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Parametric Risk Assessment of Industrial Storage Tanks

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Abstract: In the past,various damages have been observedin large number of industrial facilities during the experienced earthquakes. Different than the residential buildings, damages in industrial facilities have a significant direct influence on the economy and production in the countries. Industrial storage tanks, ruptured by earthquates, exascerbate damage through the spread of fire. Storage tanks are uniquely structured, tall cylindrical vessels, some supported by relatively short reinforced concrete columns, some supported by the ground. The aim of this study is to evaluate the seismic performance of storage tank structures in industrial facilities. The seismic performance assessment and estimation were carried out through time history analyses with variousground motion data set. After the time history analyses, a parametric approach was carried out by considering various geometrical properties during the structural investigation. With different geometry, structural behavior of storage tanks have been parametrically evaluated. Model tank structureswereanalyzed with theirsolid models with lumped mass and spring systems. For the model structures, analyses results were evaluated and compared.

Keywords: Industrial facilities, storage tanks, dynamic analysis, time history analysis, parametric seismic assessment, Seismic Risk Assessment

1.Introduction

Storage tanks are one of the major structures in the industrial facilities. In the past, Niigata (Japan) in 1964, Alaska (USA) in 1964also caused significant damage to industrial facilities as observed in 1999 Turkish earthquakes recently. In Turkey, during the 1999 earthquake, there was an industrial facility named asTupras Refinery got devastating damage as appears in Figure 1 (Turkish Press, 1999). Figure 2 shows sample damaged and undamaged storage tanks(Akinci and Kilic, 2002). As seen in the Figure 2, columns of two out of three structures have been collapsed.

Figure 1. Aerial view of Tupras refinery after the Kocaeli earthquake (Turkish press, 1999)

With the motivation of these past experiences, many research work has been published.James and Rabe (1991) has investigated a silindirical storage tank with ~80m diameter and ~26m height. They modelled the storage tank in Shell and solid members. They compared the stress results with shell and solid members. Koh et al. (1998) has investigated a storage tank with 3D models. They applied seismic loads on it and investigated the strutcural behavior of the storage tanks considering soil-structure intreaction effects. They also give the results from the experimental investigation with shaking table. They proposed a hybrid method for finite element analysis with analytical invesitigations. Livaoglu and Dogangun (2003) has discussed various frame systems of storage tank models considering various soil conditions.

Figure 2. Damaged storage tanks(Akinci and Kilic, 2002)

Storage tank models are defined with reinforced concrete columns connecting the soil to the Storage tank structures. Storage tanks have been modelled with Shell systems in the Finite Element Modeling. Results have been compared with previous research work results.

As seen, seismic hazard is one of the most natural threats for storage tanks. A seismic event can lead to subsequent events such as fire and explosion as discussed in Korkmaz, et.al(2008) and Ozbey and Sari (2007). For typical atmospheric (above-ground) storage tanks placed on a pile-supported mat of reinforced concrete, some of the potential modes of earthquake failures are storage tank buckling as defined elephant foot or element knee buckling, shell rupture at welded seams due to tension stresses beyond ultimate strength of the steel, and upper shell buckling due to sloshing behavior in tanks.

Korkmaz et. al. (2011) modelled storage tanks at 18m height with RC columns and investigated the failure at these storage tank structures. Storage tanks have been modelled in solid members. They also modelled the water effect with springs. Time history analyses results were given in graphs in the study. Mohite and Jangam (2012) has investigated structural performance of existing storage tank structures with various loading effects. Ormeno et al (2015) has carried out seismic investigation of storage tank strcutures with time history analyses. They evaluated Eurocode 8 with shear, overturing, and wall stress values.

Storage tanks are exposed to various intensities of fire and duration to failure is estimated for each intensity of fire. In order to predict the temperature distribution in the storage tank shell and the roof, a coupled heat transfer-CFD analysis is carried out in which the convective cooling effects of oil inside the storage tank is captured. Subsequently, a structural analysis is performed to quantify the effect of temperature rise in the storage tank behavior.

Finite element model of the storage tanks are developed in general purpose finite element analysis software. Both material and geometric nonlinearities are explicitly captured in the finite element analysis. Time to failure is reported. The thermo-physical properties of steel are modeled according to Eurocode 3 (2005) which provides temperature dependent conductivity and specific heat properties for both carbon and stainless steel materials. Structural response to blast loading is dependent upon both the peak pressure and blast impulse.

A review of literature shows that there has been hardly any progress made in understanding the dynamic response of liquid storage tanks under blast loading. Sari and Dyer (2005) analyzed the dynamic response of liquid-filled storage tanks under extreme blast loading. They conducted a comprehensive analysis in which the effects of fluid-structure interaction, dynamic buckling, and high strain rate effects were captured. Yasseri (2015) studied the blast pressure distribution around the storage tanks.

The methodologies outlined by Sari et al. (2015) and Yasseri (2015) are reviewed and improved to predict the performance of storage tanks under blast loading. In this study, a nonlinear finite element analysis is carried out to predict the dynamic response of the storage tanks to blast loading. Blast response of two types of secondary containment walls are evaluated; Earth dyke and Concrete wall. The concrete, the filled soil and the dense till/bedrock is modelled using Mohr-Coulomb material model. The interaction between the liquid and the storage tank shell under seismic motion is modeled directly using Lagrangian/Eulerian approach.

Methodologies such as one as discussed in O'Rourke and Pak (2000) can be used to develop storage tank seismic fragility curves. A fragility curve describes the probability of various levels of component damage as a function of measure of the seismic hazard, e.g., peak ground motion (PGA). Damage states are used to characterize component damage.Storage tanks on the path of tornado can be directly impacted by a tornado and the consequence can be overturning of the tanks, rupture of the pipe connections to the tanks, or collapse of the storage tanks in seismically active regions, or combination of these consequences.

Furthermore, the tornado may impact the storage tank terminal by tornado-induced debris impact which may result in collapse and release of storage tank’s content.The appropriate secondary containment must be designed to address the quantity of oil that may be discharged from the tank failure, quantity of liquid from fire-fighting activities, and quantity of liquid from a 1-in-10 year and 1-in-100 year 24-hour rain precipitation events. Series of events potentially leading to a secondary containment overfill are identified. Probability of multiple storage tank rupture in a single shared secondary containment is considered in the calculation for structural behavior demonstration.

