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Evaluating the Seismic Behavior of Sheet Pile Buried into the Sandy Fields

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ABSTRACT

Nowadays in the most parts of the world especially at onshore areas and steep fields, Sheet Piles are used abundantly. Considering the fact that Iran is located in an earthquake region and bearing in mind that the design of these structures are based on the Pseudostatical methods ,which is one of the weak points of these methods is "not to notify the real nature of loading which depends on the time", so, it is essential to study the more real behaviors of the earthquakes, in order to become more familiar with these types of structures under the earthquake loads with numerical simulating of the Finite Elements Method by means of dynamic analyzing together with the heavy earthquakes records in Iran and Turkey , such as Tabas, Kocaeli and Upland earthquakes. The present research, by the aid of numerical simulating of the Finite Elements Method as well, has been trying to study the effect of the burying depth parameter variations in non-anchored sheets piles, the result of the setting depth of the restraining bar and their setting angle during the dynamic loading. The conclusions expressing that the parameters such as the buried depth, setting depth of the restraining bar and their angle particularly during the dynamic loading (earthquake) have direct effects on these structures and must be considered in designing the Sheet Pile wall. Anticipating the amount of actual forces created in the anchors, dynamic analysis method estimates the amount of horizontal displacement and the amount of sheet pile rotation. These displacements cannot be set using pseudo statistic methods and are of prime importance in designing the sheet piles because in special structures, the extreme displacement leads to the emergence of damages despite maintaining general stability.
KEYWORDS: Earthquake, Modal analysis**.** Sheet Pile Wall, Seismic Behavior

1. NTRODUCTION

Although the experience with geotechnical engineering recommends the use of sheet pile wall in earthquake zones, it is not still possible to accurately anticipate. That is to say, the behavioral mechanism of the structure and/or generally dynamic loading is not reliably justifiable against earthquake in a certain framework. In this regard, the main issue challenged the engineers is the application of high reliability coefficient in improper designing and/or selecting loading functions. Since each engineering design relies on economic aspect as well as technical principles, there is still a need for the better identification of sheet pile walls dynamic behavior despite the existence of different experimental, analytical and numerical studies in the field. Considering the increasing use of sheet pile walls in civil projects in Iran and in particular in Tehran and coastal cities as well as the fact that Iran is located in an area with high earthquake risk, the present study is aimed to identify the sheet pile walls dynamic behavior and develop a way for more appropriate designing.

1.1. The Objective of the Study

Considering the abovementioned, this study is mainly aimed to examine and control displacements, the internal attempts created in the sheets in the static mode and at the time of employing dynamic loading and then to optimally and safely design sheet piles, and attempts are made to realize the following objectives:

1. Static modeling sheet pile walls using PLAXIS V8 Software and comparing it with Rowe method
2. Conducting modal analysis and determining Raili's damping coefficients
3. The dynamic analysis of anchor and cantilever sheet piles
4. Examining soil-sheet pile interaction in seismic model
5. The dynamic analysis of sheet piles anchor with respect to different parameters such as the distance, rigidity, length and angle of sheet piles and determining the sensitivity of soil-sheet pile to each of these factors

1.2. Methodology

In this study, an attempt is made to examine the effect of parameters like the distance, rigidity, length and angle of sheet pile walls as a result of static loading as well as during dynamic loading (earthquake) using the finite element software PLAXIS V8 for modeling the effect. Here, the elastoplastic behavioral model based on Moher-Colomb criterion is used for the plasticity mode of soil as well as Raili's damping rule to include system damping. In addition, to determine Rili's alpha and beta coefficients SAP 2000 Software was applied in determining the basic frequencies of system since PLAXIS V8 Software in setting special vectors (for modal analysis).

