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# Assessment of Shallow Geotechnical Properties, Koya City- North of Iraq

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**Abstract** This study can provide and used as a reference and guidance to estimate site characterization of Koya city soils. Furthermore the results obtained from the assessment can be used as potential inputs for designing structures by the city planner, civil and geotechnical engineers. In order to create a geotechnical evaluation and develop a general description for the subsoil of the study area, 33 testing stations was randomly choose through the city, each station includes 3-5 testing points. All the disturbed and undisturbed samples were predicted from (1.5-2.5) m depth below the ground level. The tests included evaluation of the visual soil classification, index properties that are liquid and plastic limits, specific gravity, grain size analysis, compaction properties in term of dry unit weight and optimum moisture content, furthermore evaluation of the swelling potential of the soil in term of soil activity also predicted. The results indicated that 18% of the testing stations were fine grain soils and 82% were coarse grain soils. The soil classification and geotechnical testing showed that there are high variety in the types of soils and their corresponding properties. This high variety is based on the variety of the geological formation of the study area adding to that the losses in fines from some station and increase of then in anther stations depend on erosion of the fines, transmission of them with moved water, then these fines regimented on other stations represent the most effective reasons. Furthermore the analysis of results shows that the fine grain soils have low swelling tendency. Results from standard compaction test showed that the average optimum content for coarse grain soils was 12.4% while the average maximum dry density was 2.0 g/cm$^3$.

***Keywords:*** *geotechnical assessment, geotechnical properties, soil classification, Koya city*

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## 1. Introduction

The first step in any engineering project is to identify and describe the subsoil condition. For example, as soon as a ground is identified as gravel, engineer can immediately form some ideas on the nature of problems that might be encountered in a tunneling project. In contrast, a soft clay ground is expected to lead to other types of design and construction considerations. Therefore, it is useful to have a systematic procedure for identification of soils even in the planning stages of a project.

There are many published experimental and theoretical investigations dealing with soil assessment and evolution of soil properties problem in Iraq and other regions in the words, but there is no studies deal with prediction of the geotechnical properties and their assessment of Koya.

Ghaidaa Al-Naimi, [1], presenting geotechnical and evaluation studies about soil parameters and shear strength of soil of Baghdad city , middle region of Iraq, and presenting many charts showing variations of different types of soil properties liquid limit, plastic limits, soil activity and other factors with depth. Bakir, [2], studied different types of soil properties of southern region of Iraq and presenting many geotechnical maps showing variations of different types of soil properties liquid limit, plastic limits, soil activity and other factors with depth soil for this area. Al Ani [3], presenting geotechnical maps for soil of Dyalaa governorate and middle region of Iraq. The study included different soil properties liquid limit, plastic limits, shear strength and other factors with depth. Mohammed Abdul – Zahra Turkie [4] presenting geotechnical maps for the soil of Baghdad, Diyala, Wasit and Babylon governorates through collecting data, tabulating the information & analyzing them, then maps were drawn for each property for different depths. He studied different types of soil properties Atterberg limits (liquid limit & plasticity index), dry unit weight, initial void ratio, fine particle percent, strength of soil in term of (number of blows in S.P.T and unconfined compression strength), compression index, organic matter percent, sulphate content and water table.

Khaled Alhadad, [5] worked on the geotechnical assessment of Soil from selected sites in Tikrit city middle of Iraq. Results of six subsurface samples at depth (0.5-1.4) m, collected from sites within Tikrit indicated coarse& fine Gypseous soils (Gravelly sand, Silty clayey sand) inorganic& non plastic, according to Unified Soil Classification System (U.S.C.S). The results indicate weak geotechnical properties, because it mostly gypseous soil with friable sandy content.

Jiang Jianping, [6], studying physical and mechanical characteristics of soft soil (including clay and silty clay) in the foundation of Sutong large bridge in lower reaches of Yangtze River, Jiangsu province, China, based on large numbers of geotechnical tests. He found variation coefficient of natural density, dry density, specific gravity of soil grain, saturation are small; the variation coefficient of natural water content, natural hole ratio, liquid limit, plastic limit are generic; and the variation coefficient of plasticity index, compress module, compress coefficient, coherent strength, inner friction angle, the standard penetration test (SPT) are big. Ali Hooshmand and others [7] studied the mechanical and physical characterization of Tabriz Marls, Iran to investigate the strength and deformation characteristics of Tabriz marls.

