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NUMERICAL ASSESSMENT OF TUNNEL SHAPE FOR LIQUEFACTION- INDUCED UPLIFT

Sami BAKOUR[1]
[1]Department of civil engineering Altinbas university Istanbul-Türkiye, bakoorsami@gmail.com
(https://orcid.org/0000-0001-9938-0960)

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Abstract
The purpose of this study is to evaluate the liquefaction and the settlement or the displacement occurring during an earthquake and causing the damage to the underground structure by uplift displacement. If the soil is saturated, then it's the soil which mostly susceptible to liquefaction especially those fully saturated soil. Sandy soil is very susceptible soil to liquefaction since its particle size are quite bigger and has irregular shaped, which leads to the existence of air gaps in between the sand particles. Liquefaction usually tends to happen in low lying regions where there's actually water underneath so like a water table underneath the soil which help the water molecules to rise up in the sand and kind of like sit below the surface, but fill some of those air gaps. Now, what happens when an earthquake hits is that the ground is shaking, and these particles are squeezed together and compressed so that the water has to go somewhere. If you imagine these particles are being squeezed together, what happens is the water molecules move upwards and it saturates all of this sand and the water bubbles up to the surface and creates low liquid a liquid Sandy. It's essentially like quicksand.
Keywords: Liquefaction, earthquake, model test, induced uplift, tunnels, shape

SIVILAŞMA KAYNAKLI YÜKSELME İÇİN TÜNEL ŞEKLİNİN SAYISAL DEĞERLENDİRMESİ

Özet
Bu çalışmanın amacı, bir deprem sırasında meydana gelen ve yer altı yapısında meydana gelen sıvılaşmayı ve oturmayı veya yer değiştirmeyi, yukarı hareket deplasmanı ile değerlendirmektir. Zemin doymuşsa, sıvılaşmaya en çok duyarlı olan, özellikle tamamen doymuş olan zemindir. Kumlu zemin, tane boyutunun oldukça büyük olması ve düzensiz şekilli olması nedeniyle sıvılaşmaya çok duyarlıdır ve bu da kum tanecikleri arasında hava boşluklarının oluşmasına neden olur. Sıvılaşma genellikle, altında gerçekten su bulunan alçak bölgelerde meydana gelme eğilimindedir, bu nedenle toprağın altındaki bir su tablası gibi, su moleküllerinin kumda yükselmesine ve yüzeyin altına oturmasına yardımcı olur, ancak bu hava boşluklarının bir kısmını doldurur. Şimdi, bir deprem vurduğunda olan şey, yerin sallanması ve bu parçacıkların birlikte sıkıştırılması ve sıkıştırılması, böylece suyun bir yere gitmesi gerekiyor. Bu parçacıkların birbirine sıkıştırıldığını hayal ederseniz, su molekülleri yukarı doğru hareket eder ve tüm bu kumu doyurur ve su yüzeye kadar kabarır ve düşük sıvı bir sıvı Sandy oluşturur. Esasen bataklık gibidir.
Anahtar Kelimeler: Sıvılaşma, deprem, model testi, indüklenmiş yükselme, tüneller, şekil

1. Introduction

In 2010 (EPFL Graph, n.d.), New Zealand was struck by a severe 7.1 (EPFL Graph, n.d.), magnitude earthquake which shocked most of the Canterbury region, soon after as 6.3 magnitude earthquake, which became known as the Christchurch earthquake devastated the region, leaving 185 dead, and 1000s (EPFL Graph, n.d.), of buildings suffering the effects of extensive liquefaction damage. Most recently, 2016 saw a 7.8 magnitude earthquake, which not only affected the Canterbury region but also shut down much of the nation's capital. Underground structures are common susceptible objects to floating and liquefaction during an earthshaking event, especially those structures located in liquefiable soils such sandy saturated soils. The higher hydraulic gradient between the soil beneath the tunnel bottom and the surrounding soil became obvious and the surrounding soil squeezing into the tunnel bottom is the major cause of tunnel uplifting. geotechnical issues such as earthquakes, settlement, requires applicable analysis to the minimum stages of the assessment methodology, same as seismic stress assessment, to do online surveys, to identify any possible, to characterize soil and finally to do an engineering judgment. The development of analytical procedures for evaluating liquefaction excitement depend on experimental data to give the link between several in situ test indicators and liquefaction resistance. The research provides some technical solutions about the liquefaction resistance, such as jet grouting, decreasing the degree of saturation etc. Tunnels can have any shape such as circular, square, semi-circle etc, each shape is designed for different demands. In this study we will study the effects of this shape on the displacements that will occurs during an earthquake.