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2. LITERATURE REVIEW

In this section, some related studies are discussed in short:

Studying the sheet pile walls was got started by Carl Trzaghi in 1920. Later, Brinch Hanson conducted studies are available on sheet piles and pressure distribution, bending anchor and deformations in sheet piles among which Chipotarif's experiments between 1943 and 1949 make critical contribution to this perception. In 40 recent years, he together with Rowe have done great works regarding sheet piles [2,3,6]. Rowe presented the effect of sheet piles flexibility on maximum bending torque, and Teng has also done the same and developed similar diagrams. Moreover, Teng and Bloom have carried out separate experiments to gain null anchor point, and now Bloom's method or bar method is one of the methods for sheet piles analysis [4]. One of these methods is USA Method which is among the pressure-diagram-aided analysis method. The method was first developed by Carry and King in 1955 and described by Bawlz in 1988. In recent decade, more extensive studies have been done on a variety of sheet piles aspects including executing sheet piles, numerical analysis method and the experimental studies of sheet piles. In 1982, Daniel and Olson studied the factors of sheet piles failure via examining their construction steps [5].

Their studies indicated that a great number of anchored sheet piles (20m high) designed based on the published suggestions by experts finally failed and created great damages. Analyzing the on-site conditions showed that failure factor is the shear rupture of soil mass and sheet pile interface which is resulted from lack of adequate knowledge of soil behavior. Between 1989 and 1993, Bica and Clayton could present empirical graphs for designing sheet piles by examining various sheet pile analysis methods. In 1998, Jane Lewis Brayand and Nak Kunag Kim introduced bar-pillar technique as a sheet pile analysis method [6]. In 1999, Brayand and Ujin Lim examined the effects of the elements of sheet pile like lumbers and anchors by means of the 3D analysis of finite element considering the effect of construction steps. Finally, in 2000, Fatih Azizi presented Desiging by the aid of Multiple Row Anchors in book "Applied Analysis in Geotechnics" and his conclusion showed that despite the existence of many methods regarding sheet piles analysis, since the data gained is limited hence the validity of design methods is questioned [1].

3. NUMERICAL MODELING OF FINITE ELEMENTS IN PLAXIS

In this study, 32 computer models were developed out of which two statistic analysis models were used for anchored sheet piles and also in 30 computer models both statistic and dynamic analyses were carried out. Dynamic analyses were done by mapping the Upland, Tabas, Kocaeli (Turkey) in 1990 and using automatic dynamic substitution. The elements used were of 15-node triangular types which are the most sustainable and accurate elements.Also, interface elements were applied around the sheet piles to show the true behavior of the structure. With respect to the great number of elements as well as the continuance of earthquakes employed and also modeling the interface elements which all are for enhancing the accuracy, the duration of calculations was 6h for a 10m sheet pile wall.

Mapping Tabas earthquake has maximum acceleration of 0.85g with duration of 33s and 0.02s steps. In 1990, Upland mapping has maximum acceleration of 0.24g with duration of 22s and 0.02s steps.

Mapping Kocaeli (Turkey) earthquake has maximum acceleration of 0.55g with duration of 20s and 0.02s steps. These mappings are illustrated in Figure 1 (a to c).

