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Evaluation of Different Methods of Sheet Piles Dynamic Analysis using Finite Element Software (ABAQUS)

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***Abstract*— Retaining walls (sheet piles) typically serving as a guardian of the soil in a wide range of projects, Maintenance of gradients, shoreline protection in areas prone to liquefaction held against lateral movement used. These types of flexible structures and behaviors have affected certain times of the load- deformation curve. This behavior is difficult to reduce its thickness dependence is complete. Soil lateral pressure in the large deformation of structures can be created depending on the length of the buried, wall thickness and hardness and soil characteristics of the front sheet pile. Stability analysis of geotechnical structures (involved with the soil) is generally divided into three categories: closed-form solution of equations, simplified solutions (and experimental) and numerical analysis. This article reviews the different methods of analysis will sheet pile during an earthquake. Lateral soil pressure method as a method Mononobe-Okabe and balance technique with some simple techniques and the results of a numerical model built with Abaqus software will be provided. The comparison to estimate the pressure and wall stress compared with the quasi-static method is performed.**

***Keywords*— sheet pile, numerical modeling, seismic behavior, soil lateral pressure**

I. Introduction

Retaining sheet pile walls are relatively thin metal shield walls, reinforced concrete or wood, which are inhibited, or pressure behind the dams are kept dirt resistant. Flexural capacity of walls of such a guard plays an important role in maintaining the structures of materials as the weight of the wall is unimportant. An example of this type, the walls of a metallic shield walls, retaining walls or behind a lace passed SUBSCRIBER concrete diaphragm walls.

Retaining walls are spent in areas of seismic activity. Earthquakes can cause permanent deformation structures are retaining. In some cases, these deformations are very large and cause significant damage. In many cases, the buffer structures during earthquakes, which are broken occasionally with disastrous economic and physical consequences [1, 2, 3 and 4]. In this paper, the dynamic lateral soil pressure theories review, the performance of several methods of analysis have been studied much in the analysis of retaining walls and the finite element method and is known as one of the conventional numerical methods are compared.

II. Methodology

A. Earth Lateral Pressure

Seismic behavior of retaining walls depends on the land side. The total pressure exerted on the wall static pressure (pressure side of the soil enabled or disabled) and is the dynamic pressure. The wall is a resultant effect on the two components. Static and dynamic lateral earth pressure theories by people like Coulomb (1776), Mononobe-Okabe - Okabe (1926 and 1929), Caquot and Kerisel (1948), Sokolovskii (1965), Chen and Liu (1990) and Lancellotta (2002) has expressed. [5 to 12].

The main methods used in this communication is based on a simple analysis of the equilibrium point, limit analysis, etc. are areas of tension. The balance between the methods is much more than others. Balance is partly based on a failure mechanism is simple and tangible. It is assumed in all points along a hypothetical failure surface at failure conditions are complete and then wedge failure for the overall balance and the block will be reviewed.

Accurate analysis of finite difference and finite element methods based on the following four requirements are met: 1 - balance, 2 - adapting to change shapes, 3 - and 4 law behaviors - boundary conditions. Simple analytical methods usually ignore one or more of the above four requirements. So expect a simple and accurate method of analysis do not provide the same answers.

This kind of view techniques are divided into two categories: static and dynamic overall. This article reviews and evaluates various methods of dynamic analysis is concerned with retaining walls elapsed. Therefore, the Mononobe - Okabe as a method based on the balance somewhat, Chen's method as the method is based on some analysis and finite element analysis as a method of numerical analysis of quasi-static loading conditions are compared and evaluated.

In addition to introducing each of these methods, Assumptions used in the methods and results were expressed about the quasi-static analysis methods for retaining walls to shield the parametric study are presented.