1.1. Liquefaction Around Tunnels

The liquefaction phenomenon and its massive hurt as shown in Fig(1) can have catastrophic effects on both above and below ground structures. Liquefaction can result in bearing capacity failures, lateral spreading and intolerable settlements for bridges, tunnels, roadways and embankments. Due to this huge hurt of liquefaction, the researchers have to figure out a solution to this phenomenon, by mitigate the occurrence of it, throughout a series of laboratory tests and numerical models the researchers tried to eliminate the damage of liquefaction by eliminate the water content in zones of liquefiable soil deposits. The techniques provide an increasement in the compressing of the pore fluid with generating an amount of gas in the soil of completely saturated sand pore by flipping the soil from a fully saturated state into a partially saturated state. Tunnels nowadays is considered as very important structure due to its huge function in saving the time, pedestrian roads etc., this study focus on tunnels and the effect of the shape when relevant to settlement. Engineering challenges the insurmountable, with the advance of the NA TM technique, tunnels are no longer considered difficult, unsafe and expensive construction works. In addition to major roadways this technique is used in homes and companies without size or obstacle limits. Diversification in the use of tunnels in engineering projects is due primarily to the development of the new Austrian tunnelling method.

Figure 1: Liquefaction phenomena

1.1.1. Liquefaction Caused By Earthquakes

Many reports on devastations due to uplift pressure in the underground (Aydingun, 2003) Design Specification of Taiwans Building Code, (Khoshnoudian, 2002); (Koseki J. M., 1997). 1964 Nigata, 1983 ChubuNihonkai, 1990 Luzon, 1993 oki-Kushiro and 1993 oki-Hokkaido Nansei earthquakes are some examples of the mentioned studies (Japanese Society of Soil Mechanics and Foundation Engineering, 1986) (Japan Society of Civil Engineers, 1993) (Khoshnoudian, 2002); (Koseki J. M., 1997); conducted with scientists in relation with past major causes of earthquakes. In this consideration Liu and Song (Liu, 2005) found the results of soil liquefaction on the underground structures phenomenon. Fig. 2 shows how liquefaction led to the upward displacement of the structure and that the studies they did show that the uplift pressure behaved underneath the underground structures.

(Liu, 2005) conducted the surface transformation in the location of tunnels showed Fig. 3. Depending on these figures, the uplift of the structure and the ground surface heft are 36 and 34 cm respectively. These values probably lead to negative effects in surface structures and modify the constraint conditions of the underground structures (Liu, 2005). The pervious results agree with those acquired by Khoshnoudian's study on the effects of the liquefaction on excavated tunnels in the liquefied soils (Fig. 4). Depending on these studies, although the features of the loads does not affect too much (Khoshnoudian, 2002), the interior loads in underground structures are different when the surrounding soils are liquefied. Thus, the uplift of the embedded structures is considered as an important cause of distortion of the underground structures while the soil is liquefied and must be considered in the future designs of underground structures.

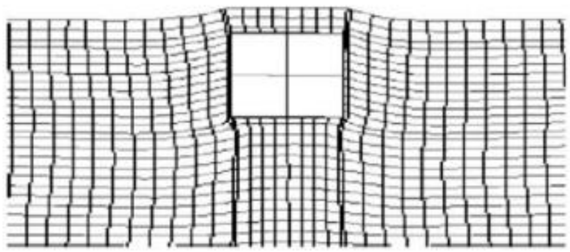

Figure 2: Shows how the dynamic loading can cause uplift in underground structure (Liu, 2005)

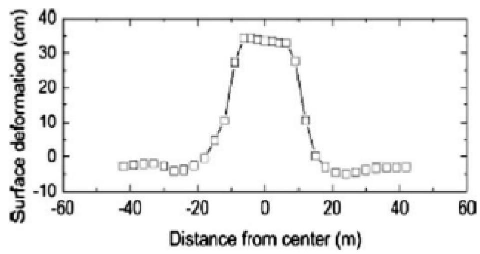

Figure 3: Shows how the dynamic loading can cause uplift in surface ground (Liu, 2005)