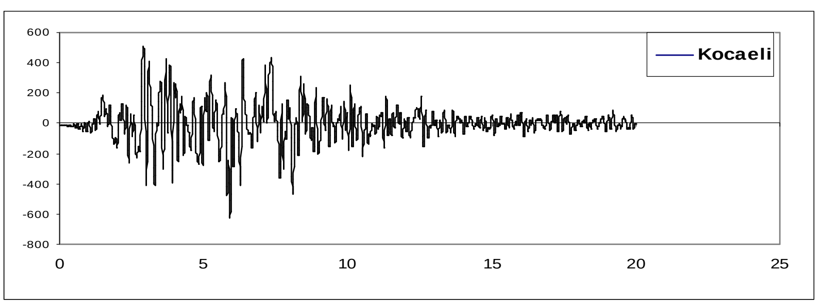

Fig. 1-a. Mapping Kocaeli (Turkey) earthquake acceleration

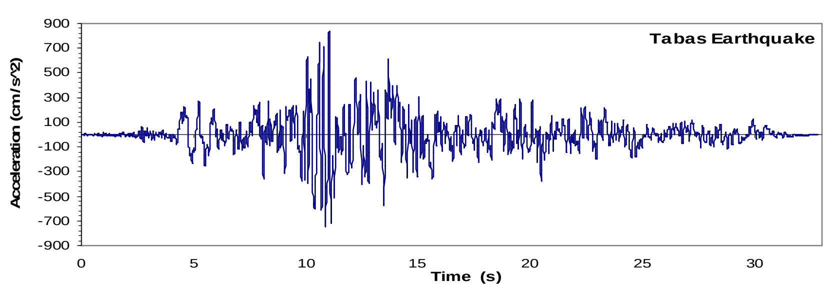

Fig. 1-b Mapping Tabas earthquake acceleration

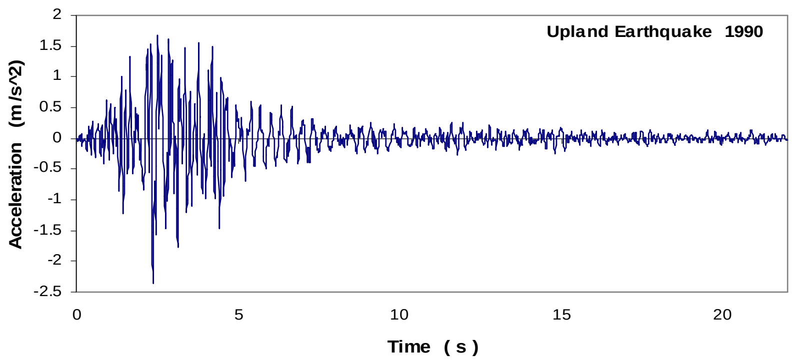

Fig. 1-c. Mapping Upland (1990) earthquake acceleration

3.1. System Damping

Selecting the amount of damping is of the controversial issues in most dynamic analyses. Raili's damping is usually taken which requires two parameters: damping coefficient and effective frequency domain to select mass and rigidity matrices by exploiting them. The damping considered here is of Raili's type and corresponds %5 damping (ξ=5%).

3.2. Materials Properties

In this study, sand soil was used with properties listed in Table 1. Moher-Colomb's model with properties listed in Table 1 was applied to model the behavior of soil behind wall. To determine the models' sensitivity to shear strength, soil internal friction angel was increased 24 with a growth rate from 2 to 34 (given the whole parameters are constant).

Table 1. The properties of the soil material used

Parameter	Φ	C	γ (kN/m3)	E (kpa)	ν
Sand	31	0	20	50000	0/3

3.3. Sheet Pile Wall and Anchors Materials Properties

The sheet pile wall is of steel with following specifications (Table 2&3). Also, anchors have the following changing characteristics.

Table 2: non-anchored sheet pile walls under study

d_e (m)	EI(kN/m)	EA(kN/m)	Buried depth(m)	Free height(m)	Type of sheet pile	Parameter
0/5	2/77E6	132/8 E6	5	6	cantilever	sheet pile1
0/5	2/77E6	132/8 E6	6	6	cantilever	sheet pile2
0/5	2/77E6	132/8 E6	7	6	cantilever	sheet pile3

Table 3: the specifications of sheet pile wall under study

Parameter	Type of sheet pile	Free height(m)	Buried depth (m)	EA (kN/m)	EI (kNm^2/m)
sheet pile	anchored	6	4	132/8 E6	2/77E6

Table 4. the characteristics of anchors used

Length of anchor bar	Axial rigidity (EA)	The depth in the earth	L- spacing
14m	Varying	2m	2.5m

In Table (4), the rigidity of anchors changes from 1E5(KN) to 4E5(KN), but a fixed rigidity 2E5(KN) is used for anchor bar in the reference model.

3.4. Boundaries and Base Conditions

Regarding the fact that type of foundation is considered as safe, the bases of foundation floor is bounded both vertically and horizontally against movement. And, lateral basis is open perpendicularly. But what matters in dynamic modeling is the selection of lateral boundaries. Here, in static conditions, first roller bases which do not allow for x-direction movement yet only at gravity-direction were used for estimating stress at basic position. Then, in dynamic conditions, absorbent boundary is replaced in two model parts. This practice leads to the satisfaction of static conditions first and the stability of model and then the substitution of the absorbent boundaries so as to prevent from the return of reflected wave inside the environment and a more realistic model to be designed.