1) Mononobe-Okabe Method

Okabe (1926) and Mononobe and Matsu (1929) under quasi-static analysis of seismic earth pressure on retaining structures were expressed. Mononobe methods - quasi-static conditions is Okabe coulomb static analysis of theory development. In an analysis Mononobe - Okabe pseudo static acceleration to enable or disable a wedge into the coulomb pseudo-static balance of forces and stresses in the failure wedge in Figure 1 is derived. [7 and 8]

Resultant forces on the wedge in a dry earth filling without adhesion of the components of quasi-static horizontal and vertical form, which is affiliated with a wedge under the static acceleration of gravity ah=kh.g and av=kv.g. The total active force exerted on the wall in a form similar to the static case is expressed as follows:

$$S_{AE} = \frac{1}{2} K_{AE} \gamma H^2 (1-k_v) \qquad (1)$$

In relation to 1, KAE dynamic pressure coefficient is soil active and is derived from the following relationship:

$$K_{AE} = \frac{\cos^2(\phi' - \beta - \theta)}{\cos(\theta)\cos^2(\beta)\cos(\delta+\beta+\theta)} \times$$

$$\times \frac{1}{\left[1 + \sqrt{\frac{\sin(\delta+\phi')\sin(\phi'-\varepsilon-\theta)}{\cos(\delta+\beta+\theta)\cos(\varepsilon-\beta)}}\right]} \qquad (2)$$

Parameters used in this equation are shown in Figure 1. In addition, □ is calculated from the relationship 3:

$$\theta = \tan^{-1}\left[K_h / (1-k_v) \right] \qquad (3)$$

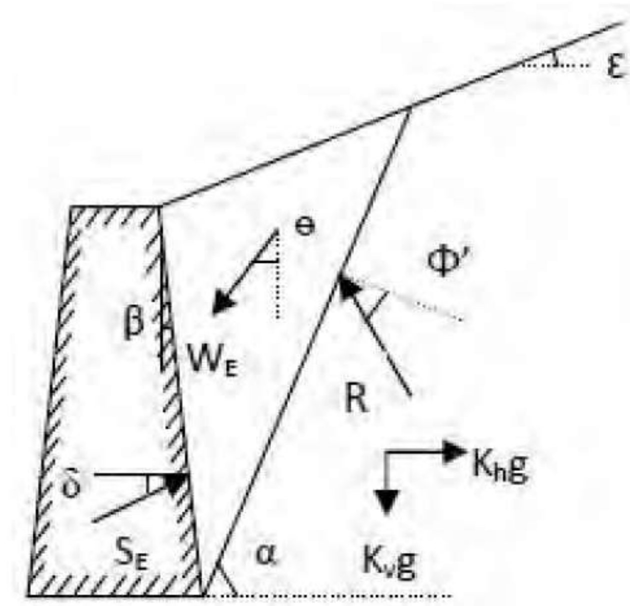


Fig. 1) Symbols and units used in the M-O analysis

Analysis based on M-O, the total active force in the foundation wall to the height of H / H 3 enters, while the laboratory results show that the location of the force located at a higher point (1). On the whole, S_{AE}, a two part static, S_A, and dynamic ΔS_{AE} be divided into:

$$S_{AE} = S_A + \Delta S_{AE} \qquad (4)$$

Static component, SA at a distance H / 3 from the top wall and acts as a dynamic component, according to Seed and Whitman (1970) at an approximate height of 0.6H is applied to the foot wall (13). Accordingly, the total active force is applied at the height h of the foot wall, which is calculated according to equation 5, and often occurs in the middle of the wall height.