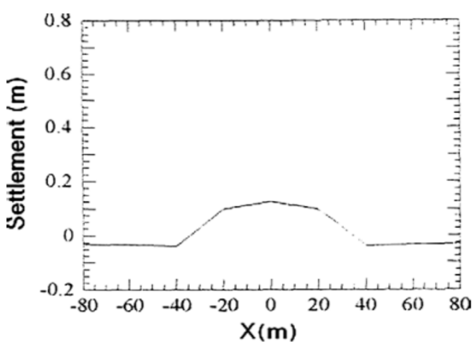

Figure 4

1.1.2. Liquefaction Mitigation

Several techniques are there, to eliminate the damage of the liquefaction phenomena such as increasing the stiffness or the strength of the structure, to resist the load and deformation that is anticipated that will be applied to the liquefied soil. other thing, that can be done, and that is commonly done is just improve the quality of the soil itself and trying to remove or take away its ability to initiate or change its susceptibility to liquefaction, If one or both of them are taken out away, then the negative effects associated with liquefaction can be perfectly avoided. And so, we refer to this improvement of the soil typically as of course ground improvement. So, with ground improvement, what else can be done on the soil is, physically or chemically alter the soil conditions at the site, so as to make them more favourable for whatever objective that needs to be to achieved with the site. ground improvement is not only done for liquefaction avoidance. its for other things too. As well if there is unstable soil due to landslides or slope issues, if there are also organic soils that can have excessive settlement and the list goes on and on. Anytime when undesirable soil conditions exist, and there's no way to stiffen the foundation or to design the structure to withstand the effects that are anticipating. Often, we rely upon ground improvement. So, for instance, in the figure (5) below, there is a machine that's installing reinforcement elements into the ground along and anticipated failure plane or shear plane that engineers are worried about might have a slope stability problem. So, ground improvement today is typically designed and installed by geotechnical specialty contractors. the question, why don't engineers just do ground improvement for every site! It's mostly due to it's high cost. Ground improvement in general, based on many experts experience in consulting, does generally increases the total cost of the project by three to 10%. So, if you weren't anticipating that, you can imagine that this could be a very significant increase in the budget.

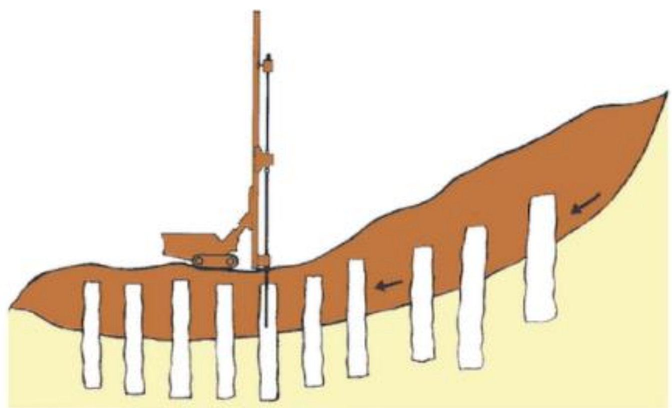

Figure 5: İnstalling Reinforcement Machine

2. Method Of Experiments (steps):

Every project is challenging, but the geotechnical analysis doesn't have to be. PLAXIS 2D, provides the power of fast computations. Perform advanced finite element or limit equilibrium analysis of soil and rock deformation and stability, as well as soil structure interaction, groundwater, and heat flow. Plaxis2D was used to run this test. And it provided very organized and accurate results. Plaxis2D is an easy and super simple program to get a result about the settlement or uplift displacement value about any demand simulation. The test starts with a saturated sandy soil sample with size of 60 by 24 M, at the bottom of the soil sample a bedrock layer was assumed to distribute the wave or to propagate the wave coming from the earthquake, at the left and right sides of the soil, a free filed layer was there to absorb the propagate of the waves coming from the earthquake, the behavior of the free field is assumed to be modelled by HS with small strain model , the bottom of the sample or the barrier layer which consist of bed rock, is simulated by linear elastic model, inside the sample a tunnels with different shapes and dimensions has been assumed in this model.

The test no 1 starts with assuming a circular tunnel with radius of 2.5 meter and depth of 7m from the surface to the middle of the tunnel as shown in fig(6), an uplift with value of 0.66m was observed. The uplift is increasing in case of increasing the tunnel dimensions or radius such as in the second test fig(7) the tunnel had a diameter of 3.5 and an approximate length similar to the one in the 1st test. An earthquake has been applied at the bottom layer of the bedrock, the used earthquake here in this model was the same one hit Kocaeli province Turkey 1999 with a magnitude of 7.6.