Landucci et al. (2009), have relied on simplified techniques and overly conservative failure criteria to develop time to failure as a function of thermal intensity curves for storage tanks. The limitations of these approaches include definition of failure criteria, due consideration for various structural types, and assumptions related to cooling effect consideration of the liquid in the storage tank. In addition, Sari et al. suggested a free field blast pressure for threshold value against domino effects. Also, Lees (1996) provided peak side on pressure as threshold for rupture of oil storage tanks. These threshold limits are overly conservative and cannot be uniformly applied for all types of storage tanks. Therefore, any risk assessment study needs to assess the structural response of the storage tanks by utilizing advanced engineering to obtain more accurate response results and to remove any conservatism involved with simplified approaches. This is a very important assessment for storage tanks especially with regards estimating risk considering the domino effects.

2. Storage Tank Models

Storage tanks with higher storage capacity are designed for industrial facilities. These facilities have huge storage capacties in total. Therefore, any failure in these storge tanks leads to catastrophic disasters of entire facility. These storage tanks are generally modelled with 100m^3 to 50,000m^{3}with the range of 0.1 to 0.5 sec of structural periods (Malhotra, 1997). In this period range, storage tanks do not have enough ductility to absorb seismic energy. Most comon ones are the ones sitting on the ground. There are also embadded ones and elevated with RC column ones serving as storage tanks in industrial facilities. Geometrical shapes can be slyindrical or rectangular depending on the storage material. If they store luqiud, they are generally constructed in sylindrical shape.

In the present study, various types of liquid storage tank structures have been investigated and a parametrical evaluation has been carried out. Fort he research, storage tanks with 21m and 17m diameter storage tanks have been considered. The models have 10m and 15m heights. Table 1 represents the model storage tanks.

Table 1. Geometrical properties of storage tank models

	Height (m)	Diameter (m)	Base Area (m^2)	Height/ Base Area	Base Area/ Volume
A	15.00	21.00	352	43.00	1.00E-04
B	10.00	21.00	352	65.00	6.67E-05
C	15.00	17.00	232	29.00	1.00E-04
D	10.00	17.00	232	43.00	6.67E-05

In Figure 3, Structural details of storage tank models are given. Structural checkfor these structures can be carried out with Finite Element methods and softwares for the buildings. However, since finite element methodology is complex and complicates, to control of safety of their design, a simplified approach is needed for assessment and evaluation of such structures.

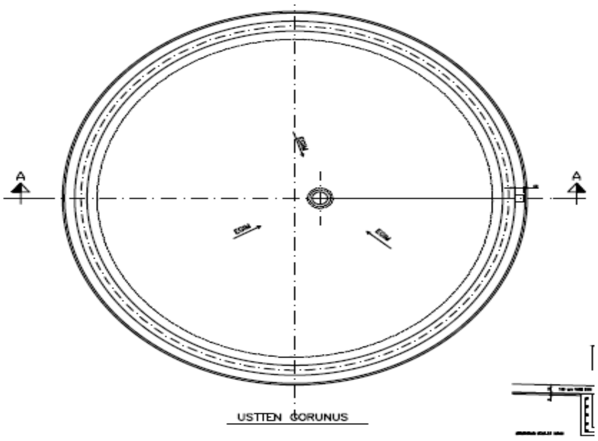


Figure 3. Structural details of the storage tank models

3. Structural Analysis of Storage Tank Structures

In the structural analysis of storage tank structures, 3D models of the buildings were created through SAP2000 software and analyses were carried out on these models. In the models, shell members were used to model the storage tank structures. Seismic loads, Jet A1 fuel oil loads, and hydrostatic loads were applied on the models for the analyses. For JET A1 fuel oil load definition, mass-spring system was used. For defining earthquake ground motion loading effect, seven different ground motion records from B type of soil were used. Via SAP2000 software, max. shear forces, stresses, and displacement values were recorded with various earthquake ground motion data as a result of time history analyses. Models were considered for various cases as bare and full-1 and full-2. In Figures 4 to 7, 3D models of the storage tank structures are given.

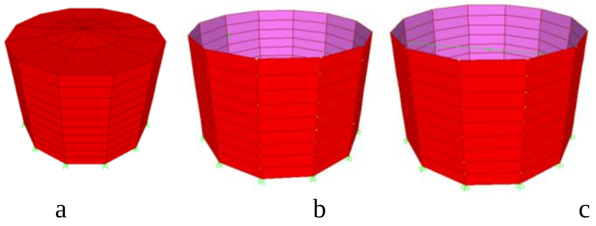

a b c

Figure 4. Model A Storage Tank a) Bare b) Full 1 c) Full 2

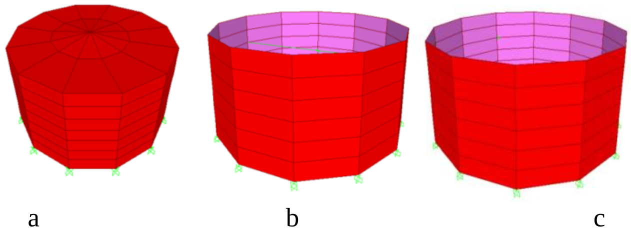

a b c

Figure 5. Model B Storage Tanks a) Bare b) Full 1 c) Full 2

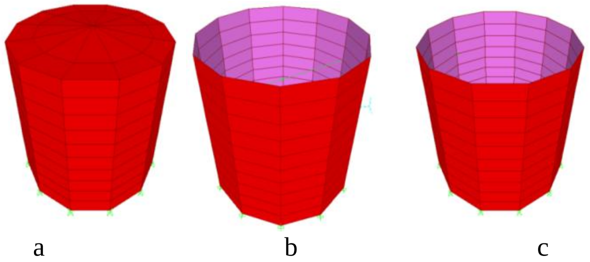

a b c

Figure 6. Model C Storage Tanks a) Bare b) Full 1 c) Full 2

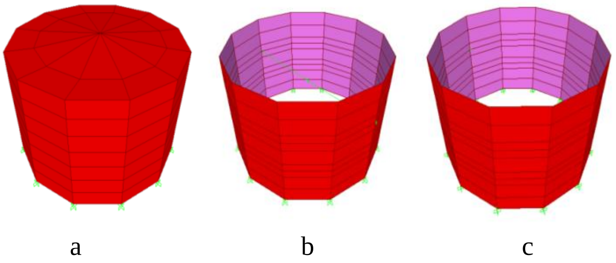

a b c

Figure 7. Model D Storage Tanks a) Bare b) Full 1 c) Full 2

In the structural modelling, spring-mass model was used. The model was introduced by Housner first to define structural behavior of rigid walled cylindirical storage tanks under earthquake loading. Housner model is depicted in Figure 8.

