The efficiency of deep soil mixing method in order to optimizing and creating retaining structure in foundation (case study: Ahvaz oil company)

Sayyed Yaghoub ZOLFEGHARIFAR$^{1,2,*}$, Mohammad GHIASI$^3$

$^1$Geotechnical Engineering phd.department of civil Engineering.faculty of Engineerig.Yasooj Branch,Islamic Azad university,Yasooj,Iran

$^2$Department of Geotechnics&Transportation.faculty of civil Engineering.university Technology Malaysia, Malasia

$^3$Geotechnical postgraduate student,Department of civil Engineering faculty of Engineering, Yasooj Branch,Islamic Azad university,Yasooj,Iran

Received: 20.04.2015; Accepted: 09.07.2015

Abstract. Deep soil mixing is a kind of optimizing method that is functional in a wide dichotomy of soils till 50 meter depth. The goal of soil mixing is achieving parameters or modified geotechnical parameters such as compressive strength, shear strength and permeability (12).

In the field of environmental also it is used to limit or fix harmful chemical material in soil. Also in building ports and marine constructs we can achieve valuable results by performing the work on barges. In using deep soil mixing, earth is modified in situ conditions, its Geotechnical features will be reached to the acceptable level and this modified ground will be a part of soil-commercial systems. Controlling and quality confirmation are also possible.

Introduction

Mixing soil in depth is a method where stabilizers such as cement or lime using a digger with hollow shaft will be mixed with soil mechanically. This process causes a uniform column production (with fixed width) from soil and additive material. With the same overlapping of before complete setting columns, continuous walls below ground level are buildable (2).

The goal of mixing soil is achieving geotechnical parameters that are modified before, Compressive strength, shear strength and permeability. In using deep soil mixing, earth is modified in situ conditions, its Geotechnical features will be reached to the acceptable level and this modified ground will be a part of soil-commercial systems (4). The obtained mixing soil resistance depends on factors such as additive material, soil kind and performing method. The method of deep soil mixing is used for optimizing the wide area of inorganic soft soil and soils that other methods of optimizing are not practical for them. With mixing soil in place we can modify different soils kind, the method of modifying depending on the rate of mixing energy and the kind of additive materials are different. Compared to other methods in modifying soft soils this method is the most economic one in for optimizing soil. Economic limitation of a time or a place sometimes because optimizing methods such as preloading or dynamic method may not be suitable. The method of deep mixing has proved itself as a suitable replacement for these two methods and also methods of deep foundations (candle components) (1).

* Corresponding author. E-mail: syzoalfeghary@gmail.com

Special Issue: International Conference on Non-Linear System & Optimization in Computer & Electrical Engineering

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Unfortunately from the beginning of using this method till today almost 40 years passed. Because of the lack of needed technology in order to performing, some cases are used in Iran. Considering this Iran has beach grounds in the north and the south and these grounds are ready to use this method for optimizing, its importance get clearer more than before especially in our country because of Seismic Fiery, the occurrence of liquefaction possibility is there in these areas. Using this method causes reduction of liquefaction potential and problems prevention (2).

The goal of this research is checking and evaluation of performance and soil optimizing for caulking and creating guide construct considering Geological and Geotechnical Engineering conditions in two projects in two regions with different Geological and Geotechnical for better understanding this method. So in this research the Geotechnical conditions and engineering geology of twins towers projects in Ardebil and hospital project of Oil Company in Abadan and the way of DSM method performance and used tools for creating a guide construct for preventing water penetrating considering geotechnical features of two projects’ place will be checked.

**Research history**

The first performance of deep soil mixing method returns to its function near Honda airport in 1971. In this project lime is used as additive material. First in most of deep mixing projects lime is used as stabilizer, but gradually and with recognition of cement effects on soil and also being available, using cement as an additive material increased.

The increase of this method in Europe started from northern countries of this continent from the middle of 1970. Below picture shows the performance of deep mixing columns based on the length of column performed in different years. The beginning of this method in the US was when a lot of specialized contractors were working in Japan. The first deep mixing project in the US in 1986 and is related to soil optimizing under a dam in Jackson River. After that wide projects were done by this method in the US so that Association of State Highway America did writing standards and regulations for performing deep mixing method with code FHWA-RD-99-138.

