

SEISMIC ANALYSIS OF A SEA WALL DUE TO WAVE AND EARTHQUAKE LOADING

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ABSTRACT

Optimal Design of quay walls against seismic forces has become a challenge for engineers. For Countries which are placed on the Earthquake Belt it is very important to investigate the strength and the behavior of quay walls against earthquakes. In this study we have investigated the behavior of cantilever quay concrete walls which has been placed on the saturated cohesive soil by finite element method. The pattern of the interaction between the soil and the structure is complicated and also consideration of the effect of interactions between soil and structure under the seismic forces would make the problem much more complicated. In this study we considered the height of the quay walls, soil type, strength and the duration of the earthquake on the Bending moment against the wall and also pressure contribution behind the wall has been investigated.

Keywords: Quay walls, Seismic loading, coupled interaction of Soil and Structure.

Introduction

Quay walls utilize to protect the coastal line in these areas. One of the methods which could analyses loads caused by Seismic forces against the quay walls is the numerical method. In this modeling method we could investigate the interaction between soil and structure. If in the modeling process soil continues long enough, far from the structure as the result of reducing the finite effect of the Computational domains our analyzed model would be much accurate and compare to the other methods much closer to the reality.

In this regard, classic methods by (1992) Futaki¹, (1970) Seed and Whitman² Rowe³ have been exerted for this problem. Also Substrate reaction method has been exerted by (1867) Winkler et al. (1996) Terzaghi⁵ and Dewaikar and Halkude (2006)⁶. In the year 1986 and then in 1995 Halliburton⁷ and Simon⁸ have used this method for analyze of the quay walls respectively. Since the year 1936 experimental methods by Terzaghi⁹ have been used despite the fact that their price would be much higher compare to the other methods. In the years 1943 and 1969 peck^{10, 11} has used the experimental methods for analyzing the problem. At the end with the invention of the finite element method and

considering the accuracy and the power of this method scientists have turned to the numerical modeling. In the year 1967 Clough¹² has built the foundation of numerical modeling by using the basic protocols of the method. Goda have checked and investigated the quay wall's designing basis and Criteria. In the year 2004 Munireddy investigated the methods of reducing pressure sequent by the impact of waves on the coastal Cason walls¹⁴.

In this study by Assumption of the elastic behavior of the quay walls we investigated the effect of the height, type and rigidity of the walls on this behavior and the distribution of the pressure and the anchor through.

Modeling Process

At the performed analyzes we have used the soil and structure modeling via the straight method with consideration of the boundaries and the commence conditions. The walls were made out of steels with favorable elastic properties and then with the beam automatic elements have been latticed. Also for the soil we have used the eight knot three dimensional MoherCulomb elements. At the Ansys software the fluid have latticed in three dimensional by the fluid element, and the interface elements have used for consideration of the

interaction between water and fluid, And then for reduction of the effect of reflection of the earthquake waves the distance till boundaries have increased. By adding the Absorbing boundary to the model the effects of the reflection have even decreased more. At the figure (1) and (2) we can see the Geometry and the lattice that have been used for the analyzing.

There are so many different methods in the Ansys software by the name of Eigen Solver for the analyzing, mode calculation and special values. Each of these methods by consideration of analyzes velocity, calculation volume, number of the requested frequency and the accuracy of the calculation has its own special usage. In this case by considering the kind of problem we faced and the necessary outputs we need, we have chosen the FULL METHOD mode. The accuracy of this kind of analyzes are influenced by the Multi Degree of Freedom selected by the model. These Multi Degree of Freedoms are one of the most important structure parameters and they are describe

the dynamic behavior of the model. For calculation of the natural periods and the general figure of the system modes, the frequency range between 1 to 10 HZ have chosen.at this range the total effective mass has reached up to 90% of the whole structure mass. We have used the modal analyze for Determination of the natural frequency value and the figures modes at the aforementioned frequency. The default assumption tangly standard at the software on the plain strain analyze mode would reach the vertical boundaries sited at the sides of the model, horizontal tangly to the horizontal boundaries sited at the lowest part of the model, would give the full transition tangly. Also both left and right boundaries are energy absorbing. The earthquake would be model by the exertion of a marked acceleration at the lower boundary. At the analyzes of this paper ,for dynamic loading we used the El Centro and Kobe earthquake mapping acceleration.at the figure below the mapping acceleration with duration of 10 second have illustrated.

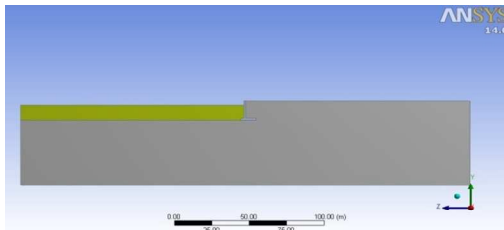


Fig1. Computational Domain (Water-Soil-Wall)

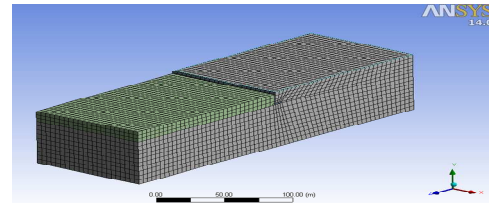


Fig2. Mesh of Computational Domain

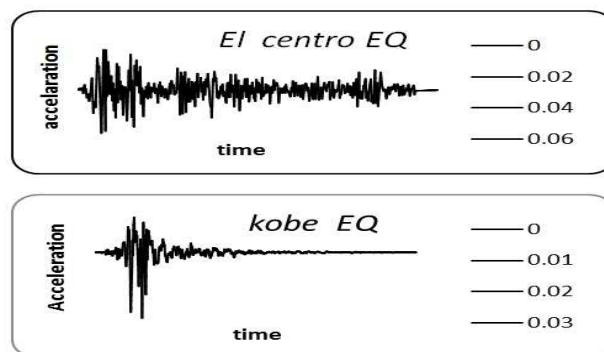


Fig3. Time history of El Centro and Kobe Acceleration

Quay wall and soil model

The behavior model for sealing soil which have been chosen at this investigation was the module of the elasto plastic Moher Coloumb which can be described by the yang module E, poison coefficient ν , cohesion(adherence) C, Friction angle ϕ and the dilatation angle. The characterizations of the both soils that have been used are described in table (1).

Analyze Assumption

The quay wall at the different analyzes had the length of 100 meter and the height between 15 to 35 meter. The soil has a layer with the characterized mentioned in table (1). The quay wall has sited at 150 meter distance from the right side boundary.at the table (2) the different height of the walls and the vicinal water has been provided. The characterization of the utilized reinforced concrete has described as $\rho_c = 2500 \text{ Kg/m}^3$, $\nu_c=0.24$ and $E_c =2600 \text{ Mpa}$. Latticing within the wall limitation has chosen to be fine (small), an instance of

finite element network produced by the software has been shown in figure (2). At the plain strain models consideration of the damp is really necessary for an accurate answer. Railey have introduced the equation (1) for damping:

$$[C] = \alpha[M] + \beta[K] \tag{1}$$

At which [C] , [M] and [K] are the matrixes of the damping , mass and the hardness respectively. In this study after taking different kind of tests the values of $\alpha=0$ and $\beta=0.003$ for answering the problem has been chosen.

Results

From figures (4) to (11) we can see the results of the investigation which includes the normal stress, quay stress, soil deformation and the von Masses stress for the quay wall with the height of 15 meter which have illustrated as Graphics. At these analyzes we have used the Kobe and el center earthquakes and also two different kind of soils.

Table1. Soil Data

Soil Numb	Cu(k Pa)	ϕ_u	$\gamma_d (kN/\tau)$	$\gamma_{sat}(kN/\tau)$	E(kPa)	ν	ψ	k_0	OCR
1	10	0	18.5	20	5000	0.495	0	0.54	1
2	70	0	18.5	20	87500	0.495	0	1.37	> 7

Table2. Length of Walls and Water

Analysis Mode	1	2	3	4	5
Length of Quay wall	15	20	25	30	35
Water Height	9	12	15	18	21