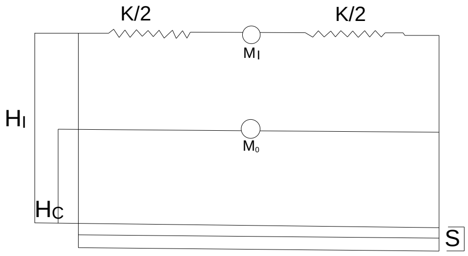


Figure 8. Mass-spring model developed by Housner

In the research, to define a parametric pattern, systemic approach was used with Time History analyses. Time history analyses were applied with various ground motion data. In Table 2, ground motion data is provided. PEER was used to select the earthquakes from B soils. Earthquake name, gpa, fault type and properties are provided in Table 2.

Table2. Used earthquake data from soil class B

	Date	M_w	PGV(cm/s)	PGA (g)	Dist (km)
Kocaeli	17/08/1999	7.4	17.7	0.2188	17
Kobe	16/01/1995	6.9	79.3	0.8213	6.9
Northridg	17/01/1994	6.7	17.6	0.364	37.9
Kocaeli	17/08/1999	7.4	79.5	0.376	3.1
Anza	25/02/1980	4.9	2.6	0.047	40.6
Cape Mendocin	25/04/1992	7.1	28.3	0.178	44.6
Loma Prieta	18/10/1989	6.9	15.6	0.113	46.9

Model parameters for storage tank structures are:

$$Mw = \pi . R^2 . h . \rho \qquad (1)$$

$$S = h - 1.5 . r \qquad (2)$$

$$Mc = Mw . 0.318 \frac{R}{h} \tanh \left(1.84 \, {}^{h}/_{R}\right) \qquad (3)$$

$$Mi = Mw \frac{\tanh\left(1.74 \, {}^{R}/_{h}\right)}{1.74 \, {}^{R}/_{h}} \qquad (4)$$

$$Hc = \left[1 - \frac{\cosh\left(1.84 \, {}^{h}/_{R}\right) - 1}{1.84 \, {}^{h}/_{R} \sinh\left(1.84 \, {}^{h}/_{R}\right)}\right] . h \qquad (5)$$

$$Hi = \frac{3}{8} h \qquad (6)$$

$$Kc = Mc \frac{g}{r} 1.84 \, tanh \frac{1.84 . h}{R} \qquad (7)$$

Here, k_c: Oscillation mass rigidity, m_c: oscillacition mass, m_i: impluse mass, h_c: oscillation mass height, h_i: impulse mass height

4. Analysis Results

In the time history analyses, seven different earthquake ground motion data were used to understand the structural behavior of the storage tanks. In storage tank structures, structural behavior has changed with the geometry of the storage tank structures. Through the structural analyses of storage tank structures, the highest values were obtained with Kobe eartquake data. Comparing with the others, Kobe earthquake data has higher gpa and gpv values. Anza earthquake is the lowest one comparing the others. When comparing the results, it is seen that, earthquake`s properties play an important role on the structural response of the structures.

When carrying out structural analyses, 12 various mode values were considered. For each structural assessment, X and Y structural behavior were compared. Base shear/weight versus displacement/hight ratios and surface stress/total stress ratios were defined as result of the analyses. These were parametric values to understand the behavior of the storage tank structures. These parameters were also sketched in the research to see the change the behavior with the geometrical properties.In Table 3, Displacement / Height, in Table 4, Base Shear / Weight values are provided. Table 5 gives the numerical values of Surfice Stress to Total stress.

Table 3. Values of Displacement / Height

	Bare Case		**Full -1 Case**		**Full -2 Case**	
	Δ/H		**Δ/H**		**Δ/H**	
	X Drct	**Y Drct**	**X Drct**	**Y Drct**	**X Drct**	**Y Drct**
A	0.0000130	0.0000131	0.0064478	0.0021789	0.0025659	0.0025597
B	0.0000130	0.0000131	0.0064478	0.0021789	0.0025659	0.0025597
C	0.0000020	0.0000019	0.0024909	0.0021680	0.0019812	0.0019812
D	0.0000026	0.0000026	0.0018945	0.0021063	0.0017714	0.0017714

Table 4. Values of Base Shear / Weight

	Bare Case		**Full -1 Case**		**Full -2 Case**	
	V/W		**V/W**		**V/W**	
	X Drct	**Y Drct**	**X Drct**	**Y Drct**	**X Drct**	**Y Drct**
A	0.0141873	0.0129498	33.6189324	50.5623671	38.4431127	39.9068742
B	0.0166796	0.0166795	14.5628906	14.5628906	27.1970301	29.6206179
C	0.0137230	0.0137425	24.3829491	14.7711751	24.3829491	26.3280566
D	0.0179123	0.0211440	21.1371601	21.8755818	26.0239174	26.0239105

Table 5. Values of Surface Stress to Total stress

	Bare Case		Full -1 Case		Full -2 Case	
	σ h/ σ max		σ h/ σ max		σ h/ σ max	
	X Drct	Y Drct	X Drct	Y Drct	X Drct	Y Drct
A	0.0000543	0.0000214	0.0001683	0.0004578	0.0002058	0.0005058
B	0.0000516	0.0000326	0.0001991	0.0002841	0.000290956	0.0007735
C	0.0000368	0.0000537	0.0002239	0.0002748	0.000179955	0.0002478
D	0.0000551	0.0000802	0.0002074	0.0002841	0.000200853	0.0002766

4.1. Assessment of Model AStorage Tank Structure:

For Model A, for bare case, the highest values were recorded as highest displacement as 0.742mm, highest stress value as 9.525 Mpa, Highest base shear as 89,442.24kN for Kobe earthquake. The lowest scores were recorded as lowest displacement as 0.0276mm, lowest stress value as 0.248 Mpa, lowest base shear as 3,927.39kN.

