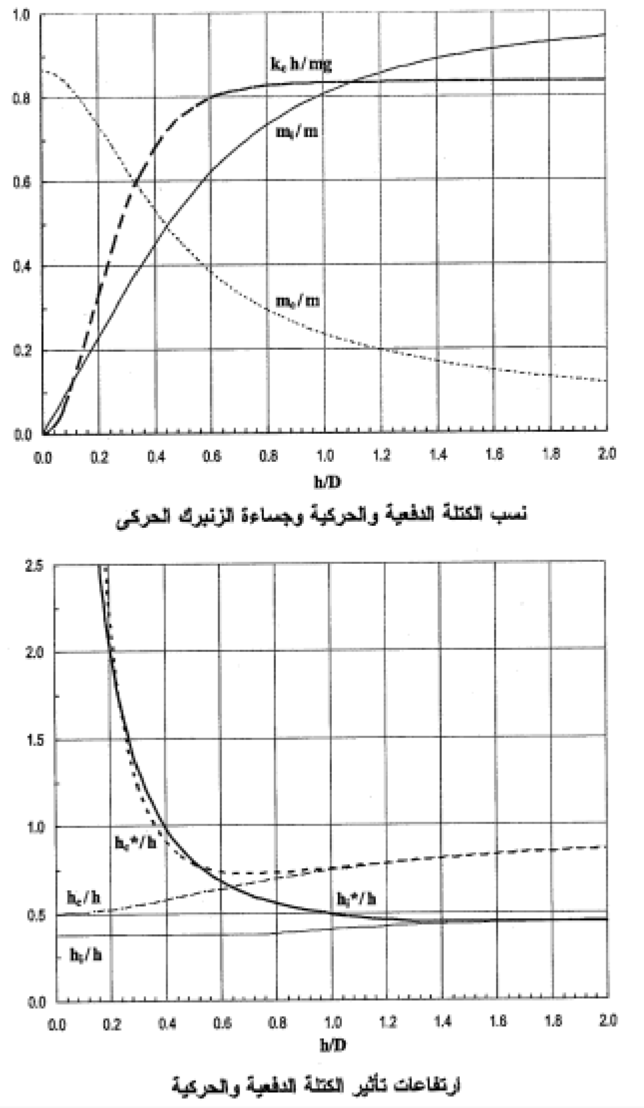


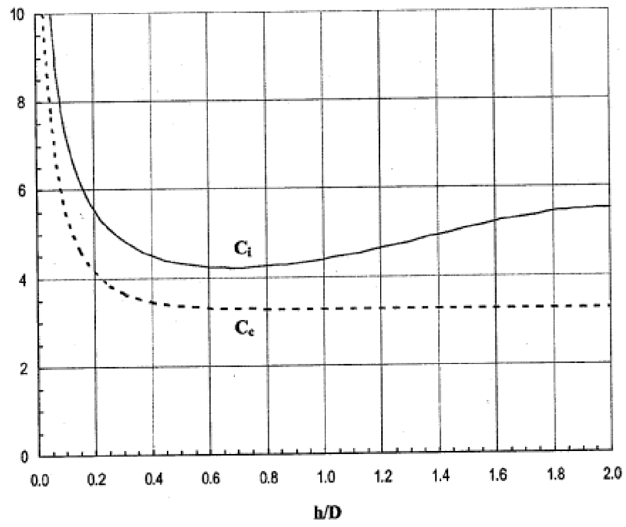
Figure: Mechanical parameters of the cylindrical tank

3- Add container mass to the impulsive mass of the liquid.

4- Calculate the convective mode`s period (T_c) using the stiffness and mass from step (2)

5- Calculate the impulsive mode`s period (Ti), using factor (C_i).

5.1 $Ti = (\frac{1}{\sqrt{2000}})*(\frac{Ci\ H}{\frac{\sqrt{tu}}{D}})*(\frac{\sqrt{\rho}}{\sqrt{E}})$



شكل (١٠-٤) معاملات الزمن المودى الدفعية (C_i) والحركية (C_c) للخزانات الإسطوانية.

Figure: Ci factor

6- Calculate spectral acceleration using impulsive and convective modes` periods
7- Calculate base reactions using SRSS.