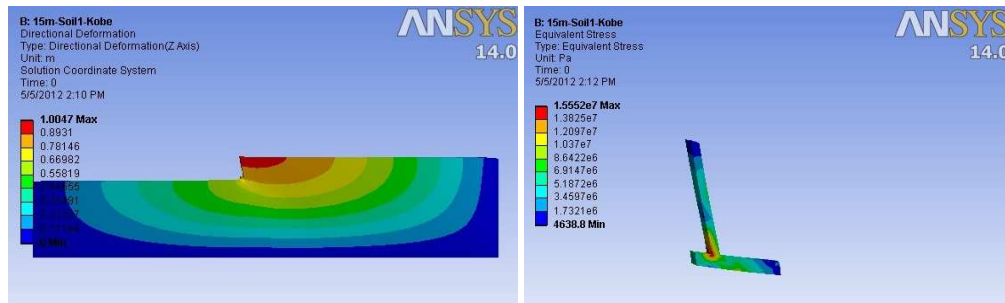


Fig4. Von Masses Stress and Wall Deformation for type 1 Soil under Kobe earthquake

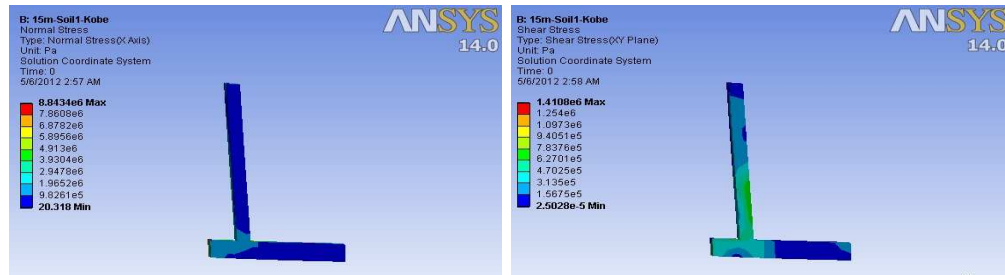


Fig5. Shear and Normal Stress for Soil 1 under Kobe earthquake

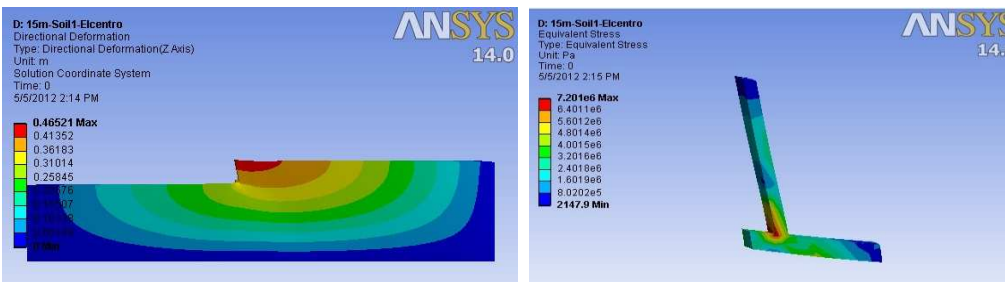


Fig6. Von Masses Stress and Wall Deformation for Soil1 under El Centro earthquake

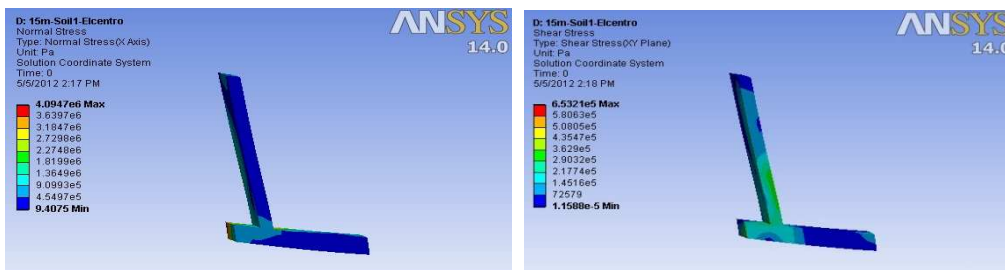


Fig7. Normal and shear Stress of quay wall for Soil 1 under Earthquake

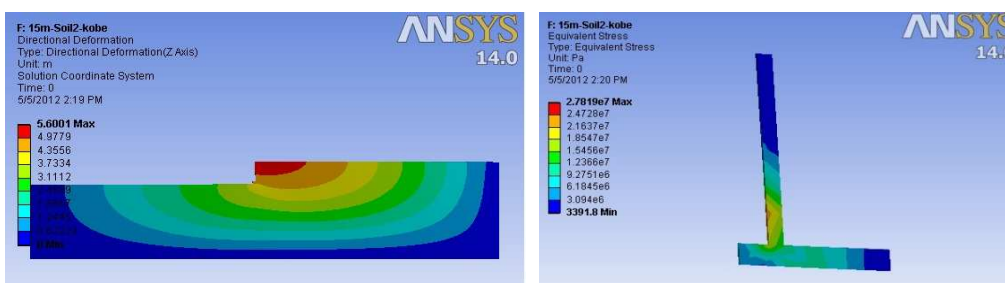


Fig8. Von Masses Stress and Wall Deformation for Soil 2 under Kobe earthquake

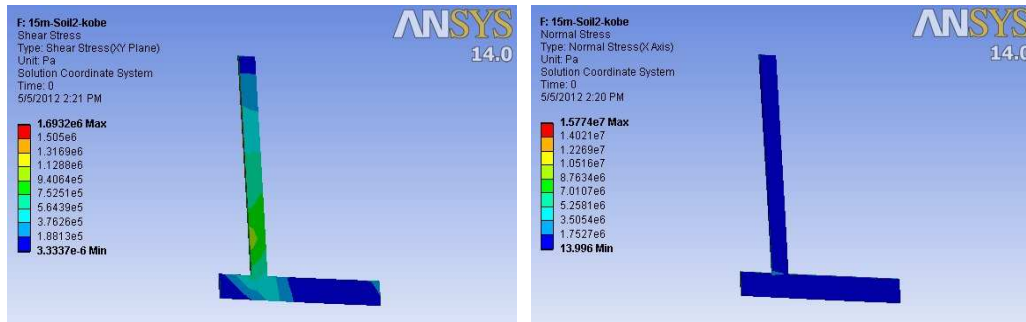


Fig9. Shear and Normal Stress of Wall for Soil 2 under Kobe earthquake

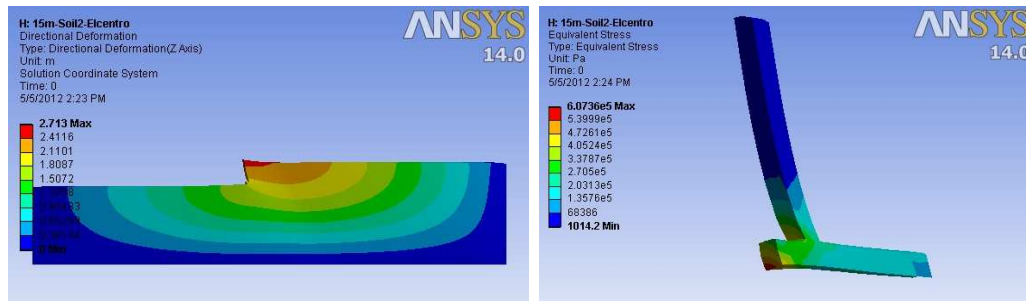


Fig10. Von Masses Stress and Wall Deformation for Soil 2 under El Centro Earthquake



Fig11. Normal and Shear Stress of wall for Soil 2 under El Centro Earthquake

These analyzes could be the criterion for designing these kind of walls in relation with comparison to the values of the shifting of the wall and the existing maximum stress with the allowed values.

Investigation on the effect of the wall depth

The effect of the quay wall height on the submission, quay and the pressure behavior has been illustrated. the effect of the increasing depth on the distribution of the soil pressure have been illustrated in

figure(12).as you can see from this diagram as the depth increases the value of the average and maximum pressure forcing on the soil would be increases too. Diagram (13) illustrates the effect of increasing quay wall height on the maximum submission forcing through the wall.as you can see with the increasing wall height the maximum submission over the wall would increase too. In figure (14) we have illustrated the quay stress changes in relation with the height of the wall.