For Model A, for Full-1 case, the highest values were recorded as highest displacement as 441.69mm, highest stress value as 3559.129 MPa, Highest base shear as 536,183.6 kN for Kobe earthquake. The lowest scores were recorded as lowest displacement as 3.851 mm, lowest stress value as 38.494 MPa, lowest base shear as 34,996.9 kN.

For Model A, for Full-2 case, the highest values were recorded as highest displacement as 130.6188mm, highest stress value as 2,785.934 MPa, Highest base shear as 467,116.6 kN for Kobe earthquake. The lowest scores were recorded as lowest displacement as 4.021 mm, lowest stress value as 41.113 MPa, lowest base shear as 16,830.8kN.

4.2. Assessment of Model BStorageTank Structure:

For Model B, for bare case, the highest values were recorded as highest displacement as 0.76 mm, highest stress value as 9.413 MPa, Highest base shear as 160.7289 kN for Kobe earthquake. The lowest scores were recorded as lowest displacement as 0.0273 mm, lowest stress value as 0.245 MPa, lowest base shear as 3.92739 kN.

For Model B, for Full-1 case, the highest values were recorded as highest displacement as 235.92 mm, highest stress value as 2,375.49 MPa, Highest base shear as 205,615.1 kN for Kobe earthquake. The lowest scores were recorded as lowest displacement as 1.85 mm, lowest stress value as 30.756 MPa, lowest base shear as 4,318.618 kN.

For Model B, for Full-2 case, the highest values were recorded as highest displacement as 49.551 mm, highest stress value as 1,025.75 MPa, Highest base shear as 205,615.1kNfor Kobe earthquake. The lowest scores were recorded as lowest displacement as 1.850 mm, lowest stress value as 22.615 MPa, lowest base shear as 11,824.6 kN.

4.3. Assessment of Model CStorageTank Structure:

For Model C, for bare case, the highest values were recorded as highest displacement as 0.047 mm, highest stress value as 3.581 MPa, Highest base shear as 129.922 kN for Kobe earthquake. The lowest scores were recorded as lowest displacement as 0.0276 mm, lowest stress value as 0.248 MPa, lowest base shear as 3.20 kN.

For Model C, for Full-1 case, the highest values were recorded as highest displacement as 135.133 mm, highest stress value as 3,365.639 MPa, Highest base shear as 371,340.1 kN for Kobe earthquake. The lowest scores were recorded as lowest displacement as 4.11 mm, lowest stress value as 83.225 MPa, lowest base shear as 13,484.76 kN.

For Model C, for Full-2 case, the highest values were recorded as highest displacement as 111.140 mm, highest stress value as 3,028.117 MPa, Highest base shear as 371,340.1 kN for Kobe earthquake. The lowest scores were recorded as lowest displacement as 3.81 mm, lowest stress value as 85.779 MPa, lowest base shear as 107,541.1 kN.

4.4. Assessment of Model DStorageTank Structure:

For Model D, for bare case, the highest values were recorded as highest displacement as 0.0413 mm, highest stress value as 2.152 MPa, Highest base shear as 130.104 kN for Kobe earthquake. The lowest scores were recorded as lowest displacement as 0.0033 mm, lowest stress value as 0.085 MPa, lowest base shear as 3.194 kN.

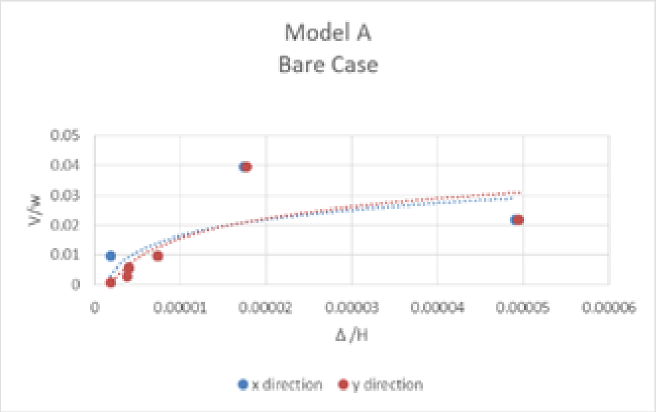
For Model D, for Full-1 case, the highest values were recorded as highest displacement as 51.029 mm, highest stress value as 1,506.8 MPa, Highest base shear as 167,735.6 kN for Kobe earthquake. The lowest scores were recorded as lowest displacement as 2.39 mm, lowest stress value as 46.066 MPa, lowest base shear as 7,977.178 kN.

For Model D, for Full-2 case, the highest values were recorded as highest displacement as 37.32mm, highest stress value as 1,292.96 MPa, Highest base shear as 167,735.6 kN for Kobe earthquake. The lowest scores were recorded as lowest displacement as 2.29 mm, lowest stress value as 46.993 MPa, lowest base shear as 7,430.312 kN.

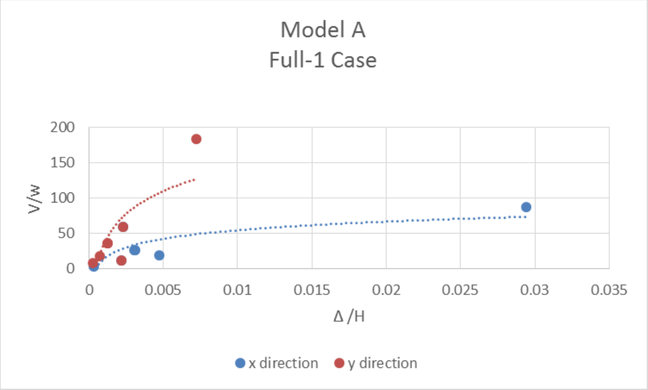
In the structural analyses, storage tank models were considered as bare and full to investigate the liquid effect on the storage tanks. For understanding the the difference in between the models, models were investigated in two combinations in terms of solid-liquid interaction. This was carried out via spring-mass relationship which is the most common methods for such structures. Full condition were titled as Full-1 and Full-2.