$$h = \frac{S_A \cdot \frac{H}{3} + \Delta S_{AE}(0.6H)}{S_{AE}} \qquad (5)$$

M-O Analysis results show that the vertical component of acceleration earthquake Kv, 1/2 to 2/3 of the horizontal component of earthquake acceleration Kh, is having less than 10 percent of the total active force, SAE impact. Total stress on the earth filling on the retaining wall, non-sticky, dry conditions are calculated by the following relationship:

$$S_{PE} = \frac{1}{2} K_{PE} \gamma H^2 (1-k_v) \qquad (6)$$

In relation to 6, K_{PE} ratio on the dynamic pressure of the soil which is calculated from equation 7:

$$K_{PE} = \frac{\cos^2(\phi' + \beta - \theta)}{\cos(\theta)\cos^2(\beta)\cos(\delta - \beta + \theta)} \times \frac{1}{\left[1 + \sqrt{\frac{\sin(\delta + \phi')\sin(\phi' + \varepsilon - \theta)}{\cos(\delta - \beta + \theta)\cos(\varepsilon - \beta)}}\right]} \qquad (7)$$

Similar to the active mode, the total active force can be divided into two parts: static and dynamic [14].

$$S_{PE} = S_P + \Delta S_{PE} \qquad (8)$$

Dynamic soil pressure on the component side in the opposite direction it enters the static component. And thus reduces the power is off [15]. The M-O method has limitations, however, because the coulomb theory is in static conditions, the total force on the soil, especially for the $\delta \phi'/2$ conditions of the estimates [15]. Due to these reasons, M-O method should be used more carefully.

2) *Numerical analysis method*

This method is based on the soil mass behind the wall is treated in different modes. Modes of behavior depending on the wall displacement and strain levels in the soil can be elastic, elasto-plastic and plastic is. Active and passive seismic lateral pressures depending on the mode of behavior between low and high Lower Bound Upper Bound is limited. Lower limit is related to the conditions and criteria with the surrender of the dynamic balance retaining wall are on the brink of failure. While the above conditions occurred in the rate of work done by external forces, internal forces are greater than or equal to the energy dissipation rate. And this is definitely the case that failure has occurred and the object is moving large displacement. However, assuming a reasonable upper bound estimate of the geometry must be done quickly.

There are some important points in connection with the analysis that is also somewhat similar to the balance of the four requirements for the solution does not satisfy. Specifically, the lower limit on the extent of compatibility of deformation and displacement boundary conditions are ignored. And while the upper bound of the equilibrium and boundary conditions are not in force. So expect the same this does not provide answers and mechanisms depending on the speed of a hypothetical failure and give different answers.

Chen and Rosenfarb (1973) and Chen (1981) with a spiral fracture mechanism, passive and active seismic pressure into retaining walls high theory to assist in the analysis so calculated and presented in relation nine [16]:

$$K_E = N_\gamma + \frac{2q}{\gamma H} N_q + \frac{2c}{\gamma H} N_C \qquad (9)$$

In this regard γ soil density, q is the uniform load on the levee, c adhesion of soil and H is the height of the wall. Coefficients by Chen and Liu (1990) the critical failure mechanisms were calculated and are presented in tables [11]

B. *Numerical Analysis*

To meet the numerical analysis based on four theoretical considerations in general are a problem. There are usually different methods of numerical analysis, finite element; finite difference FDM & FEM , discrete element (DEM) boundary element (BEM) and other methods that try to meet all requirements related to the equilibrium, compatibility Transformations, behavioral law and boundary conditions have the force of movement. This study focuses on the finite element method using commercial software ABAQUS to investigate and compare the results of this analysis in comparison with simple methods such as limit equilibrium analysis examines the extent.. The dynamic lateral pressure using the quasi-static analysis of retaining walls has been evaluated. In this study, ABAQUS 6.11 software was used to model a wall pass. Page analysis of strain and drainage conditions has been considered. This software package consists of square elements of Element's eight transmitters. Assuming linear elastic behavior of retaining wall has been spent and the Contact Mechanic for modeling contact between soil and soil interactions and the shield or shields are used.