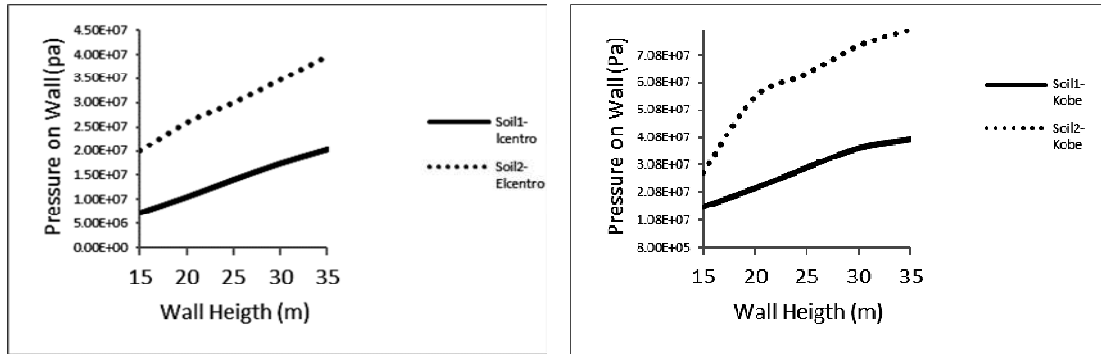


Fig12. Effect of Depth on Pressure Distribution of Soil

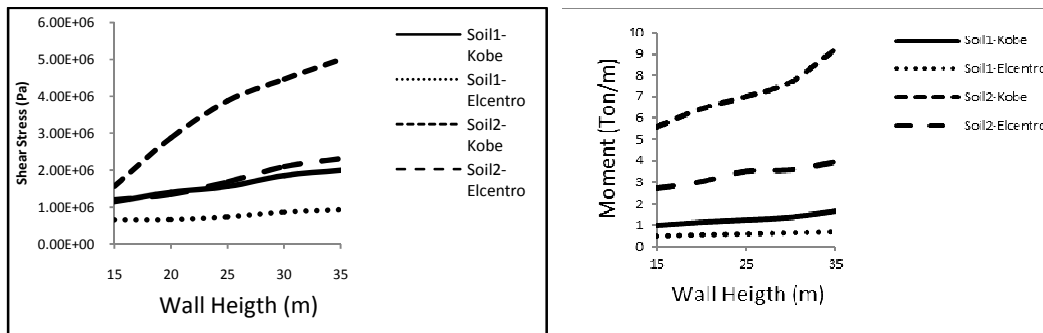


Fig14. Effect of Depth to Shear Stress on Wall

Fig13. Effect of Depth to Maximum of Moment on Wall

Investigation on the Effect of soil Type

At this part of the study we have investigated the soil sex and the important matters which can related to that.as the figure (15) shows the average and the maximum pressure on the soil (2) are much higher than the soil (1) according to the analyzes above. This difference has a lot more for the wall with 30 meter height and Kobe earthquake. the figure on the right side shows the results of the analyze under the Kobe loading and the figure on the left side shows the analyze under the el centro earthquake loading. Also as can be seen in figure (16)the maximum submission for the soil (2) at all the walls are much higher than soil (1). for 30 meter height wall and the Kobe earthquake loading this difference is much noticeable than the others. In all the diagrams from (15)to (17) on the horizontal columns(lines) 1 means the wall with 15 meter height , 2 means the wall with 20 meter height, 3 means the wall with 25 meter height, 4 means the wall with 30

meter height and 5 means the wall with 35 meter height.

The investigation of the effect of the earthquake

At this part of the investigation we would study the effect of maximum changes of the earthquake acceleration on the submission, quay and the distribution of soil pressure .first note at figure (16) which illustrate the changes in pressure according to the changes of the maximum earthquake acceleration and then figure (17) shows the changes in the value of submission over the quay wall and the effect of mapping acceleration on it .and it is important to note in this investigation the Kobe and the El Centro used as a default mapping acceleration. As you can see in the picture with increasing in earthquake acceleration the value of the submission exerted would increased. also as you can see in figure 18 as the maximum earthquake acceleration increases the quay loading forces would increases.at the figures (15) in the

horizontal axis the number 1 means the wall with 15 meter height, the number 2 means the wall with 20 meter height, the number 3 means the wall with 25 meter height,

number 4 means the wall with 30 meter height and at last the number 5 means the wall with the 35 meter height.