3.5. Dynamic Loading

The dynamic analyses done are of non-linear type. In this study, attempts are made to use the mapping of three real earthquakes acceleration in Iran and Turkey such as Tabas, Kocaeli and Upland earthquakes.

4. RESULT AND DATA ANALYSIS

4.1. Buried Depth Parameter in Non-anchored Sheet Piles

As mentioned in previous studies, results of the analyses showed that the buried depth parameter is a key factor in the extent of horizontal displacements and bending anchor.

Results from nine models including three buried depths in each of which three acceleration mappings are used at static and dynamic modes are presented in Table 5:

Table 5. Explaining the buried depth parameter in non-anchored sheet piles

Buried depth	Static		Dynamic					
			Tabas		Upland		Kocaeli	
	U_x	M	Ux	M	Ux	M	Ux	M
D-5	-0/51	761	3.17	1090	0/65	873	1/82	1010
D-6	0/157	781	2/47	1400	0/31	1070	1/02	1270
D-7	0/09	798	1/52	1720	0/17	1160	0/62	1650

In the above Table, the amounts of displacements are in meter and are in k/Nm for bending anchor.

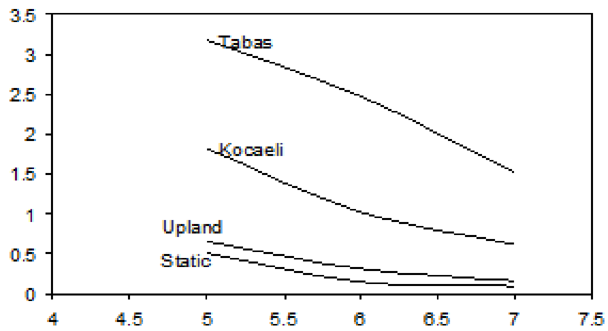

Fig. 2: the horizontal displacement top non-anchored sheet pile for the buried depth

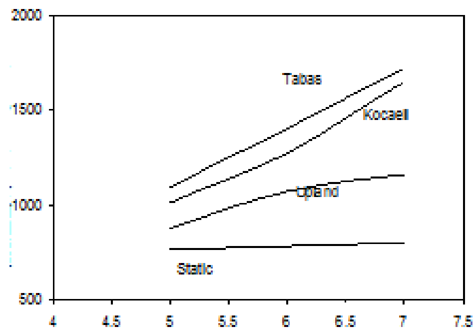

Fig. 3: maximum bending anchor of non-anchored sheet pile for the buried depth

As seen in Figures 2 and 3, as the buried depth increased in both statistic and seismic modes, the horizontal displacement of top non-anchored sheet pile decreases. Yet, maximum bending anchor of non-anchored sheet pile increases. The interesting point is that in non-anchored sheet piles, horizontal displacement is significant; for instance, for the sheet pile wall (buried depth: 7m), the horizontal displacement of top non-anchored sheet pile under soil statistic pressure is about 10cm and under Kocaeli earthquake is about 60cm. This amount reaches 152cm in stronger earthquakes like Tabas which results in damages to existing facilities and/or the fall of the protected area. In the amounts of buried depth, these amounts barely increase. Therefore, it can be concluded that in earthquake-inducing areas sheet piles are not to be used. In addition, in designing non-anchored sheet piles both strength and displacement parameters must be controlled.

4.2. Examining the Effect of Anchor Bars Location

Based on Figure 4 which related to the depth of anchor location (1m underground), it is seen that 1m depth is shallow because the sum force resulted from passive pressure emerged against the dead man system is small and this is the same thing driving the system.