5. Conclusion

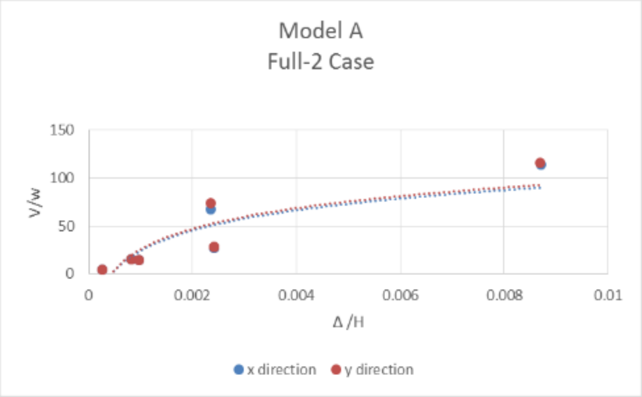
For a simplified assessment, a parametric approach would be neccessary to investigate the storage tank streuctures. Therefore, in the present research, a parametric investigation was carried out in regards with time history analyses. For four different models, bare, Full 1 and Full 2 combinations were applied to understand the structural behavior of storage tank models. Time history analyses were carried out with 7 different ground motion data via SAP2000 software. Storage tank models were modelled with mass-spring models for understanding liquid effect on the structures.In Figures 9 to 12, the base shear/weight vs displacement/hight were sketched.



a) Model A Bare Case



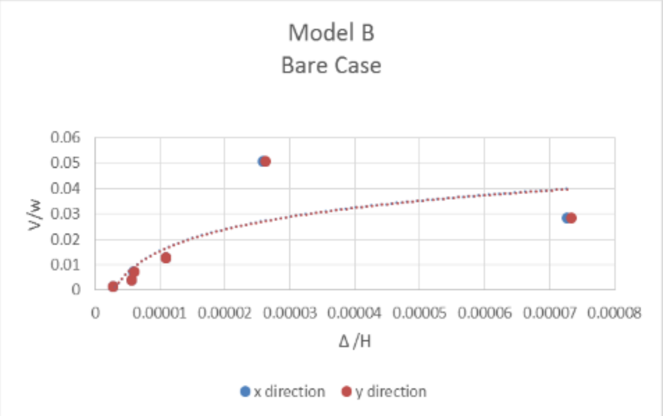
b) Model A Full 1 Case



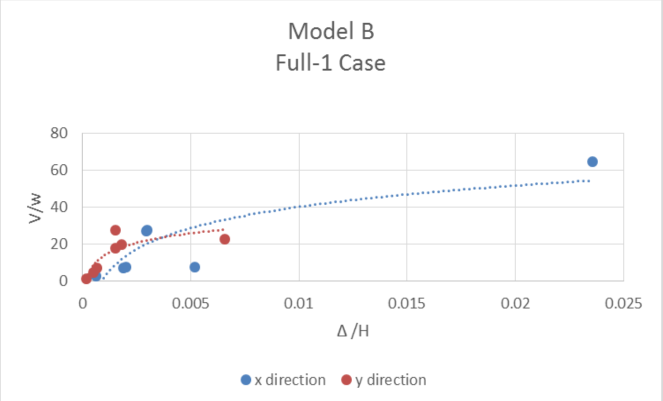
c) Model A Full 2 Case

Figure 9. Model A Storage Tank- Base Shear / Weight vs Displacement / Height

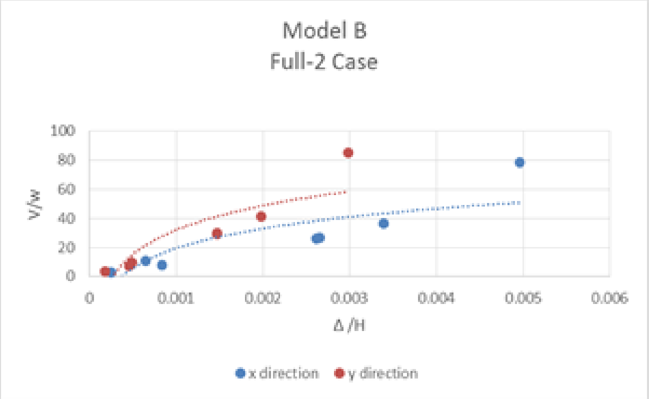
Through out the investigation, from the all ground motion data, Kobe earthquake played an important role for the structures. Especially for the full cases, structures reached higher values comparing to bare case. According to the sketched graphs, with Kocaeli earthquake, structures reached acceptable values. With Anza earthquake, storage tank structures got lower values. Hence, with various earthquakes, structural behavior changes significantly. Graphs, plotted according to structural analyses, shows the structural behaviors of different types of tanks with different geometric properties for definng effects of geometry in the structural behavior.