Stress–strain behavior is investigated by various in situ and laboratory tests. The results indicates The parameters $q_u$ (uni-axial compressive strength), NSPT, and Es (Young's modulus) have good correlation with depth, Among the three types of Tabriz marls, yellow and gray/black marls have the lowest and the highest strengths, respectively.

The present study represent the first one that deal with assessment of the geotechnical properties through Koya city by selecting 33 testing station. The testing results from this study will represent a data base for the shallow geotechnical properties of Koya soil and this may be a guide to the designer through the primary projects planning stage.

## 2. Study Area and Geological Setting

Koya (Koysinjaq) districts (Figure 1) is located within Erbil Governorate in northeast. Koysinjaq (Koya) geographically is a mountainous area with different uphill at the north, while at the south and southwest, fertility plain extends to the border of Erbil with Kirkuk city, which represents the historical alluvial plain of the Tigris River. The intensive farming of wheat and barley are distributed at the plain of Erbil south of Koysinjaq (Koya) districts. Accordingly, the average depth of the soil increases from the north to the south to reach up to 1.3 meters [8].

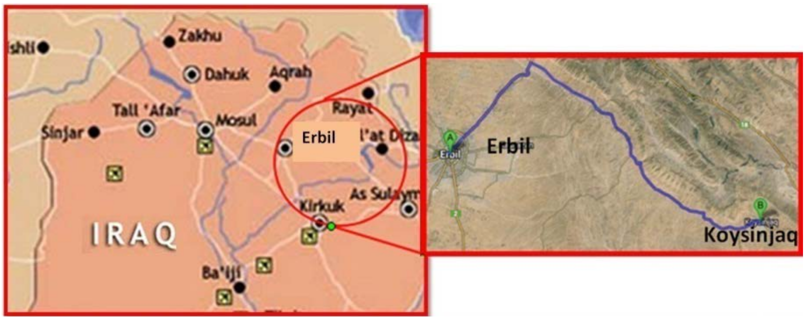


**Figure 1.** Location of Koysinjaq area according to the Erbil city at Kurdistan region of Iraq, (source: flickr.com and Googol map)

According to the tectonic classification of Iraq by Buday and Jasim [10] the study area belongs to High Folded Zone and Foot Hill Zone of Chamchamal-Butma Sub zone. This zone occupies the central part of the unstable shelf area and it's characterized by thick sedimentary cover, narrow anticlines and broad flat Synclines, [9]. Stratigraphically the exposed formations in the study area from older to younger are: ***Kolosh Formation:*** The age of this Formation is of Paleocene – Lower Eocene [11] this Formation represents the NE part of Haibat Sultan Mountain it consists of Green, dark grey shale and thin lenses of sandstone, the overlying Formation is Gercus. ***Gercus Formation:*** The age of this Formation is of middle Eocene [11] it represent the NE side of Haibat Sultan Mountain. This Formation consists of alternation of red claystone, siltstone and sandstone tongue of limestone exist. ***Pilaspi Formation:*** This formation is of Middle–Upper Eocene [10,11]. It forms continuous steep ridges at the crest and southwestern sides of Haibat Sultan Mountain. The formation in the study area is consists mainly of light gray and yellowish white color, well bedded fissured limestone and marly limestone. ***Fatha Formation:*** This formation is of Middle Miocene age [11]. It forms a continuous belt at the southwestern side of Haibat Sultan Mountain. The formation consists of cyclic deposits of mudstone and thin layers of limestone and gypsum, mudstone is reddish brown in color, soft and represents the main constituent of the formation. Limestone is light grey and brown in color, well bedded and hard, some limestones are fossiliferous with chertnodules, also gradual changes of marl and marly limestone occur at the middle part of the formation characterized by contain high fissures and joints and considered as a good aquifer, the thickness of the aquifer is 188m. ***Injana Formation:*** This formation is of upper Miocene age [11]. This formation consists of fine grained molasse sediments, which include sandstone, red or grey colored siltstone and claystone.