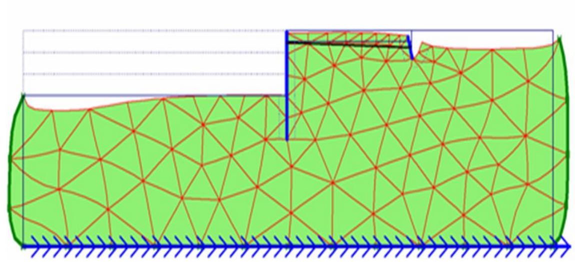

Fig. 4: the sheet pile system deformation mesh for 1m anchor depth

With respect to the results of maximum displacement gained from three models for depths 1, 2, and 3m of the anchor bar location (Fig. 5), it is observed that in dynamic mode if the anchor is located in 2m depth, we will have the least horizontal displacement.

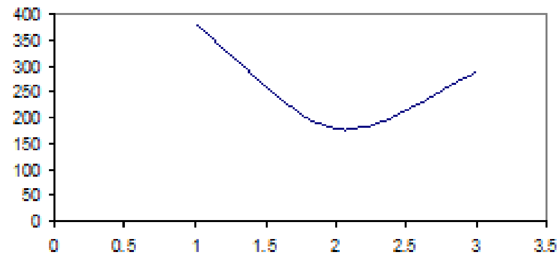

Fig. 5: studying the effect of anchors depth on the maximum horizontal displacement of sheet pile

4-3- Anchor Location Angle to Horizon Parameter

In this discussion, statistic and dynamic analyses are done on six models with angles 0, 20, 30, 45, 52.5, and 60 degrees with Tabas earthquake record.

It is concluded from Figure 6 that in statistic mode, the increase in the location angle of anchors inclination leads to the increase of top sheet pile wall horizontal displacement, but the changes are insignificant. Yet, it is seen in the seismic mode that as the angle increases from 0 to 30, top sheet piles moves toward the bulkhead. As seen in Figure 7, the anchor inclination force increases and angle 30° reaches its maximum amount. But with an increase from 30 to 60 degrees, top sheet pile wall moved toward excavation section and the force created in anchor bar has also a descending trend.

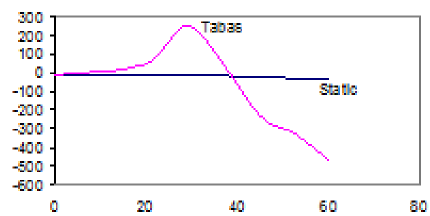

Fig. 6: studying the effect of anchors angles on the horizontal displacement of top sheet pile

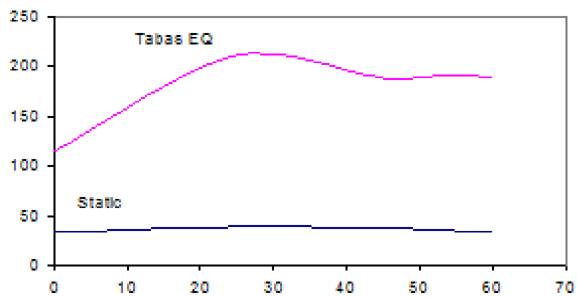

Fig 7: studying the effect of anchors angles on the force created at anchors

As an important conclusion, it can be said that angle 30 was the best for anchors with maximum efficiency because in the angles more than 30, the extent of effect by the vertical force of the anchor inclination is more than the effect of increasing the depth of Grut section. Rather, at angles>30, anchor inclination force will play a smaller role in restraining the sheet pile. This is because its horizontal component will be smaller. Based on Figure 8, as the inclination angle increases, the sheet bending anchor changes at static mode are not significant, yet they are descending for seismic mode. That is as the inclination angle increases, maximum bending anchor in sheet piles decreases. It is due to the results from the previous paragraph because at top sheet pile horizontal displacements, soil is placed in a new mode of stresses. On the other hand, the stress is dispersed again and leads to the reduction of the sheet pile wall bending anchor.