1) *Soil-Structure Interaction*

Generally the interaction of soil and structural failure caused by two phenomena in the following structures on soil deformation and dynamic structure of the surrounding soil is on the move. Methods of Analysis and Evaluation of Soil Structure Interaction in the following three main groups of structures, and direct solution of the mixed solution can be summarized. The most commonly used methods, the direct solution method are based on the finite element method is formulated. The purpose of the survey and soil structure interaction in dynamic analysis based on the bumpers direct solution, by the dynamic stiffness and how the waves travel at the border is a shield and the surrounding soil. So you calculate the force and displacement on the boundary has infinite dynamic stiffness due to the following relationship is obtained.

$$K(x,t) = \frac{P(x,t)}{U(x,t)} \qquad (10)$$

To achieve this aim, the dynamic analysis of the shield and the surrounding soil and soil structure interaction and wave propagation in the soil, the elasto-plastic model is used. This model includes non-linear behavior and can give criteria for soil based on the yield surface in stress - strain considered. This paper has been used in modeling the Draker-Prager behavior that the relationship is described as follows:

$$F = \alpha J_1 + \sqrt{J_{2D}} - k = 0 \quad (11)$$

J1 in the first constant stress tensor and the second fixed J2D stress tensor is crops. And k values in the above equation, the model parameters are based on soil adhesion and friction angle are calculated. But the major problem in the process modeling environment that is unlimited and it is estimated by the soil and structure interaction in seismic analysis, be defined as a boundary value problem. In other words, the soil around the tank, which must contain an unlimited environment modeling and analysis of waves in an infinite medium are published. Unlimited modeling environment to prevent the waves reflected back from the reservoir, the boundary model. So in a limited model, attenuation materials alone are not the desired energy. To achieve this goal at the lateral boundaries of a given model, each node of Element in the spring - in three orthogonal directions perpendicular to the damper is used to return the tank thus waves in the lateral borders of the desired model, will depreciate. Noteworthy point in this approach, define and select the correct material damping parameters to be set correctly model.

The most important part in the modeling analysis based on the shield in the soil and soil structure interaction, soil and structural modeling of the interface. Generally two methods for solving Abaqus software there is contact with the penalty function method and the method call as it is mentioned Kinematics. The penalty function method, there is no limit to the sinking of two surfaces together. While this method Kinematics calls, the two-level dive at each other is zero. In the present paper for the modeling of soil slip between the shield and on the overall German Contact Kinematics based on, with characteristic Tangential Behavior in the boundary between soil and the tank wall is used. Element and configure the relevant parameters on the friction between the shield and the Abaqus software can surrounding soil and is intolerant of traction by the soil surrounding the model. Soil Structure Interaction of element applies this transcending feature.

2) Model Specifications

Figure 2 Schematic geometry of the problem was gone for a retaining wall in this article shows. As is seen holding a sheet pile wall excavation to a depth of 4 m in sandy soil conditions, the model has been drained. Structural parameters required in this analysis are presented in Table 1.

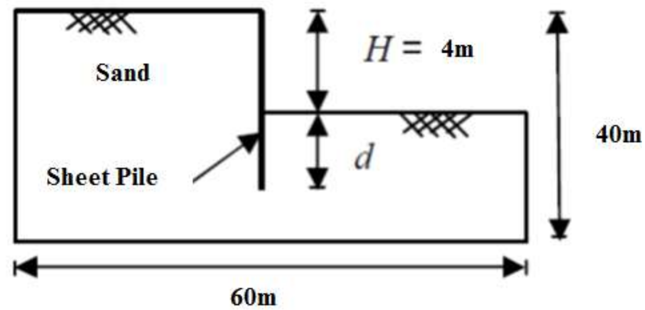


Fig. 2) Schematic view of the geometry

Table 1: Behavioral Parameters of Materials Used In the Numerical Analysis

The studied Parameters	Magnitude
Effective internal friction angle of sand	30
Deformation modulus of sand	5 MPa
Poisson coefficient	0.35
Specific weight of dry sand	17 kN/m^3
The axial stiffness of sheet pile	3E6 kN/m
The bending stiffness of sheet pile	8E4 kN.m^2/m

In this study the quasi-static behavior of this quasi-static Sheet pile wall that its amplitude is variable, deals tangly considering different lengths of 3, 4 and 5 m.

