Investigating The Effect of Soil Behavioral Model On The Performance of Micro Pile System Under Dynamic Loading

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Abstract: This article aims to perform finite element modeling for micro pile under dynamic loading, which investigate the effect of soil parameters around the micro pile in the bending moment provided along micro pile group. Today, micro piles are one of the most important and applied elements of reinforcement and optimization of foundations in seismic regions where are subjected to seismic damages. In this article, numerical modeling is performed by using 3D finite element software ABAQUS. Soil behavior has been considered as elastic and elastoplastic through Mohr coulomb model. Implicit method has been used in dynamic analysis. Investigations show that improvement of soil parameters reduce the bending moment applied on micro pile, and soil inelastic model increase the performance of micro pile in seismic loading.

Key-Words: Micro Pile Group, Seismic, Finite Element, Elastoplastic

1 Introduction
Micro piles are replacement piles with small diameter (usually less than 12 inch) which are provided by injection or excavation and used for foundation reinforcement and increase of soil bearing capacity[1]. Ductility and flexibility are among significant advantages of these micro piles in seismic regions[2]. After earthquake surveys show evident of the function of micro piles under earthquake effect. Micro piles are able to be installed in high elevated and limited access locations, and they can be set such that make little annoy for adjacent buildings. Micro piles can also be used single or in group as a component of soil-pile system. The analysis of recent earthquakes and results from shaking table experiments and centrifuge and finite element analysis indicate the importance and application of micro piles as an effective solution. These experiments and numerical modeling showed that seismic loading cause inertial forces to be applied on flexible piles[3]. Some researches have been performed on the performance of micro piles under dynamic loading in recent years using the importance of micro pile system in reinforcement, retrofit, bridge base and historical building projects. The research of Yang et al (2000)[4] is included who perform a series of shaking table experiments in order to study the behavior of a single micro pile under seismic loading. The researches of Shahrour and Juran (2004)[5] were another one that performs centrifuge experiments on a single micro pile, a group of micro piles, and a network of micro piles. Sadek and Shahrour(2004) [3] performed a 3D analysis of micro piles under dynamic loading. Investigated variable was the micro piles' inclination, the behavior of elastic soil, and studying oblique and vertical micro piles. In this article, elastic and inelastic behavior as well as the effect of changes in micro piles’ adjacent soil parameters under dynamic loading has been investigated. Inelastic behavior of soil is defined by Mohr coulomb failure criteria. In this article, Real earthquake accelerogram has been used in dynamic loading.

2 Finite element modeling
In order to analyze the behavior of soil-micro pile-structure system in numerical analysis, 3D model and ABAQUS software have been used. Only half of the main model has been provided due to the geometrical symmetry and preventing from long time calculations and also reduction of degrees of freedom.
freedom. Given micro piles group is a 2*2 group. In parametric studies, elasticity module of the soil is variable, while the behavior of the soil has been considered elastic and also inelastic. Micro pile behavior is also elastic. Reference model for micro pile and soil geometry model have been shown respectively in Figures (1) and (2).

Fig (1). Micro Pile Geometry Model

Fig (2). Soil Geometry Model

3 Soil finite element model
In this modeling, soil environment have been assumed isotropic. The dimensions of soil environment are (20*20*15m) which are respectively length, width, and height of the soil profile. There are unlimited boundaries with 15m length around the main environment of the soil in order to model damping lateral boundaries, which can be observed in soil geometry model. The elements used in the soil include 8 nodes and 8 nodes with reduction integral of standard elements from 3D stress family. Meshed soil sample and the location of pile in soil have been shown in figures (3) and (4).

Fig (3). The Location of Micro Pile in Soil

Fig (4). Meshed Soil Sample

4 Micro Pile and Cap Finite Element Model
Micro pile group used in main model is of 10m length and 20cm diameter, in which 60cm of micro pile is out of the soil. On the upper part, micro pile is connected to a concrete cap. The element used in micro pile is standard and from 3D stress family. The cap used is made from rigid material with material properties similar to micro piles which have 30cm thickness and 2m width and rigidly connected the micro pile, which is free of contact whit the soil. Meshed micro pile and cap have been shown in Figures (5) and (6).