a) Model B Bare Case

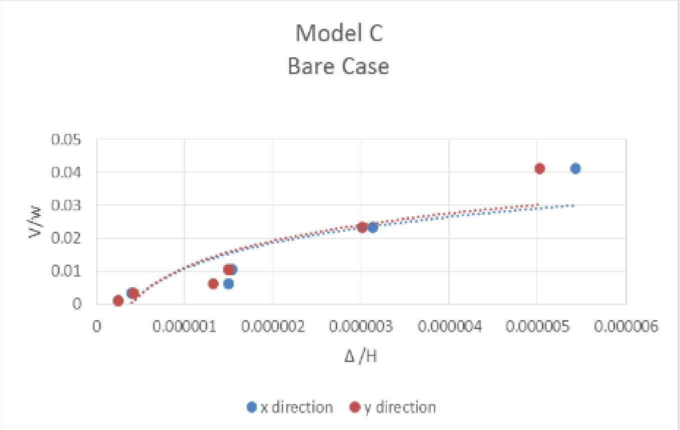


b) Model B Full 1 Case

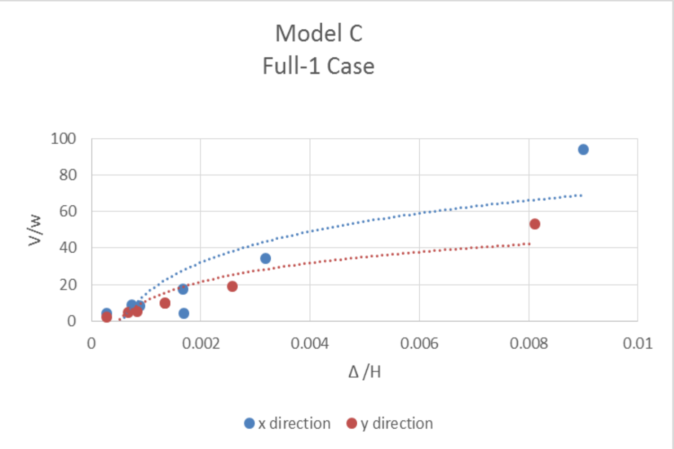


c) Model B Full 2 Case

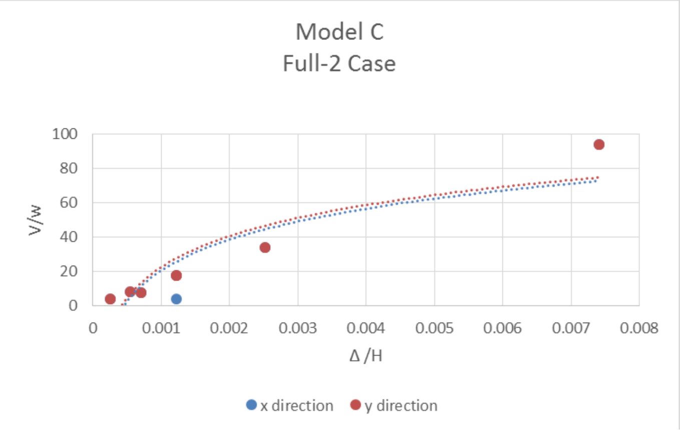
Figure 10. Model B Storage Tank- Base Shear / Weight vs Displacement / Height



a) Model C Bare Case



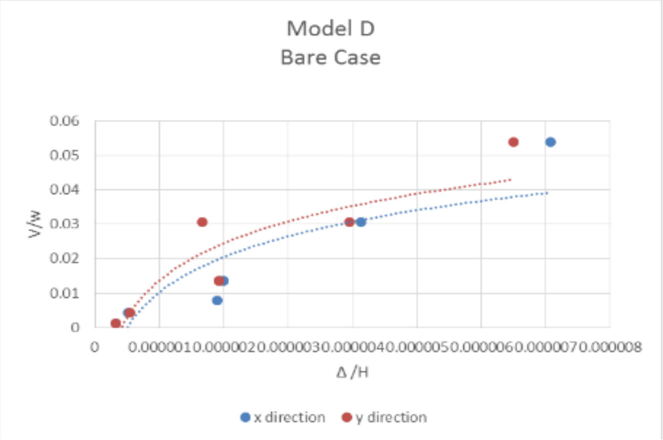
b) Model C Full 1 Case



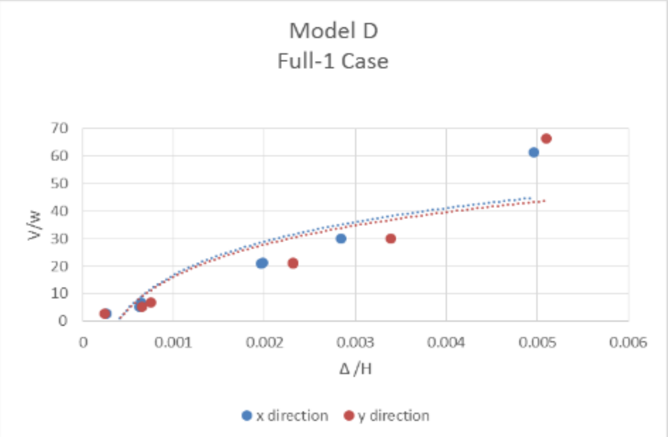
c) Model C Full 2 Case

Figure 11. Model C Storage Tank- Base Shear / Weight vs Displacement / Height

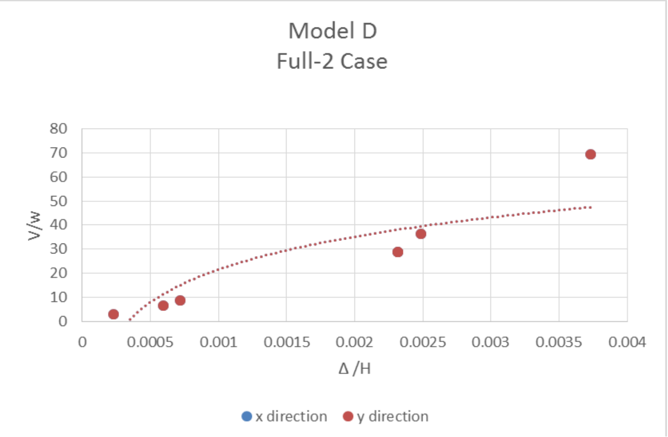
In Comparision Figures 9, 10, 11 and 12 with each other, Model A presents a higher Base Shear / Weight vs Displacement / Height for Full in Full 1 and 2 cases. While Model B and D are higher at the Bare cases. Model D present a lower ratio at Full 1 and 2 cases.Model C present better performance comparing to Model B for full cases while Model C has higher ratio for the bare case. In such comparision, Models present similar behaviors in bare cases for given contions.



a) Model D Bare Case



b) Model D Full 1 Case



c) Model D Full 2 Case

Figure 12. Model D Storage Tank- Base Shear / Weight vs Displacement / Height

Figures 13 to Figure 16 give surface stress/total stress. After comparing Base Shear / Weight vs Displacement / Height ratios, stress distribution in the tanks are important and they demonstrate the behavior tendency of the tanks. Comparing to other earthquake data,Cape Mendocino data had higher results in stress distribution for Model A. Comparing to other models, Model A reached higher value as seen in Figuresand stresss distribution is demanding comparing to other models.