Each analysis was carried out in four successive stages: first vaccination sheet pile operations were performed in the soil. In the second and third stages of excavation was conducted in two consecutive steps and finally the fourth stage of quasi-static acceleration applied finite element analysis was performed.

III. Results and Discussion

Figure 3 shows the model built in ABAQUS software. Horizontal movement and lateral borders of the lower border of the mobility is limited. The quasi-static conditions at the center of mass and constant acceleration is applied to all elements, and finally analyzing the stress - strain has been done. Quasi-static lateral pressure behind the wall was calculated. The calculated lateral pressure, the software can calculate the bending moment is spent.

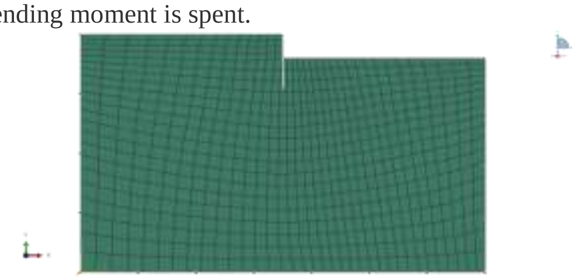


Fig. 3) Meshed Model in ABAQUS software

In Figure 4, the bending moment calculated by the numerical analysis, the wall is plotted for different Kh.

Seen that with increasing acceleration amplitude, Kh bending moment generated in the shield wall increases.

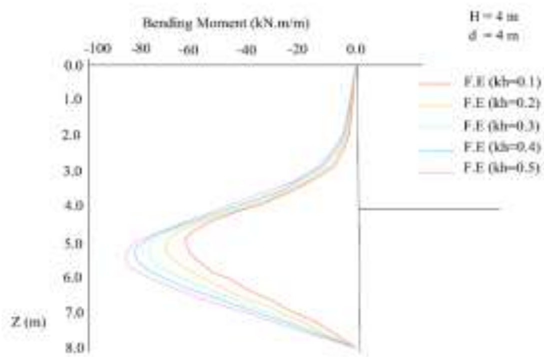
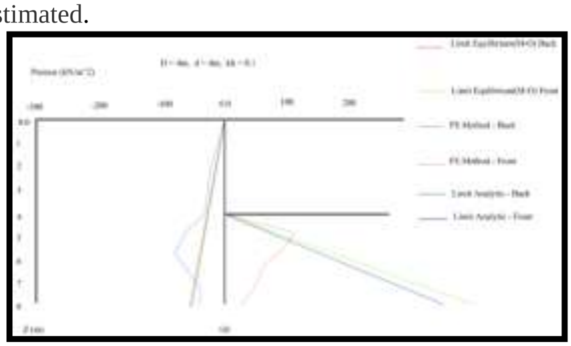


Fig. 4) Bending moment in wall height from finite element analysis of quasi-static

Quasi-static lateral pressure profile changes on active and passive soil retaining wall pass through various methods including finite element, Mononobe - Okabe limit has been calculated and analysed and is depicted in Figure 5. The results suggest that the back wall (active conditions) finite element analysis for larger values of lateral pressure in comparison with other methods (balance and analyse some extent) show. The reason is that the theory of equilibrium and limit analysis assuming this is the height of the free wall and front wall of the tangly area are ignored. Therefore it is expected to provide less of the active state. However, the front walls (the disabled) are calculated without considering lateral pressure on the soil behind the wall can be larger to provide the answer. In other words, to calculate the pressure on the back wall and front wall of the pressure and force on force role played resistance and refraining from the calculated pressure to enable it to be a low estimate. In the calculation of the pressure off the front wall and pressure is the force behind the walls is the driving force that regardless to this, the estimation results in excessive pressure on it to be estimated.