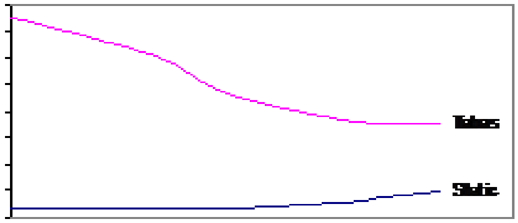

Fig. 8: studying the effect of anchors angles on the maximum bending anchor of sheet pile wall

5. CONCLUSION

The results of this study can be listed as follow:

1. Comparing between the results from the dynamic modeling of the anchored and non-anchored sheet piles to the sheet pile's horizontal displacement, it was figured out the non-anchored sheet piles reach instability level (extreme horizontal displacement). So, it can be concluded that in the earthquake areas, non-anchored sheet piles must be used.
2. In designing the non-anchored sheet piles, both strength and displacement criteria must be controlled.
3. As well as anticipating the amount of actual forces created in the anchors, dynamic analysis method estimates the amount of horizontal displacement and the amount of sheet pile rotation. These displacements cannot be set using pseudo statistic methods and are of prime importance in designing the sheet piles because in special structures, the extreme displacement leads to the emergence of damages despite maintaining general stability.
4. As an important result of this study, it can be said that angle 30 was the best for anchors with maximum efficiency because in the angles more than 30, the extent of effect by the vertical force of the anchor inclination is more than the effect of increasing the depth of Grut section. Rather, at angles>30, anchor inclination force will play a smaller role in restraining the sheet pile. This is because its horizontal component will be smaller.

REFRENCES

Uromiehi, A. (2002). Soils in Construction Plans, Tarbiat Modarres University's Scientific Works Press.

Shapur Tahuni (2004), Geotechnical Engineering Principles, Foundation Engineering, Pars Aiin Press, VOL(2).

Brinch Hansen, J. *Earth Pressure Calculation. PhD thesis, University of 1953.*

Forces in a circle of rupture. The Danish Geotechnical Institute, 1957. Bulletin No.2.

Bowles, J.E. (1988). Foundation Analysis and Design. Mc.Graw-Hill.

Rowe, P.W. (1952). Anchored sheet-pile walls. Proceedings of the Institution of Civil Engineers, 1:27_70

Bowles, J., (1996), "Foundation Analysis and Design", the McGraw-Hill Companies, Inc, USA.

Singh, M. and Rao S., (2005), "Bearing Capacity of Shallow Foundation in Anisotropic Non-Hoek-Brown Rock Masses", Journal of Geotechnical and Geoenvironmental Engineering (ASCE), 131 (1), pp 1014-1023.

U.S. Army Corps of Engineers, (1994), "Rock Foundations", Engineer Manual, EM 1110-1-2908.

Fahimifar, A., (2010), "Foundation Designing in Dam Structures", Amirkabir University of Technology Edition.

Ramamurthy, T. and Arora, V.K., (1994), "Strength Prediction for Jointed Rocks in Confined and Unconfined States", Int. J. Rock Mech. Min. Sci. Geomech. Abstr. 31(1), pp 9-22.

Serrano, A. and Olalla, C., (1994), "Ultimate Bearing Capacity of Rock masses", Int. J. Rock Mech. Min. Sci. Geomech. Abstr. 31(1), pp 93-106.

Serrano, A. and Olalla, C., (1996), "Allowable Bearing Capacity of Rock Foundations Using a Non-linear Failure Criterium", Int. J. Rock Mech. Min. Sci. Geomech. Abstr. 33(4), pp 337-345.

Serrano, A. and Olalla, C. and Gonzalez, J., (2000), "Ultimate Bearing Capacity of Rock masses Based on the Modified Hoek-Brown Criterion", Int. J. Rock Mech. Min. Sci. 37, pp 1013-1018.

Zhou, X.P. and Yang H.Q. and Zhang Y.X. and Yu M.H., (2009), "The Effect of the Intermediate Principal Stress on the Ultimate Bearing Capacity on Rock masses", Computers and Geotechnics, 36, pp. 861-870.

Yu, M.H. and Zan, Y.W. and Zhao, J. and Mitsutoshi, Y.A., "Unified Strength Criterion for Rock Material", (2002), Int. J. Rock Mech. Min. Sci. 39(8), pp 975-989.