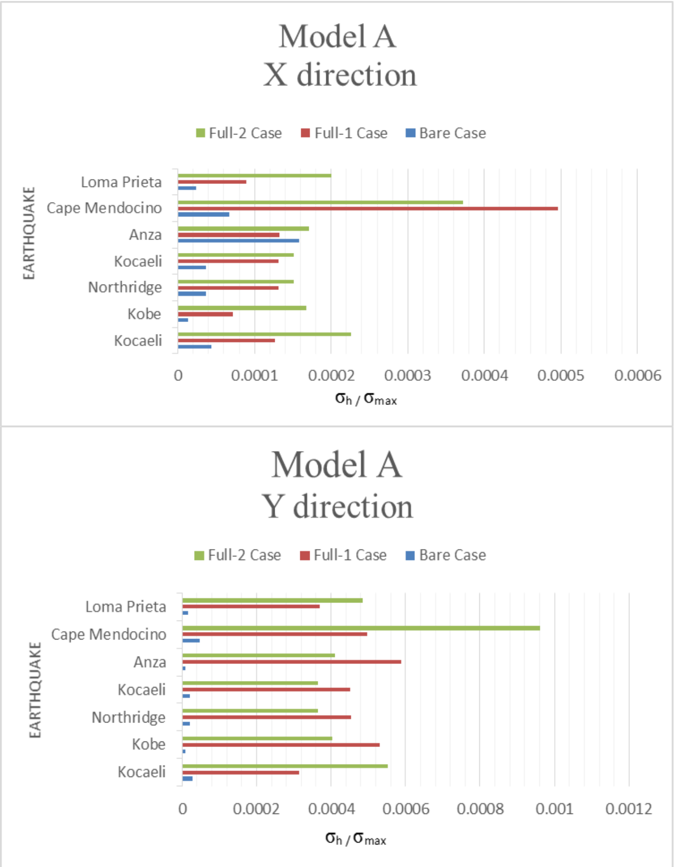


Figure 13. Model A Storage Tank- ratio of Surface Stress to Total stress

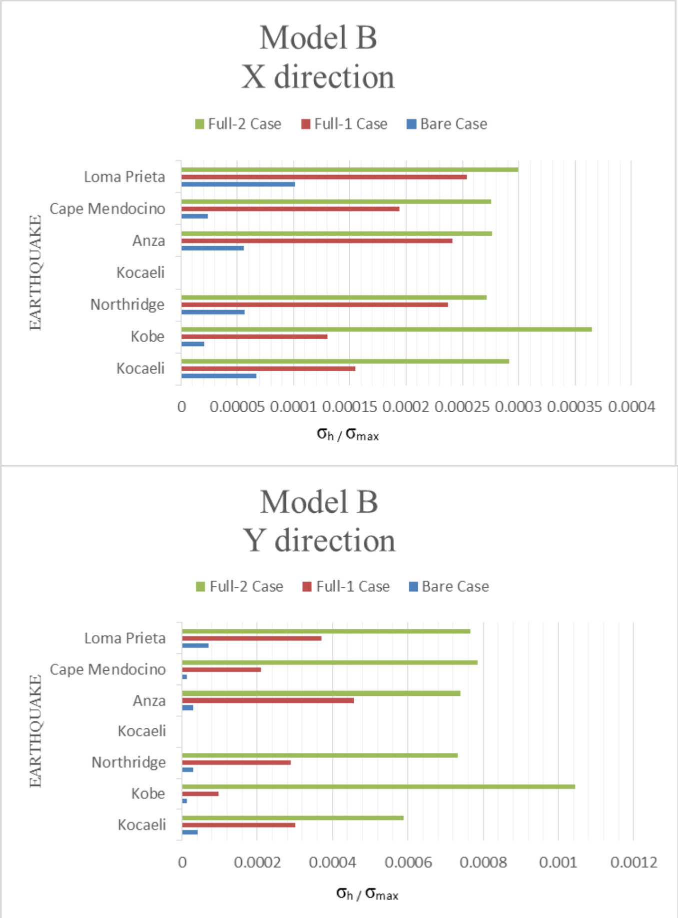


Figure 14. Model B Storage Tank- ratio of Surface Stress to Total stress

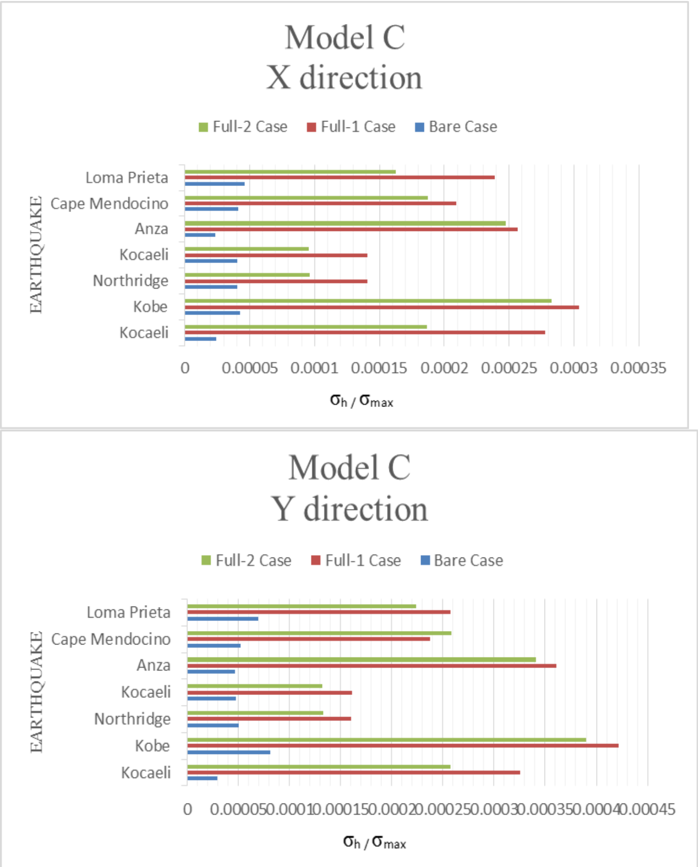


Figure 15. Model C Storage Tank- ratio of Surface Stress to Total stress

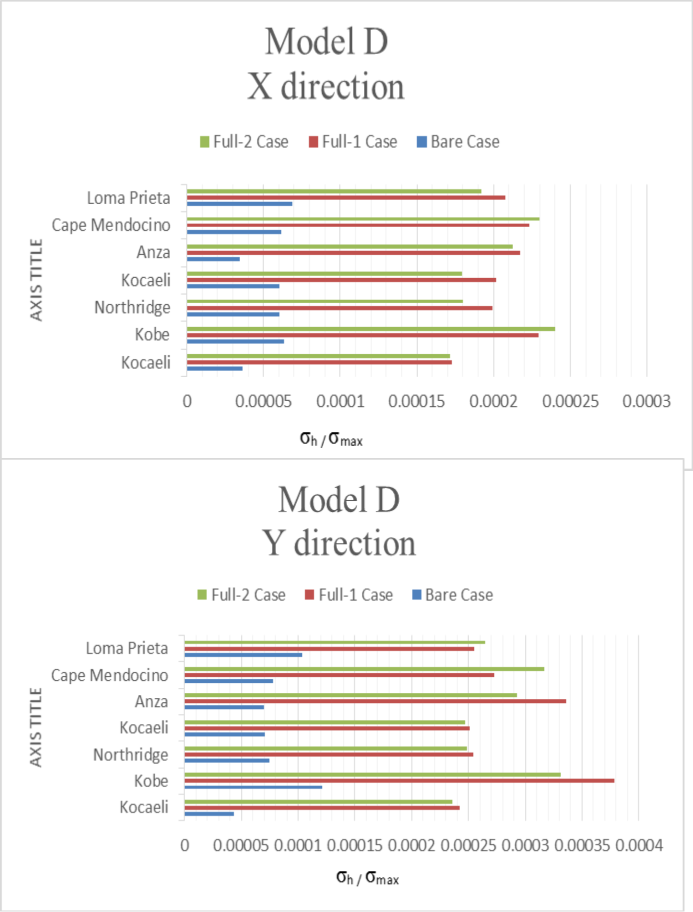


Figure 16. Model D Storage Tank- ratio of Surface Stress to Total stress

References

1. Celep Z. Kumbasar N., (2001) Introduction to Earthquake Engineering, 3rd Edition, Istanbul Technical University, Istanbul, Turkey-In Turkish-
2. Celep, Z., Kumbasar, N., (1996) Reinforced Concrete Buildings, SemaMatbaacılık, İstanbul, Turkey-In Turkish-
3. Celep, Z., Kumbasar, N., (2001) Structural Dynamics, RehberMatbaacılık, Beta Dağıtım, s. 18-20,241, İstanbul, Turkey-In Turkish-
4. Doğangün, Ayvaz, Y A., Durmuş, A. Erthquake Analysis of Water Tower, Proceedings of the Fourth International Conference on Civil Engineering, Tehran, Iran, Vol. I,pp. 439-448. 1989.
5. Dogangun A, Livaoglu R, (2003), Investigation of Storage Tanks in Various Soil Conditions, Sakarya University, Natural and Applied Science Journal, 7,3, 70-77 -In Turkish-
6. Eurocode 3. Design of steel structures - Part 1-2: General rules - Structural fire design. December 2005. EN 1993-1-2.
7. Gabriele Landucci, GianfilippoGubinelli, Giacomo Antonioni, Valerio Cozzani. The assessment of the damage probability of storage tanks in domino events triggered by fire, 1206-1215, s.l. : Accident Analysis and Prevention, 2009, Vol. 41.
8. Hakkak, C. E., (2012) Teorical and Experimental Investigation of Water Tank Structures Cukurova University Journal
9. Haslak, Y. Y., (2012) Investigation of Water Storages Balikesir University Journal, Balikesir, Turkey
10. Housner, G.W., (2011) The dynamic pressures on accelerated fluid containers, Bulletin of Seismological Society of America, 47, 1, 15-39, 1957.
11. Housner, G.W., (2011) The dynamic behavior of water tanks, Bulletin of Seismological Society of America, 53, 381-387, 1963.