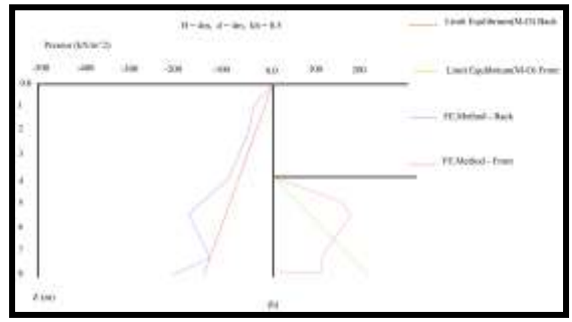


Fig. 5) Comparison of active and passive lateral pressure quasi-static finite element analysis methods, the limit equilibrium and limit analysis a) Kh=0.1 b) Kh=0.5

As seen from Figure 5 is a front wall so that the conditions imposed on the finite element analysis of lateral pressure on the smaller values than the other two offers. Results to calculate the quasi-static force off the back bumper and the front wall of the lateral pressure change on soil profiles are presented in Figure 6 and are confirming the above. For different values for quasi-static active condition, quasi-static active force arrived to spend more time in comparison with other methods. And contrast in terms of passive, active force is less than pseudo-static. Probably due to the plastic zone at the high acceleration forces on the front wall was increased and decreased.

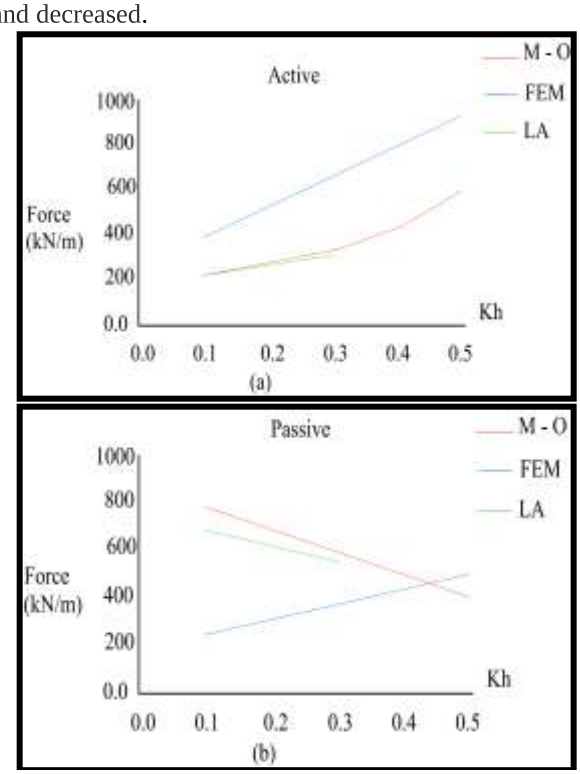


Fig. 6) Quasi-static lateral force of active and passive soil calculated with finite element methods, the limit equilibrium and limit analysis. a) Active conditions (back wall) b) Non-active conditions (front wall)

IV. CONCLUSIONS

Finite element analysis results in comparison with other methods ranging from simple limit equilibrium and limit analysis shows that:

- With the acceleration applied to quasi-static finite element model of a shield wall, bending moment caused by increases in spending.

- On the wall behind where soil conditions are established, in situations like this, the calculated results on the quasi-static pressure and the equilibrium extent and methods of analysis are much lower than the results of finite element analysis. The reason is that in expanding the balance somewhat (method Mononobe - Okabe) and extent of analysis (based on the assumed failure mechanism and the formation of a wedge failure), who spent part of the retaining wall is tangly is ignored. In other words, the theory that weight for retaining wall built almost at ground level are presented.

- Soil conditions on the wall in front is established, the results of the quasi-static pressure and force on the soil and limit equilibrium methods of analysis, finite element analysis of quasi-static limit of the results are that is because the pressure on the soil, the active force of the driving force behind a wall that has been ignored, and therefore larger answers derived.

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