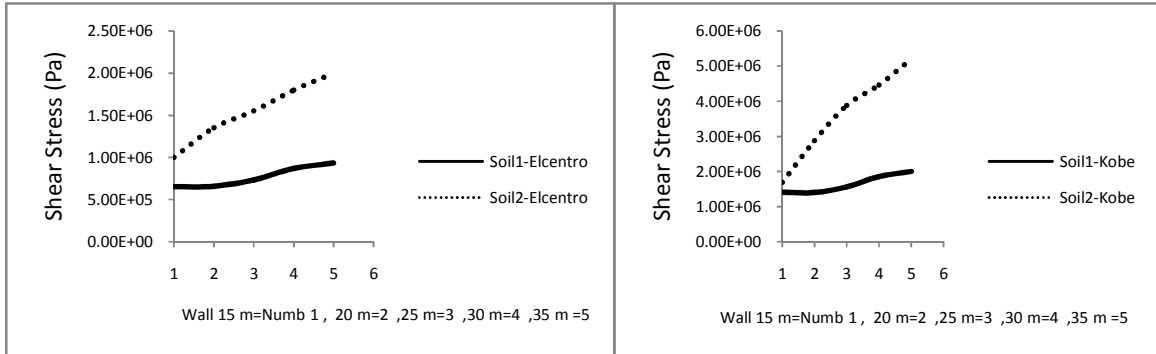


Fig15. Effect of Soil Type on Shear Stress act on Quay Wall

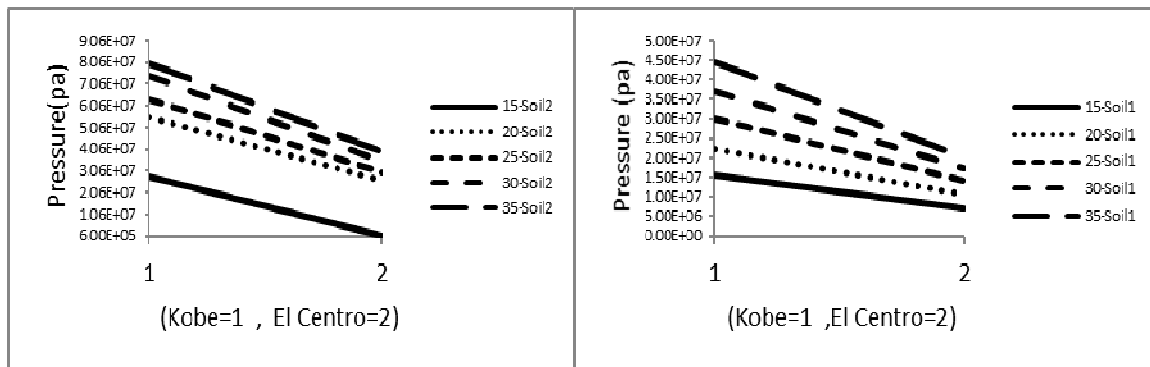


Fig16. Effect of Earthquake on Soil Pressure on Wall

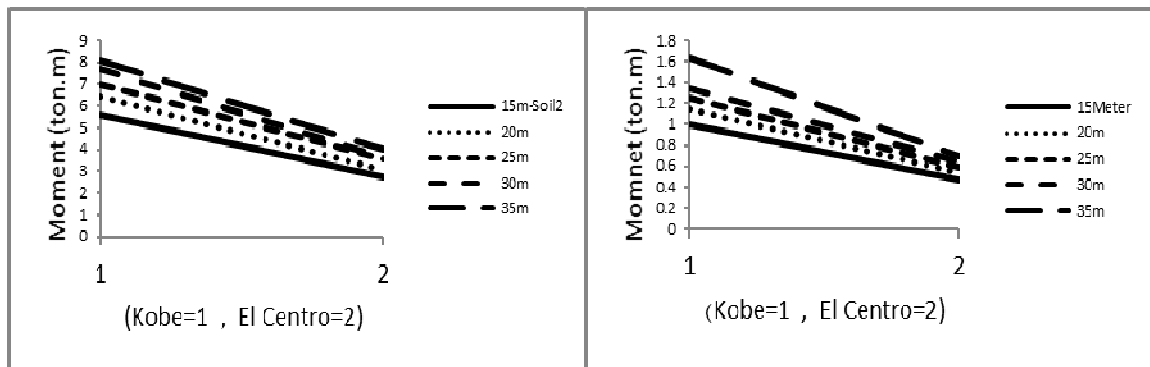


Fig17. Effect of Earthquake on Moment Act on Quay Wall

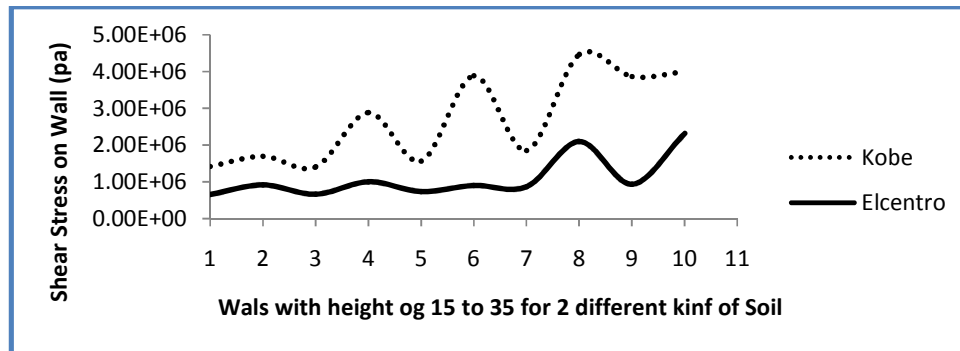


Fig18. Effect of Earthquake Type on Shear stress on Wall

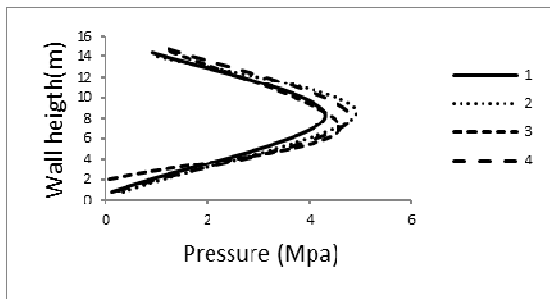


Fig20. Pressure Distribution of Mononobe Okabe For Wall Height of 15 m Soil 1 and 2 under Kobe and El Centro Earthquake

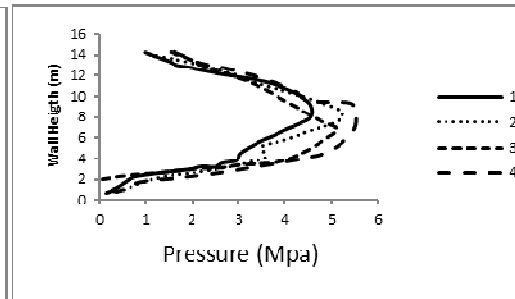


Fig19. Pressure Distribution on Wall Height (15m)

In the figure (18) the number 1 means the wall with 15 meter height and the soil number 1, the number 2 means the wall with 15 meter height and the soil number 2, number 3 means the wall with 20 meter height and soil number 1, number 4 means the wall with 20 meter height and the soil number 2 and as described it goes until number 10 which means wall with 35 meter height and the soil number 2.

Investigation on the distribution of pressure behind the wall and comparison between this distribution and the value of the Mononobe okabe method

As you can see from comparison between figures (19) and (20) the equation which has been estimated from the Mononobe okabe method has less value compare to the real values in the walls and as the wall height and also the earthquake intensity increases this difference would increase too.

Conclusion

The results of this investigation illustrate that the recommended method which works as the basis of numerical method can cover all the limitation of the Mononobe Okabe method and with usage of this method we can investigate the functions such as behind the walls nonlinear geometry, the sealing strength of the studding and so on which cannot be calculated by the Okabe method. With this numerical method we can determinate the soil sidelong loading forces over the quay walls in both static and dynamic mode. And with consideration in this point that as the height of the quay walls increases into the bed depth the pressure constant over the wall, the submission over the wall would increase. The results of the Okabe method for quay wall are very conservative. As the height of the wall increases this method has much more errors. So as the result it is essential to use other methods for determination of the discussed issues.

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