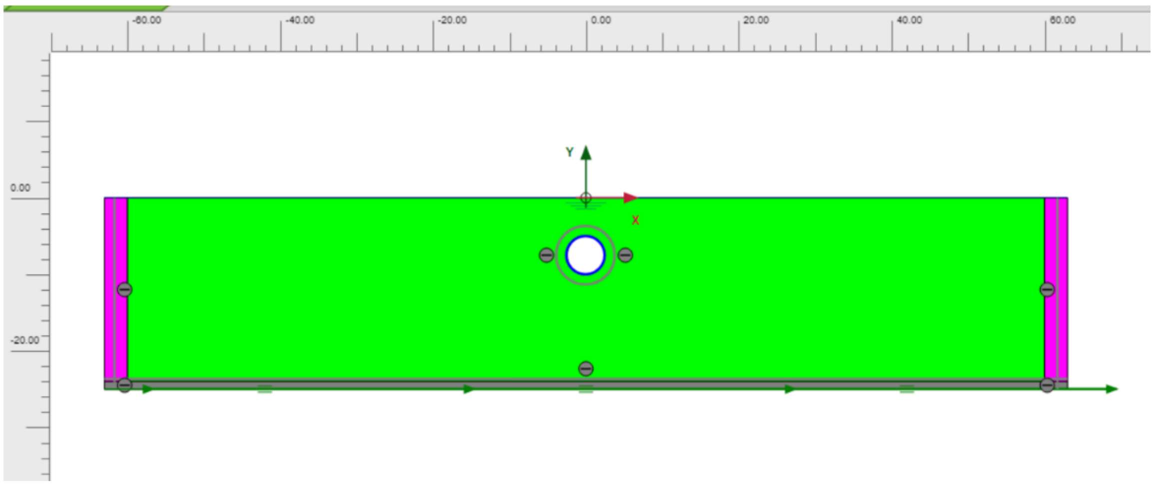

Figure 6: Plaxis2D

2.1. Comparison Between Tunnel with Dimensions of D=5 For Circle and L=5m For Square

2.1.1. Circular Tunnel With Radius Of 2.5m Model.

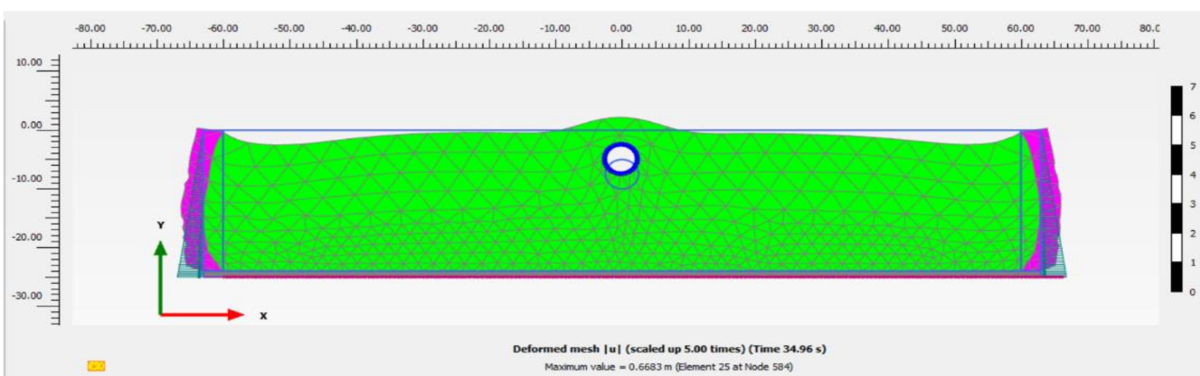

Figure 7: Simulation Using Plaxis2D

2.1.2. Square Shape Analysis Side 5m And 7m Depth To The Middle Of The Tunnel