**Deep mixing method introduction**

Deep soil mixing is a method where some stabilizer such as lime or cement using a digger with hollow axis will mix to soil mechanically. This process causes a uniform column production (with fixed width) from soil and additive material. With the same overlapping of before complete setting columns, continuous walls below ground level are buildable (3).

The goal of mixing soil is achieving geotechnical parameters that are modified before, Compressive strength, shear strength and permeability (2). In the field of environmental also it is used to limit or fix harmful chemical material in soil. Also in building ports and marine constructs we can achieve valuable results by performing the work on barges. In using deep soil mixing, earth is modified in situ conditions, its Geotechnical features will be reached to the acceptable level and this modified ground will be a part of soil - commercial systems. Controlling and quality confirmation are also possible. Mixing system may have single drills a diameter of 0.6 to 1.5 m. and or a collection of two to eight drills a diameter 1.5. These columns are performed in depth of 20 meter in the US and in depth of 60 meter in Japan. Deep soil mixing is such optimizing method that is used in a wide depth of soil about 50 meters. The goal of mixing
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soil is achieving geotechnical parameters that are modified before, Compressive strength, shear strength and permeability. In the field of environmental also it is used to limit or fix harmful chemical material in soil. Also in building ports and marine constructs we can achieve valuable results by performing the work on barges. In using deep soil mixing, earth is modified in situ conditions, its Geotechnical features will be reached to the acceptable level and this modified ground will be a part of soil-commercial systems. Controlling and quality confirmation are also possible (6).

Economic limitation of a time or a place sometimes because optimizing methods such as preloading or dynamic method may not be suitable. The method of deep mixing has proved itself as a suitable replacement for these two methods and also methods of deep foundations (candle components).

Unfortunately from the beginning of using this method till today almost 40 years passed. Because of the lack of needed technology in order to performing, some cases are used in Iran. Considering this Iran has beach grounds in the north and the south and these grounds are ready to use this method for optimizing, its importance get clearer more than before especially in our country because of Seismic Fiery, the occurrence of liquefaction possibility is there in these areas. Using this method causes reduction of liquefaction potential and problems prevention.

These days with attempts of geotechnical experts and Iranian mechanic and relying on knowledge and several decades experience in form of engineering offices such as Civil static have passed all barriers and opened a beginning for performing this new method in country and with successful performance of several projects in Iran, have brought the promise of rapid development of deep mixing method in our country.

**Project location**

The place of project is in Abadan, Montazeri street, next to Imam Khomeini in an area of about 7568 square meters and environment about 374 meters in maximum 6 floors (in southern part). Excavation site of the project has been done using deep soil mixing, steel profiles and soil anchors joint implementation till depth of 5.6 to 6.6 toward ground. (figure 1 and 2 shows the location of project).
Geology of region

The most important delta deposits in the beach of Persian Gulf are created in the mouth of the Arvand River. All swampy areas of this region must be considered as present delta deposits. Abadan delta that Abadan is located on it is created from sediment deposition in the river mouth and Minol Island is one of small triangles of this delta (18). River alluvial usually has layers and are very changeable. Among layers, layers with lenses with different size can be found. Permeability of the sediments in horizontal direction is more than right direction. Clay alluvial is usually soft and sands are loose or have a little dense (19). Hunt in 1984 named one of alluvial deposits samples as delta deposits in classification of soils and based on origin and the location of formation. He introduced the location of delta deposits or estuarine, delta or estuary and clearly as variable, loose, often fine-grained that gradually change to coarse grained. In location of sea water entry, the path of Jaryanroud may be reversed frequently. This can be because of inundation or the tides. In the final parts of river and in place of its facing with sea fine-grained usually is left. The volume of these deposits must be in a way that the tides, waves or sea streams cannot carry and spread it out. The other important factor is existence of calm and low energy environment. In such these areas the gradual accumulation of sediments and its going ahead toward sea creates delta. Delta deposits that are made in sea beaches are usually a mixing of fine grained sand, clay and silt (19). Generally according to geology maps national Iranian Oil Company, Abadan is a flat region and completely covered by alluvial deposits including clay fine grained, silt and sand. Under these deposits that has a thickness of about 10 to 50 meters, there are geologic unruﬄed deposits related to Aghajari formation.
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Designing and relevant calculation to stabilizing and sealing the pit walls of Oil Company

1- Geotechnical parameters of location soil

Geotechnical parameters are done based on the results of standard penetration test (SPT) and lab tests of geotechnical studies. In first and second phase and field observations of project location and engineering judgment of these advisors are presented in tables 1 and 2 for short term and long term mood.

It is noticeable that groundwater level in first phase studies are reported in depth of 2 meters from natural ground level and in second phase studies in depth of 1.4 meter of natural ground level. In all calculations, underground water level is considered as natural ground level.

Table 1. Short term geotechnical parameters.

<table>
<thead>
<tr>
<th>Layer No.</th>
<th>Soil Type</th>
<th>Depth (m)</th>
<th>$\gamma$ (kN/m$^3$)</th>
<th>$c_u$ (kg/cm$^2$)</th>
<th>E (kg/cm$^3$)</th>
<th>$\nu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Clay</td>
<td>0-4</td>
<td>20</td>
<td>0.5</td>
<td>750 C$_u$= 375</td>
<td>0.4</td>
</tr>
<tr>
<td>2</td>
<td>Clay</td>
<td>4-20</td>
<td>20</td>
<td>0.2-0.5</td>
<td>1000 C$_u$= 200-500</td>
<td>0.4</td>
</tr>
<tr>
<td>3</td>
<td>Sand</td>
<td>20-30</td>
<td>20</td>
<td>0</td>
<td>500</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>Clay</td>
<td>30-35</td>
<td>20</td>
<td>0.7-0.8</td>
<td>1000 C$_u$ = 700-800</td>
<td>0.4</td>
</tr>
<tr>
<td>5</td>
<td>Clay</td>
<td>35-40</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Long term geotechnical parameters.

<table>
<thead>
<tr>
<th>Layer No.</th>
<th>Depth (m)</th>
<th>$\gamma$ (kN/m$^3$)</th>
<th>$c'_u$ (kN/m$^3$)</th>
<th>$\phi'$ (degree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0-10</td>
<td>20</td>
<td>0.12</td>
<td>22</td>
</tr>
<tr>
<td>II</td>
<td>10-20</td>
<td>20</td>
<td>0.12</td>
<td>20</td>
</tr>
<tr>
<td>III</td>
<td>20-30</td>
<td>20</td>
<td>0.07</td>
<td>33</td>
</tr>
</tbody>
</table>

2- Sealing and stabilization plan

Considering high level of underground water the operation of sealing and stabilization walls is done as follows:

2-1- Sealing walls

Building walls sealing are checked in different methods. Considering usual methods such as digging by Garb in urban areas is not possible because of the possibility of damaging installations and other structures and also considering the need to reduce the wall width (more using ground) after several studies, it has been decided to use deep soil mixing columns performance. In this plan bean-shaped columns are predicted beside each other with enough overlapping. Figure 3 shows the way of overlapping and the form of columns DSM.
Figure 3. The way of overlapping and form of DSM columns.

**DSM columns features**

The length of DSM columns is considered 10 meter in areas that the depth is 5.6 and 10.5 meter in areas with 6.6 meter depth. It is noticeable that addition to walls sealing, increasing water route and as result reduction of Hydraulic gradient in front of walls are also this plan goals. In order to perform DSM columns first digging operation till final depth is done and then water-cement slurry will be injected from the end to up.

**Walls stabilization**

1) **The use of inhibitory**

In order to stabilize wall an inhibitory row is used. the roles of inhibitors addition to wall stabilization and providing confidence coefficient, considering implementing of prestressing force, is preventing creation of harmful deformation in adjacent structures as well.

2) **Soldiers beams**

In order to provide soldier beam that is formed from steel profiles I, sheets with a thickness of 5, 6 or 8 mm are used. These profiles will be inhaled in DSM columns and before setting (by vibrated hammer). The length of profiles for mentioned depths is respectively 8 and 9. The horizontal distance of profiles from each other will be 1 meter and are performed in the center of bean shaped columns DSM.

3) **Waling**

In order to equal distribution of pre stressed power and integration soldiers’ beam, in elevation positions of inhibitory 2 profiles UNP120 are performed with enough distance and inhibitors will be locked on it in distance of soldiers’ beams.
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4) Executive characteristics

The way of designing and also executive characteristics of each used elements in stabilization and sealing systems are as follows:

a) DSM columns

The method is blades With rotating were driven into the soil and then with arriving in wanted depth the stream of cement slurry will be leaded through soil and simultaneously with bladders turning, the harmful soil will be mixed with slurry and the mixing of cement-soil (Soil Crete) will be obtained. In this project DSM columns with double axis addition to sealing in order to stabilizing the depth wall are used too that for this before hardening of slurry, steel profiles will be placed inside bean shaped columns.

- DSM columns administration
  - Wight ratio of water to cement: 0.8
  - Cement grade: about 235 kilogram on meter (without considering tails and other cases)
  - Overlapping of bean shaped columns: from each side 40 centimeter (in some parts of southern front the overlapping of even columns from one side is 50 centimeter and the other side 30 centimeter).
  - The bean's center to center distance: 1 meter

Considering above, the able of results for foundation sediment center are as follows:

Table 3. The results of center seepage.

<table>
<thead>
<tr>
<th>-</th>
<th>-Plaxis 3D Foundation mm Millimetre</th>
<th>Plaxis 3D 2012 mmMillimetre</th>
<th>Plaxis 3D 2012 equivalent method mm -Millimetre</th>
<th>SES Method mm -Millimetre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undrained-with DSM Short-term rehabilitation before consolidation</td>
<td>- 24.54</td>
<td>-</td>
<td>- 28.61</td>
<td>- 29.1</td>
</tr>
<tr>
<td>Drained-with DSM Long-term improvement after consolidation</td>
<td>- 49.75</td>
<td>- 44.83</td>
<td>- 46.29</td>
<td>- 42.11</td>
</tr>
<tr>
<td>Undrained Without DSM Short-term rehabilitation before consolidation</td>
<td>- 28.82</td>
<td>-</td>
<td>- 29.98</td>
<td>-</td>
</tr>
<tr>
<td>Drained-with DSM Long-term improvement after consolidation</td>
<td>- 60.74</td>
<td>- 55.03</td>
<td>- 54.98</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 4. The amount of seepage of whole foundation on DSM columns in foundation corner toward the length of columns (Following extensive interaction time of the North).

<table>
<thead>
<tr>
<th>Total column length</th>
<th>Whole seepage $S_1+S_2+S_3+S_4$ (millimeter)</th>
<th>$S_1+S_2+S_3$ (millimeter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meter</td>
<td>Millimeter</td>
<td>Millimeter</td>
</tr>
<tr>
<td>8</td>
<td>52</td>
<td>45</td>
</tr>
<tr>
<td>10</td>
<td>43</td>
<td>40</td>
</tr>
<tr>
<td>11</td>
<td>41</td>
<td>38</td>
</tr>
<tr>
<td>12</td>
<td>38</td>
<td>35</td>
</tr>
<tr>
<td>14.4</td>
<td>52</td>
<td>32</td>
</tr>
</tbody>
</table>

Columns block seepage (millimeter) $S_1$
Consolidation seepage (millimeter) $S_2$
elastic clay seepage (millimeter) $S_3$
Sand elastic seepage (millimeter) $S_4$
Figure 2. The images of performing plans of deep soil mixing of Oil Company Abadan hospital location.

1- DSM method as soil optimizing with chemical stabilizer such as lime or cement is used in grounds with sand soils.

2- In Ahvaz Oil Company hospital project for building a soldier construct sealing wall for excavation DSM 3 axis method with water, cement stabilizer till depth of 15 meter will be performed. In order to performing this method in project location 4 boreholes machines were drilled that some physics and mechanic experiments were done on it that their results are as follows:

- Underground water in project location is in depth of 1.30.
- The kind of soil is fine grained and consists of clay and silt (ML and CL)
- Relative density of soil is in depth of 40 meter equal 20 KN m
- Uniformity coefficient of place soil gradually increases to the deeper one and place between 0.5 to 0.8 kilogram on Cm²
- Modulus of elasticity also with increase of depth will increase so that it will reach in low depth is 375 and depth 30 meters is equal 800 kilogram on Cm²
- According to single axis experiment the resistance of place soil gradually will be decreased to the depth so that it will reach in low depth 1.44 and higher one to 0.7 kilogram on Cm²

Also considering the results of geotechnical tests of place soil, the length of DSM columnsare considered 10 meter in areas that their depth is 5.6 and 10.5 meter in area that its depth is 6.6, according to below features:

- Wight ratio of water to cement: 0.8
- Cement grade: about 235 kilogram on meter (without considering tails and other cases)
- Overlapping of bean shaped columns: from each side 40 centimeter (in some parts of southern front the overlapping of even columns from one side is 50 centimeter and the other side 30 centimeter).
- The bean's center to center distance: 1 meter

References