- **Conical container`s mechanical parameters**

The mechanical model developed by El Damatty and Sweedan (2006) includes rigid, flexible, and sloshing components. In this paper, six parameters are obtained from this mechanical model, flexible mass ratio (mf/mt), impulsive mass ratio (mr/mt), flexible mass height ratio (hf/hw), convective mass ratio (ms/mt), convective mass height ratio (hs/hw), and sloshing frequency (fs). Also mo is equal to (mr-mf) is added to the base of container.

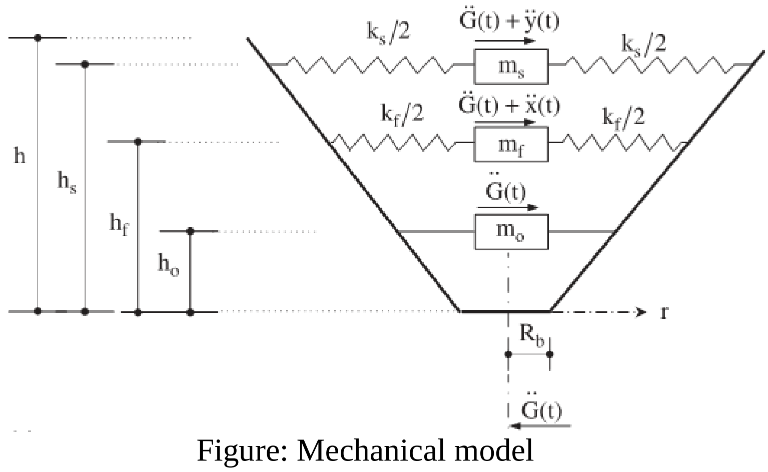


Figure: Mechanical model

- **Finite element model**

SAP2000 software is used in this paper. Walls of the container are modelled using the shell element with fixed restraints at the base. The impulsive mass is distributed equally over joints of walls at a height of h_f, convective mass is put at the centre and at a height of h_s from base and connected to the walls joints link of stiffness of $k_s/2$. Response spectrum curve defined in ECP 201-2012 Type (1), zone (1) and ground tyoe “C” with “I” factor = 1.0 and “R” factor = 2.0.

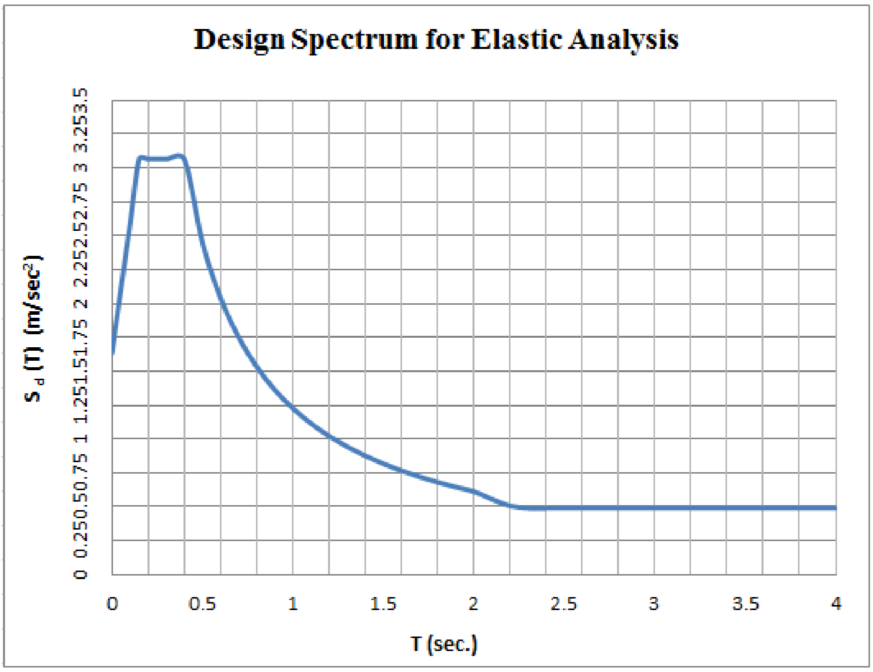


Figure: Response spectrum curve used in the analysis

- **Parametric study**

A set of ground conical tanks are studied. Results from finite element models and ECP 201 method are compared to each other. The studied tanks contain a wide range of different Θ_v (vertical inclination of tank walls with vertical axe) with these values: 5°, 10°, 15°. For each Θ_v different height of water and base radius are studied with height to base radius ratios of: 2 and 2.5. Also water volume is taken 250 m3, 500 m3 and 1000 m3. The studied tanks contain water with 80% of container height. The studied tanks are assumed to be concrete tank with grade Fcu=30 Mpa.