## 3. Methodology

In order to study the geotechnical properties of Koya city soil, 33 testing stations were randomly chosen within the city as shown in Figure 2, each station include 3-5 sampling points. Table 1 shows the geological formation for each station, the predicted samples were from "Fatha Formation and Injana Formation". The samples "disturbed and undisturbed samples" were predicted from (1.5-2.5) m depth below the ground level. The tests included evaluation of the soil classification, index properties "liquid limit, plastic limit and plasticity index", specific gravity, grain size analysis, compaction properties in term of dry unit weight and optimum moisture content, and permeability. Furthermore the soil activity also predicted based on the results of index properties and grain size analysis.

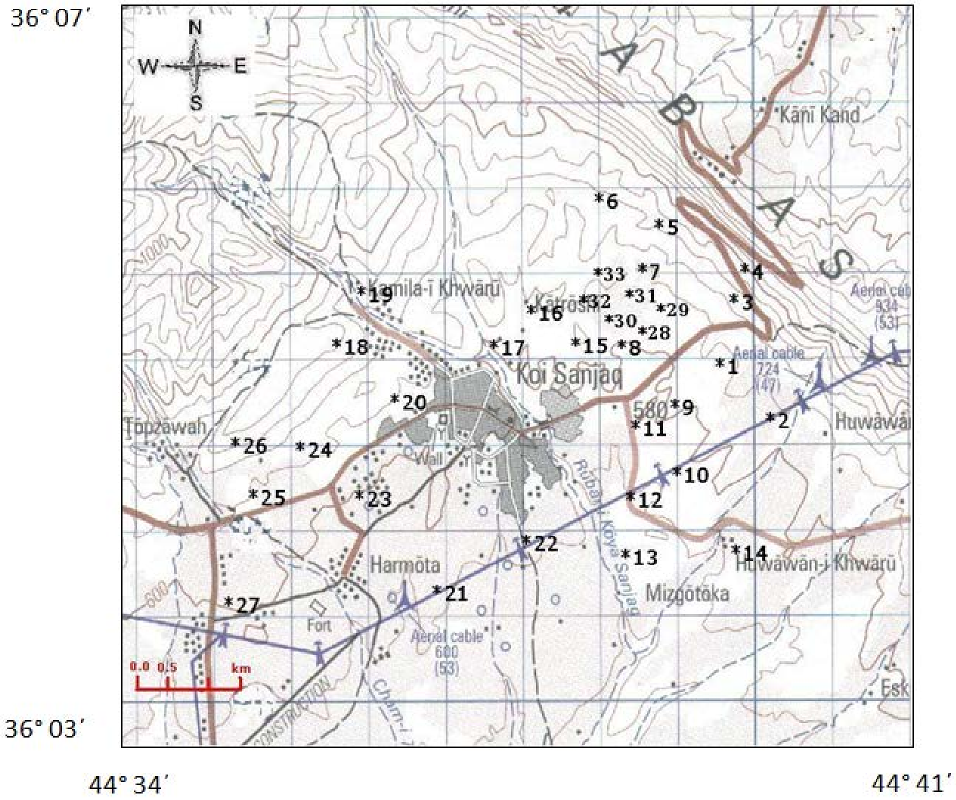


**Figure 2.** Location map of Koya city, which indicates the testing stations (Basir, 2013).

**Table 1. Station geological formation.**

| Station No. | Geological formation | Station No. | Geological formation |
|---|---|---|---|
| 1 | Fatha | 18 | Injana |
| 2 | Fatha | 19 | Injana |
| 3 | Fatha | 20 | Injana |
| 4 | Fatha | 21 | Injana |
| 5 | Fatha | 22 | Injana |
| 6 | Fatha | 23 | Injana |
| 7 | Fatha | 24 | Injana |
| 8 | Fatha | 25 | Injana |
| 9 | Fatha | 26 | Injana |
| 10 | Injana | 27 | Injana |
| 11 | Injana | 28 | Fatha |
| 12 | Injana | 29 | Fatha |
| 13 | Injana | 30 | Fatha |
| 14 | Injana | 31 | Fatha |
| 15 | Injana | 32 | Fatha |
| 16 | Injana | 33 | Fatha |
| 17 | Injana | | |

# 4. Results and Discussion

Laboratory tests were performed on selected samples from each station. In order to determine the physical properties of soil samples at the study area some laboratory tests were carried out in accordance with the British Standard (BS) and American Society for Testing and Materials (ASTM).

The carried laboratory tests included consistency &Atterberg Limits (ASTM D-4318), Water Content (ASTM D-2488), clay activity, grain size analysis (ASTM D-422), specific gravity, (ASTM D-854), and maximum dry unit weight and optimum moisture content (ASTM D-698). Furthermore, the permeability of the tested stations were predicated in accordance with (ASTM-2434) for coarse grain soil while for the fine grain soil the permeability determined in accordance with falling head test.

## 4.1. Grain Size Analysis and Hydrometer Analysis

Soils consist of a mixture of particles of different size, shape and mineralogy. Because of the size of the particles obviously has a significant effect on the soil behavior, the grain size and grain size distribution are used to classify soils. The grain size distribution describes the relative proportions of particles of various sizes. Tests were performed in general accordance with ASTM Test Method D 422.

Hydrometer analysis were performed to determine the grain size distribution of fine –grained soils having particle sizes smaller than 0.075 mm and when percentage of finer is greater than 12% with weight approximately equal to 50 gm. Results of grain size and hydrometer analysis of 33 sample stations indicate that there is high variety in the percentages of gravel, sand and fines “silt and clay”.

Figure 3 shows the distribution of gravel sand and fines “silt and clay” in percent within stations, the results show that maximum gravel percent is 58.16% at station 9, while the minimum gravel percent recorded is 20% at station 32. Furthermore the sand percentage ranged from 83% at station 25 to 7% at station 30. Percentage of fines that recorded through this investigation ranged from 87% at station 29 to 0.4% at stations 3 and 4. The losses in fines from some station and increase of then in anther stations depend on erosion of the fine and transmission of them with moved water.

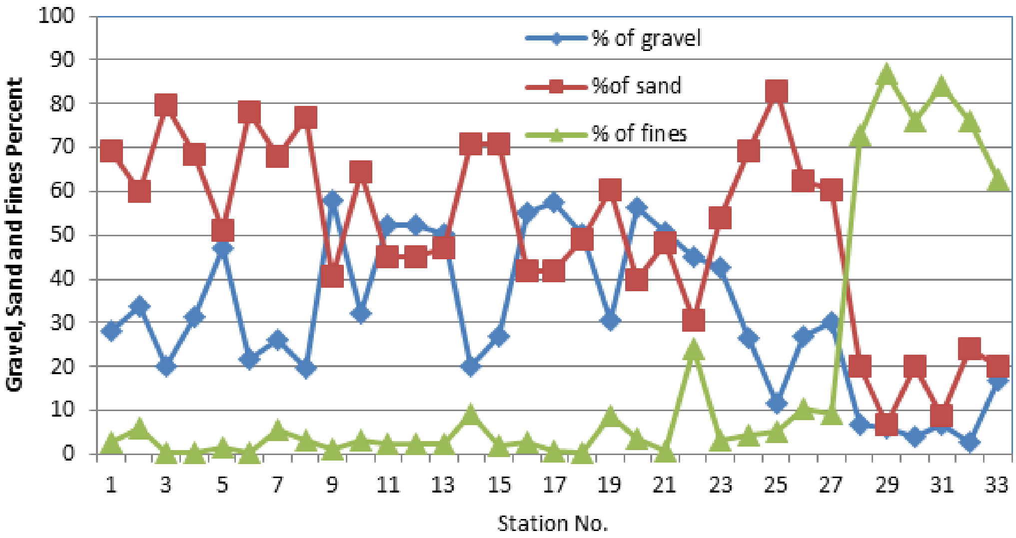


**Figure 3.** Percent of gravel sand and fines at each tested station within Koya city.

## 4.2. Atterberg Limits and Soil Classification

Atterberg Limits tests were performed to classify soils and in order to predict some notification about the soil behavior like assessment of swelling potential based on the liquid limit. Tests were performed in general accordance with ASTM Test Method D 4318. Figure 4 show the variation of liquid limit “L.L” plastic limit “P.L.” and the corresponding plasticity index “P.I”. The results show most of fine recognized as low plastic materials. The liquid limit range is (8.2 %– 50.6%) while the plastic limit range is (5.9% - 30%). The plasticity index varies from 4.8 minimum to 23.1% maximum.

The results obtained from grain size analysis and Atterberg limits were used in soil classification of the testes soil sample using the unified soil classification system “USCS”. There are nine groups of soil were recognized that are well graded sand “WS”, Well graded gravel “WG”, poorly graded sand “PS”, poorly graded gravel “PG”, well graded sandy clay “WS-SC”, well graded sandy silt WS-SM” and well graded gravely silt “WG-GM” for coarse grain soils, while low plasticity clay “CL” and low plasticity silty clay “CL-ML” as shown in Table 2.

**Table 2. Unified soil classification system results for tested stations within Koya city**

| Station No. | Soil Classification | Station No. | Soil Classification |
|---|---|---|---|
| 1 | WS | 18 | PG |
| 2 | WS | 19 | WS |
| 3 | WS | 20 | WG |
| 4 | WS | 21 | WG |
| 5 | WS | 22 | WG-GM |
| 6 | PS | 23 | PS |
| 7 | WS-SC | 24 | WS |
| 8 | PS | 25 | WS-SC |
| 9 | WG | 26 | WS-SC |
| 10 | WS | 27 | WS-SM |
| 11 | WG | 28 | CL-ML |
| 12 | PG | 29 | CL-ML |
| 13 | PG | 30 | CL-ML |
| 14 | WS-SC | 31 | CL |
| 15 | WS | 32 | CL |
| 16 | PG | 33 | CL |
| 17 | WG | | |

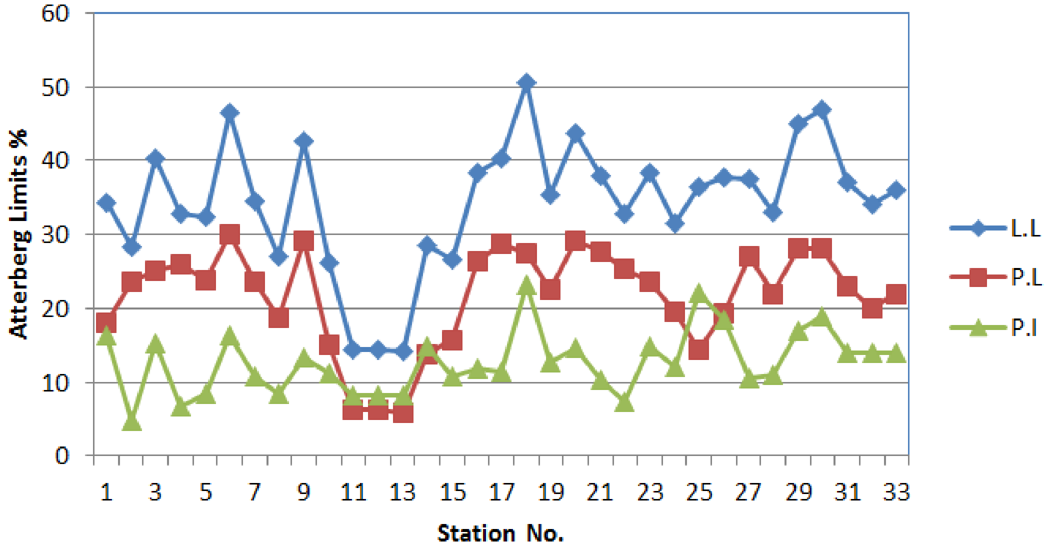


**Figure 4.** Variation of Liquid limit, Plastic limit and plasticity index at different station within Koya city

### 4.3. Specific Gravity

The specific gravity of soil, Gs, is defined as the ratio of the mass in air of a given volume of soil particles to the mass in air of an equal volume of gas free distilled water at a stated temperature (typically 68° F {20° C}). Specific gravity was evaluated in general accordance with ASTM Test Method D 854. The specific gravity of soils is needed to relate a weight of soil to its volume, and it is used in the computations of other laboratory tests.