Fig (5). Meshed Cap Model

Fig (6). Meshed Micro Pile Model

5 Boundary conditions and contact surface model
One of the most important issued in analysis of micro piles is to determine boundaries conditions. In dynamic loading, we can not use constant boundary conditions to prevent from established wave energy
reflection; since these boundaries leads to the change of existing stress conditions in the model, and brings the problem out of ordinary state. In such problems, damping elements are used. In this article, infinite element modeling around the model has been used. The bottom of model has been considered in association with bed rock. Therefore, the nodes are used with constant boundary conditions.

In symmetrical boundary, this conditions are applied so that the system is not allowed moving in that direction. In order to excavate the soil before installing micro pile, constant boundaries conditions have been considered which will be inactive after installation of micro piles. Then, contact surfaces include the contact of micro pile with soil, and the contact of micro pile with cap. In ABAQUS software, these contact surfaces are defined in interaction section. ABAQUS software presents the behavior according to the kind of contact including tangential and vertical behavior [6]. Tangential behavior has been used in the contact of shaft micro pile with soil, hard contact was also used in the contact of micro pile and soil. Friction coefficient of 0.4 has been used in tangential contact, and geometrical properties are allocated to the surfaces.

### 6 Dynamic loading

Accelrogram of Manjil earthquake (1990) has been used in dynamic loading. In this loading, mentioned earthquake was applied as acceleration time history at the bottom of the model. Acceleration figure and related properties have been shown in table (1) and Figure (7), respectively.

<table>
<thead>
<tr>
<th>Records</th>
<th>Station</th>
<th>Frequency Content(Hz)</th>
<th>PGA(g)</th>
<th>PGV(cm/s)</th>
<th>PGD(cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manjil(1990)</td>
<td>Abbar</td>
<td>0.1-20</td>
<td>0.56</td>
<td>59.1</td>
<td>25.9</td>
</tr>
</tbody>
</table>

### 7 Finite element analysis

Figure (8) and (9) shows the time history diagrams of the effects of elasticity modules on bending moment established in cap for elastic and elasoplastic states. It can be seen, in cases where micro pile is placed in soils with elastic and elastoplastic properties, that bending moment in the cap is reduced with increase of soil rigidity. This time reduction, which is considered as elastoplastic soil behavior, shows more reduction than elastic soil behavior, which indicates the inelastic behavior of the soil in decrease of the moment provided by inertial forces applied on micro piles.
In figures (10) and (11), bending moment push curves along micro pile have been shown under the effect of elasticity module parameters. Figure (10) shows the increase of soil rigidity from 20 to 60 (Mpa) in bending moment push along micro pile with elastic behavior, and it can be observed that by increasing soil rigidity, the moment applied on micro pile is decreased. This reduction with increased rigidity from 60 to 100 Mpa is significant. Figure (11) shows the effect of soil rigidity on bending moment push along micro pile with inelastic behavior. So, this figure (11) indicated that increased rigidity in soil with inelastic behavior also reduce the moment applied on micro pile under dynamic loading. It can be observed in comparison to elastic model.

**8 Conclusion**

Today, micro piles are one of the most important and applied elements of reinforcement and optimization of the soils in seismic regions. This article tries to investigate bending moment according to elasticity module in elastic and elastoplastic soil for micro pile groups along micro piles by using ABAQUS software and considering dynamic conditions. At the end, after analysis and investigations, it was found that maximum bending moment in the caps has been occurred in all performed models. And gradually, it decreases from up to down of the micro pile. In comparison to the bending moment applied on micro pile, this value in elastic soil is more than elastoplastic one according to the elasticity module; it shows that inelastic behavior of the soil cause less inertial forces to be applied on micro pile. As a result, the moment applied on micro pile in the soil with elastoplastic behavior will reduce. Finally, elastoplastic model of the soil improve the response of micro pile group under seismic loading.
References: