# Evaluation of Geotechnical Properties of Soil Profile along the Third Line of Mashhad Light Train

**Sarah Vahedi[1], Sepideh Nasseh[1*], Mohammad Ghafoori[2], Gholam Reza Lashkaripoor[2]**

1)Student of Engineering Geology, Faculty of Sciences, Ferdowsi University of Mashhad

2)Professor of Engineering Geology, Faculty of Sciences, Ferdowsi University of Mashhad
09155190564- eng.geology@yahoo.com

## Abstract
*The light train project of Mashhad city has been started in 1381 to help the transportation system in the city. The third line of this project has approximately 19 $^{Km}$ length, from northwest to southeast. Low ground water table is helpful in this project because this line will be done as a tunnel. Engineering properties of soil is so important in developmental and constructive plans. This paper deals with the geotechnical and geological engineering characteristics of the third line of Mashhad light train. Finally, the soil profile is presented according to correlation between boreholes information, sampling and geotechnical data.*

**Keywords:** *Geotechnical properties, Engineering geology, Mashhad light train, Soil profile*

## 1 Introduction
Mashhad is the second major city in Iran with the population of over 2.2 million and more than 13 million visitors and pilgrims in a year. Therefore the current transportation system is not convenient. According to the surveys, trains are better than buses in cities because more than 7000 passengers in one hour travel in one direction. There are different types of railway systems such as light train, metro, monorail and tramway. Based on evaluating these different types, the experts decided to choose light train for this project because its velocity and capacity is more than tramway and the costs are lower than metro. After that, four lines were suggested for Mashhad city. The third line starts from the end of Emamieh boulevard in Ghassem Abad and passes through Imam Ali highway, Janbaz boulevard, Ferdowsi boulevard, Towhid street and Imam Reza street and finally ends in Mashhad South Bus Terminal. In this project, 9 test pits and 11 boreholes were drilled and different tests were carried out (figure 1).

## 2 General Geology
The study area is a part of Mashhad plain. This plain is located on northeast of Iran, between longitudes $58^{\circ}\ 20'$ and $60^{\circ}\ 08'$ E and latitudes 35 40 and 36 03 N. Mashhad plain is a part of Kashaf Rud river catchment area.
There are two different mountain ranges around this plain. Hezar Masjed mountain on north and Binalood mountain on south. These mountains include different geological formations from Precambrian to Quaternary. Mashhad city has been developed on young alluvial sediments of Mashhad plain. These sediments are results of Kashaf Rud river activity and seasonal floods of local rivers. The sediments have originated from Binalood and Hezar Masjed mountains. The maximal thickness of these alluvial deposits is about $250^{m}$.

## 3 Geotechnical and Engineering Geological Properties

Mashhad plain sediments are generally of flood plain type. The main factor of sedimentation in Mashhad city basin is minor streams originated from the southern mountains. These streams often pass through schist and phyllite (Ghafoori et al., 1384).

According to borehole data in a specific direction, it is possible to correlate different information in different depths. Thus boreholes drilled in the third line were evaluated. The sampling was done. The tests were carried out on samples are as follows: standard penetration test (SPT), sieve analysis, hydrometer analysis, Atterberg limits, density, triaxial compression test, direct shear test, consolidation, swelling, penetration test and some chemical tests (Mahar Ab Consulting Engineers, 1384).

### 3-1 Boreholes in General

Determination of quantitative, qualitative and engineering properties of soil in the site is so important. Therefore, 11 boreholes and 9 test pits were drilled. Based on this study, about 80% of the region soil is clay, silt or silty sand. In most parts of the site, specially the eastern part, the amount of salt ions and totally alkali properties of soil is considerable. Granullar materials in these series may result in increasing soil penetration coefficient. Table 1 includes the borehole data in general.

### 3-2 Geotechnical and Engineering Properties of Soil Profile

Figure 2 shows the soil profile along the third line. This profile starts with sandy soil (SW-SM, SP-SM, SM, SC-SM) and gravelly lenses (GW-GM, GP, GP-GM, GM) on Emamieh boulevard (NW). In this part, dry density varies from 1.4 to 1.86 and water content from 3.6 to 9.2. The SPT number is more than 30. This number shows that the soils are strong. As it is shown in figure 2, the clayey and silty interlayers appear in borehole $TP_6$ that is drilled on Janbaz boulevard. In $BH_8$, located on Khosravi street, fine grained materials overcome sandy soils. Clayey and silty soils have a water content of 23% and dry density has slightly reduced rather than sandy soils. But their SPT numbers show a sharp decrease, however SPT numbers in sandy lenses increase locally.

Soil strength is often a result of cohesion and internal friction. In this project, C and φ have been determined from direct shear and triaxial compression tests. Based on the results, cohesion range is between 0.11 and 0.51 $Kg/cm^2$ and internal friction varies from $20.1^\circ$ to $37.5^\circ$. Totally along the line toward South Bus Terminal, φ decreases and C increases due to abundance of fine grained soils in the last parts of the line (Figure 3). Density is applied to determine the stability and overburden pressures. In soil mechanics, dry density is usually used instead of density because it is constant and free from water content. Figure 4 shows the changes in dry density at depths $10^m$ and $20^m$. Based on the diagrams in figure 4, $\gamma_d$ reduces toward the last borehole due to decreasing in grain size and compaction. The $\gamma_d$ range is from 1.38 to 1.93 $gr/cm^3$.

The plasticity of the soil increases toward the South Bus Terminal, considering liquid limit and plasticity index. This shows low quality in materials or in other words, reducing the grain size. Figure 5 shows PI versus LL. Using Casagrande Chart (1932) as shown in figure 5, the fine grained soil type is resulted CL-ML.

Standard penetration test was carried out to determine the soil strength and compactibility. Changes in SPT numbers along the line is shown in figure 6. A reduced trend is observed in SPT numbers due to the change in soil types.

**3-3 Swelling Potential**

LL and PI are broadly used for evaluating the swelling potential of soil (Thomas et al., 2000). Table 2, demonstrates the relationship between plasticity and swelling potential (Harrison et al., 2003). Based on the results, the region soil has a low swelling potential, however, this problem is probable around boreholes $BH_4$, $BH_8$ and $BH_{10}$ that are located on Janbaz boulevard, Andarzgoo street and Imam Reza street respectively.

**3-4 Collapsibility**

Collapsible soil is an unsaturated soil that during saturation shows a great deal of dilatation (Das, 1985). In the recent project, the collapsibility potential has been evaluated in 8 boreholes that consist of silty soils. Priklonski criterion has been used to calculate the collapsibility coefficient ($K_D$) according to the following equation (Priklonski, 1952) :

$K_D$=natural water content-PL/PI

Moreover, the collapsibility potential ($C_p$) is also calculated using the following equation:

$C_p=e_1-e_2/1+e_0$

Where $e_1$ is void ratio before saturation and $e_2$ is void ratio after saturation.

Based on the results, in boreholes $BH_5$, $BH_{11}$ and $BH_{12}$ on Gharani boulevard and Imam Reza street, the collapsibility potential is considered.

**3-5 Liquefaction**

Liquefaction is another problem involved in civil projects. Along the third line, due to low ground water table and the possibility of drainage in sandy layers, the risk of liquefaction is not expected.

**4 Conclusions**

Four different groups suggested to classify the soil along the third line of Mashhad light train are as follows:

1) Geotechnically proper; SW-SM; on Emamieh boulevard; boreholes 1 to 5
2) More proper than the first group; GW-GM; on Imam Ali square and Janbaz boulevard; boreholes 5 to 10
3) Approximately weak; SC-SM; from Abbasi junction to Andarzgoo street; boreholes 10 to 16
4) Geotechnically weak; CL-ML; from Andarzgoo street to Mashhad South Bus Terminal; boreholes 16 to 20

Generally speaking, from beginning to the end of the site, geotechnical properties of the soils weaken, however, geotechnically very weak soils such as Pt, OH, MH, CH and OL do not exist in boreholes.

Toward the Mashhad South Bus Terminal, the amounts of LL, PI and C increase and the amounts of $\gamma_d$ , $\varphi$ and SPT numbers, decrease because of the changes in grain size.

Swelling phenomenon is likely in boreholes $BH_4$, $BH_8$ and $BH_{10}$ but liquefaction is not expected because of the low ground water level in boreholes with sandy layers and these layers are not limited between impermeable layers so that the drainage is possible.

## 5 References

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**Table 1) boreholes in general**

| Borehole No. | Unified Classification | Borehole No. | Unified Classification |
|---|---|---|---|
| $TP_1$ | SW-SM | $BH_4$ | SM -SC |
| $TP_2$ | SW-SM | $TP_8$ | SM |
| $BH_1$ | SM-SC | $TP_9$ | SM -SC |
| $TP_3$ | SW-SM | $BH_5$ | SM -SC |
| $BH_2$ | SM-SC | $BH_6$ | SM/CL |
| $TP_4$ | GM-GC | $BH_8$ | ML |
| $TP_5$ | GW-GM | $BH_9$ | CL-ML |
| $BH_3$ | SM -SC | $BH_{10}$ | CL-ML |
| $TP_6$ | GW-GM | $BH_{11}$ | CL-ML |
| $TP_7$ | SM | $BH_{12}$ | CL-ML |

**Table 2) relationship between plasticity and swelling potential**

| Liquid Limit (%) | Plasticity Index (%) | Swelling Potential (%) |
|---|---|---|
| 50> | 25> | low |
| 50-60 | 25-35 | moderate |
| 60< | 35< | high |

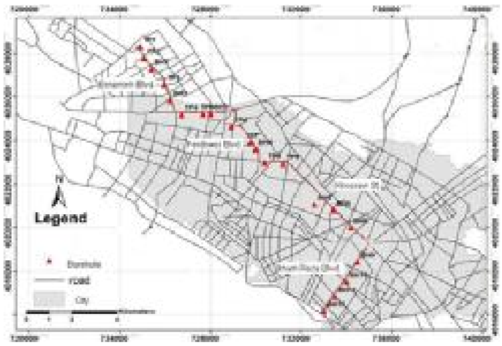


Figure 1) location of Line 3 and drilled boreholes

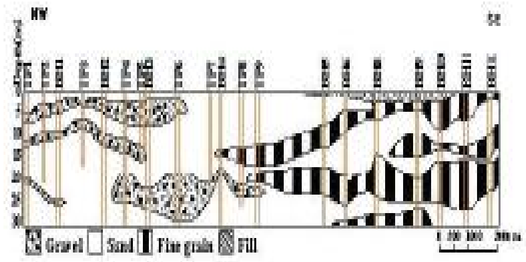


Figure 2) soil profile along the third line

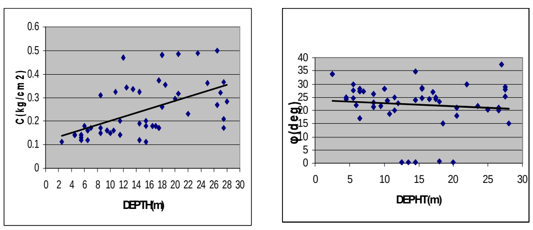


Figure 3) changes in C and φ versus depth

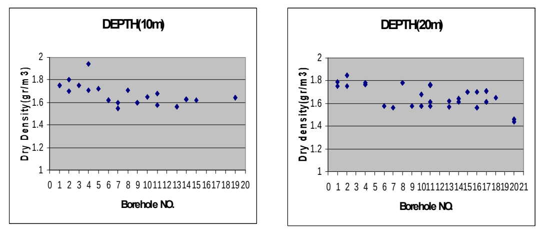


Figure 4) variations of $\gamma_d$ in depths $10^m$ and $20^m$

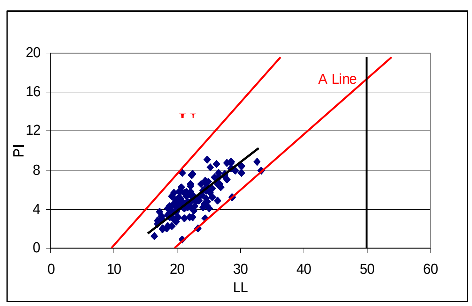


Figure 5) PI versus LL

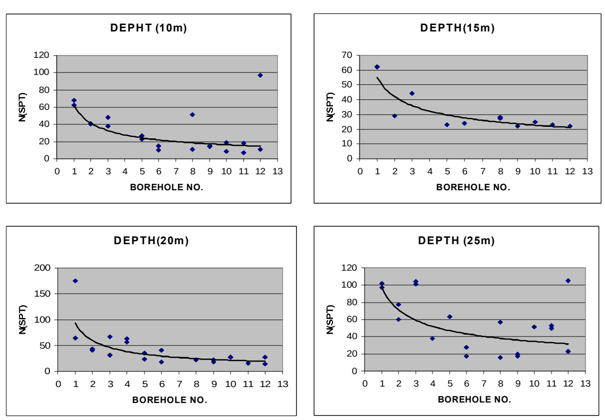


Figure 6) variation of $N_{(SPT)}$ in depths 10, 15, 20, $25^m$