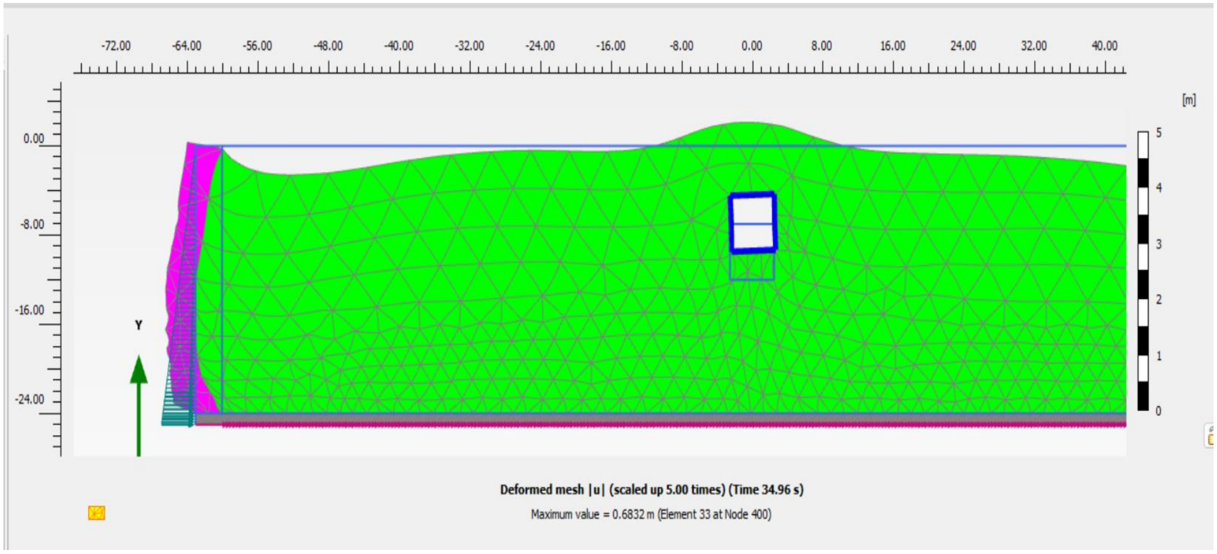

Figure 8: 5M length tunnel displacement.

2.2. Comparison Between Tunnel with Dimensions of D=10 For Circle and L=5m For Square

2.2.1. Circular tunnel with radius of 5M

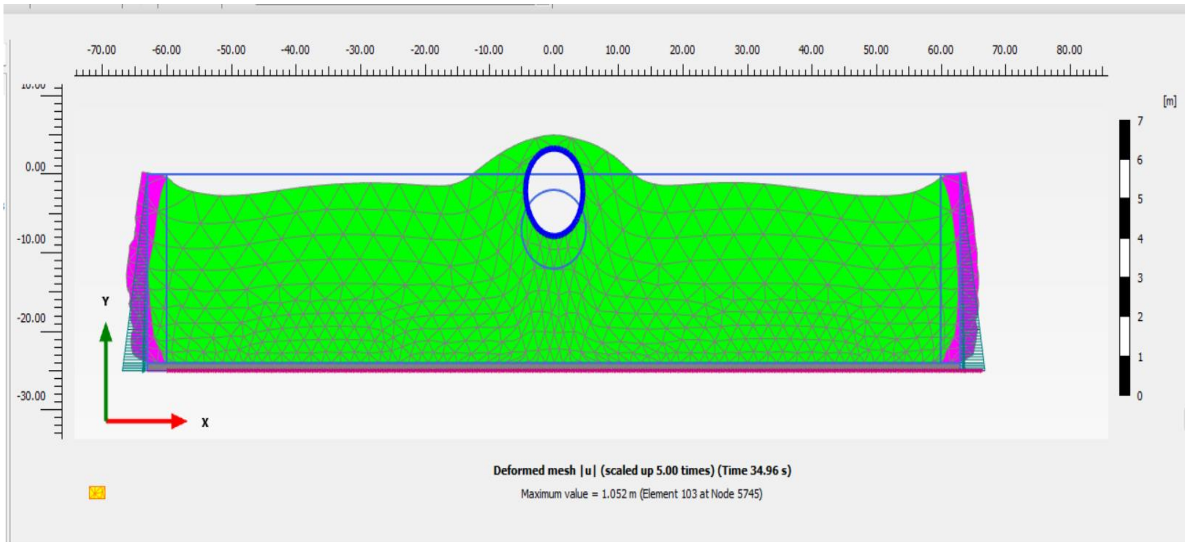

Figure 9: Increasing The Radius Increases The Uplift Displacement.

2.2.2. Square Tunnel With 10 M Side Length

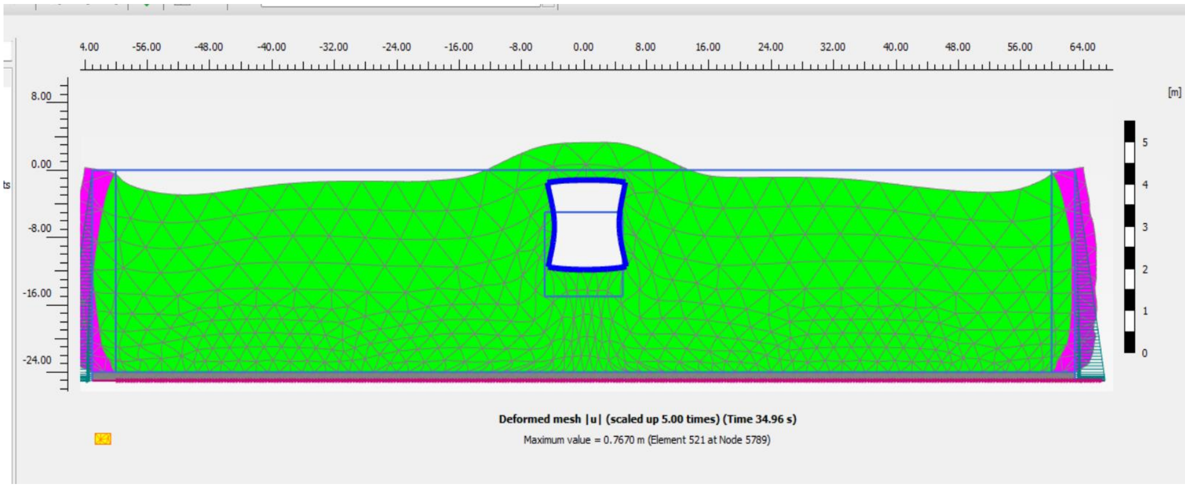

Figure 10: Uplift Increased In The 10m Side Length Square Tunnel

3. Discussion and Comparison

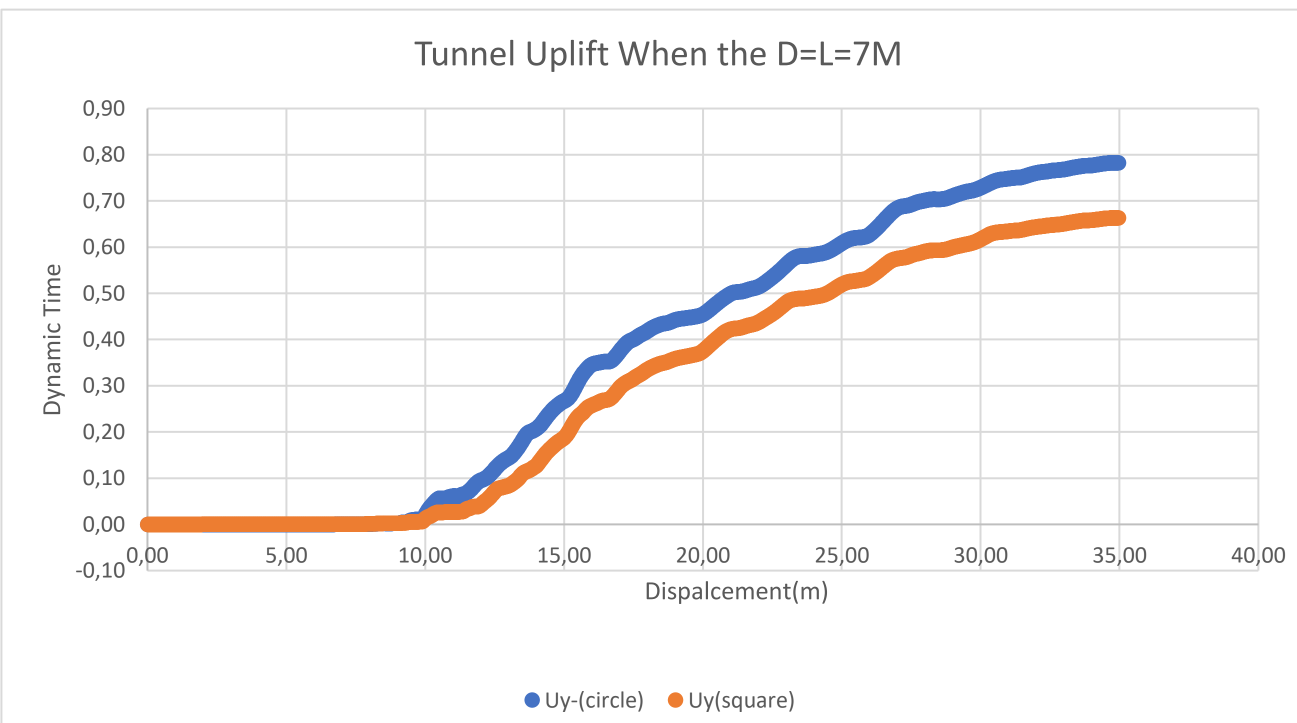

Figure 11

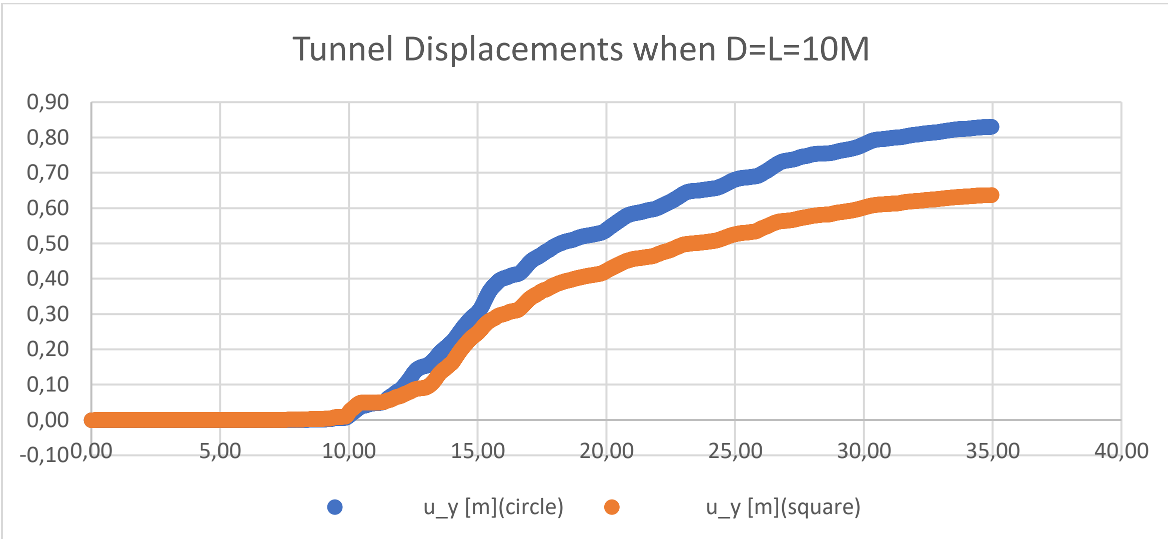

Figure 12

Finally, we can see the differences in values between the two tunnel shapes and the increase in displacement value that occurred as the size of the tunnels was increased as in figure 34. also we can see from figure 33, that if we have a specific dimension for the two shapes, the square tunnel will have less displacement, whereas as the dimension or size of the tunnels is increased, we will see that the circle tunnels will have a larger uy with values exceed 1 meter.

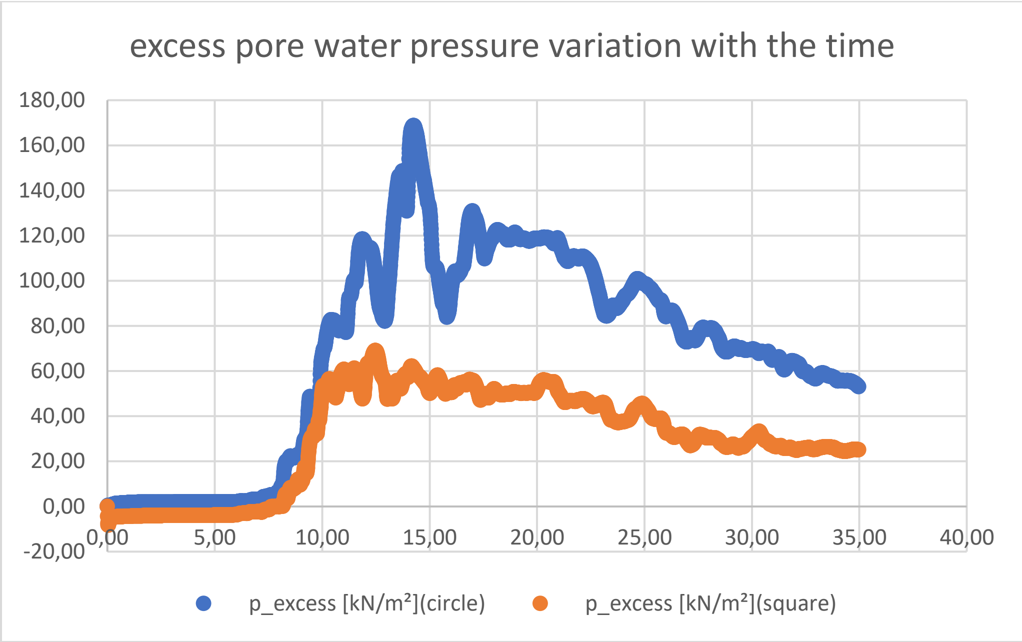

Figure 13

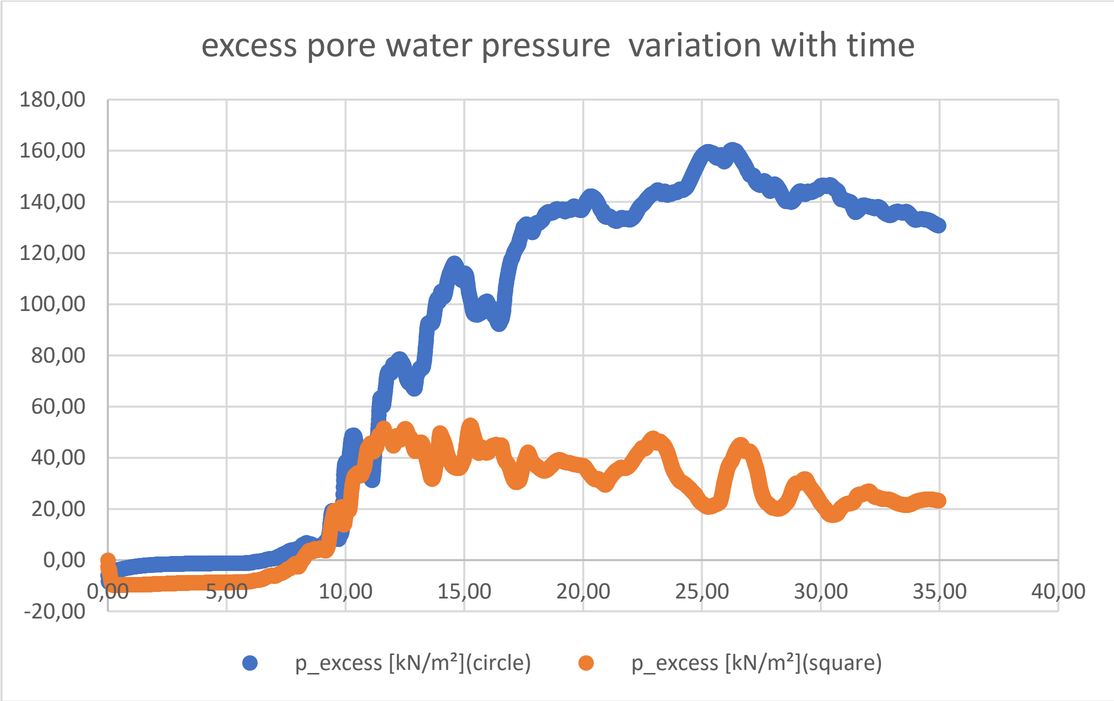

Figure 14

4. Conclusion

The aim of the study is to evaluate the liquefaction phenomena and to limit the damage caused by it. Through many conducted researches and studies, the hurt of the liquefaction due to an earthquake was successfully eliminated by many techniques such as Jet grouting, air bubbles injection. In this study, the effect of the shape and the size, was discussed and conclude that, the uplift of a tunnels increases with increasing the size of a tunnel, such as increasing the diameter of the tunnel in case of circular tunnel and increasing the dimensions of the sides lengths in case of the square or rectangular shape. Although in one study it was mentioned that increasing the diameter of an object, decrease the settlement occurrence, but the study was for those structure above the ground surface or same level of GS. The reason behind the increasement of the uplift displacement is that when increasing the area or dimension of a tunnel, the pressure on the tunnel increases too, there is a direct correlation between the area and the pressure, regardless on the effect of the weight of the tunnel, its assume that same weight here but different size like for example less used quantity in the bigger tunnel. Whatever, as shown in table(1) the uplift in the circular tunnel is more comparing with the square one. So for the liquefaction uplift displacement solution related to the shape, according to the current study its recommended to use a square tunnel with less diameter to have better safety factor.

Table 1

❖ Test Category 1	No of test	Diameter	uplift (m)
Tunnel (Circular shape) with approximate same depth from the surface to middle of the tunnel.	1	5	0.6579
	2	7	0.7642
	3	12	1.052
❖ Test Category 2	No of test	Length	uplift (m)
Tunnel (square) shape with approximate same depth from the surface to middle of the tunnel.	4	5*5	0.6832
	5	7*7	0.6974
	6	10*10	0.7670

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