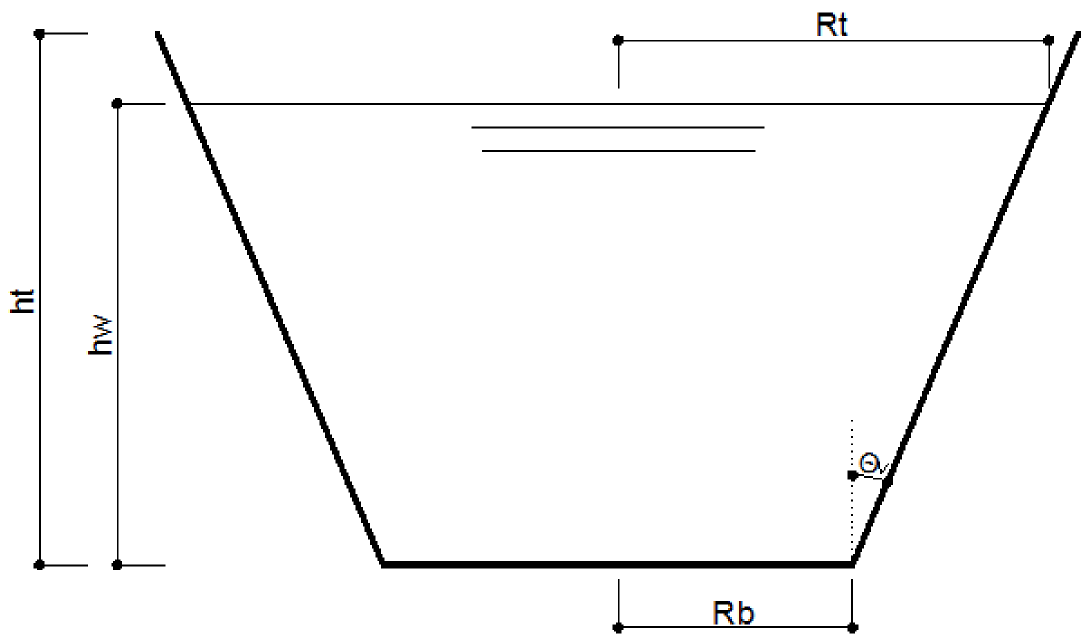


Figure: Conical container geometry

• Results

Results are shown in the following table.

The base shear forces show good match between FEM and ECP 201. For the base moment, ECP 201 is about 15% to 40% less than FEM in case of ground tanks.

Table: Ground tanks` result

h_w/R_b	Volume (m^3)	θ_V	Base shear (KN)		Base moment (KN.)	
			FEM	EC8	FEM	EC8
2.0	250	5^o	273	340	1309	940
		10^o	263	311	1300	787
		15^o	251	284	1238	669
	500	5^o	513	676	3067	2331
		10^o	490	604	3009	1869
		15^o	474	549	2911	1575
	1000	5^o	967	1387	8382	7221
		10^o	908	1216	8180	7087
		15^o	843	1091	7980	6955
2.5	250	5^o	291	376	1600	1194
		10^o	275	334	1508	946
		15^o	261	304	1432	797
	500	5^o	542	740	3667	2898
		10^o	513	647	3469	2236
		15^o	487	583	3306	1843
	1000	5^o	1024	1526	8603	7392
		10^o	965	1310	8175	5536
		15^o	907	1164	7650	4463

• Summary and Conclusion

In this paper, a study is done on a set of conical ground tanks to evaluate the approximate procedure used in ECP 201-2012 for studying conical tanks under earthquakes loads through comparing ECP 201 method results with finite element models results. It was concluded ECP 201 equivalent method doesn't represent the actual dynamic behaviour of the conical container accurately. Base shear resulted from ECP 201 procedure showed a good agreement with FEM, but overturning moment resulted from ECP 201 is about from 15% to 40% less than FEM. So it is recommended not to follow the approximate method used in ECP 201-2012 and 3D analysis is highly recommended to estimate the response of conical shape tanks under earthquakes loads.

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