12. Korkmaz, A., Carhoglu, I. and Sari, A., (2008) Earthquake Assessment of Storage Tanks in Industrial Facilities in Turkey, 6th GRACM International Congress on Computational Mechanics, Thessaloniki, 19-21 June 2008.
13. Korkmaz, K.A., Sari A., Çarhoglu, A. I., (2011) Seismic Risk Assesment of Storage Tanks in Turkish İndustrial Faciliies, Journal of Loss Prevention in the Process Industries 24(4):314-320.
14. Lees, Frank P. (1996) Loss Prevention in the Process Industries. s.l. : Butterworth-Heinemann.
15. Mohite, P. M., veJangam S.A., (2012) Parametric Study of Behavior of an Elevated Circular Water Tank By Non-Linear Static Analysis, Global J. of Engg. & Appl. Sciences, 2 (1).
16. Malhotra, P., (1997) Method for seismic base isolation of liquid-storage tanks, Journal of Structural Engineering, ASCE, Vol. 123, No. 1.
17. Ormeño M., Larkin T., Chouw N., (2015) Evaluation of seismic ground motion scaling procedures for linear time-history analysis of liquid storage tanks, Engineering Structures 102.
18. O'Rourke, Michael and So, Pak (2000) Seismic Fragility Curves for On-Grade Steel Tanks, Earthquake Spectra, Vol. 6, No. 4
19. Ozbey, C. and Sari, A. (2007) Damage to Petrochemical Facilities during Earthquakes; American Institute of Chemical Engineers, 2007 Spring National Meeting, 41st Annual Loss Prevention Symposium, Houston, TX, April 22-26, 2007.
20. PEER (2017) “USGS,” http://earthquake.usgs.gov/(accessed Jan. 1, 2017)
21. Sari, A., Dyer, J. (2005) The Dynamic Contribution of Explosion to Domino Effects.
22. Sari, A., Azimov, U. and Nguyen, H. A (2015) Unified Risk-Based Approach for the Assessment of Accidental Loadings, The First International Conference on Structural Safety under Fire & Blast, CONFAB 2015, 2nd-4th Glasgow – United Kingdom.
23. Wilson, E. ve Habibullah A., (1998). SAP 2000 Integrated Finite Element Analysis and Design of Structures Basic Analysis, User Manuel, CA, USA.
24. Yasseri, S. Blast Pressure Distribution around Large Storage Tanks. FABIG Newsletter. 2015, 67.