Form analysis of the results of present study, the average values of specific gravity of soil, Gs in different locations of Koya city with different depths are presented in Figure 5. The results indicate that the range of specific gravities from a minimum of 2.3 to a maximum of 2.86. The wide variation between values of specific gravity because of the nature of the soil formation in the area is almost not similar and has not the same formative resources.

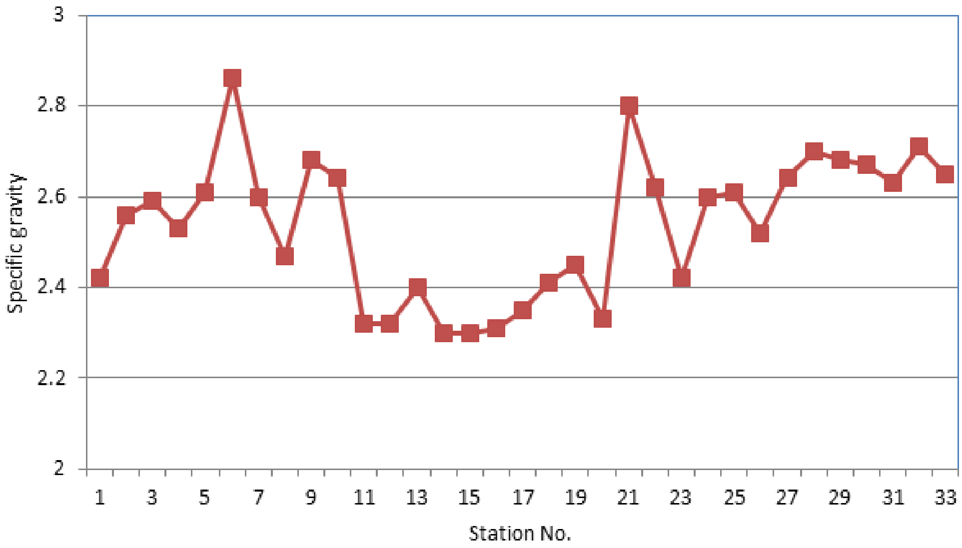


**Figure 5.** Specific gravity test results at different stations within Koya city

### 4.4. Soil Activity

Bowles, 1984, defined soil activity as a relation between plasticity index to percent finer clay content, which can expressed as a: Soil Activity = PI/finer less than 0.002 mm. In the present study, according to the results of Atterberg limits and grain size analysis for stations (28-33), The average ratio of plasticity index to clay content (soil activity) is (0.19). The average values of soil activity in different location at Koya city shown in Figure 6 the results indicate that the clayey soils recognized within the tested area have poor clay activity according to ASTM specifications, so these soils have low swelling tendency.

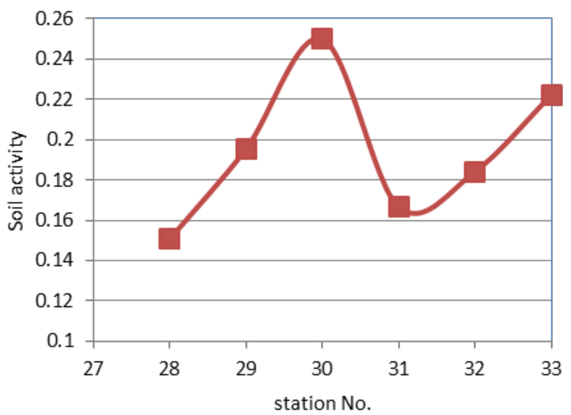


**Figure 6**. Soil activity for clayey and silty- clay “Stations 27-33” within Koya city

### 4.5. Optimum moisture content and Max. Dry density

Optimum moisture content and maximum dry unit weight tests were performed to evaluate moisture conditioning requirements during site preparation and earthwork grading, soil overburden, active and passive earth pressures, relative soil strength and compressibility. Optimum moisture content and maximums dry unit weight were evaluated in general with accordance to ASTM D 698 - standard test methods for laboratory compaction characteristics of soil using standard effort.

The results of present study for stations (1-27) of noncohesive soils showed that the average values of optimum moisture content in different location of Koya city is 12.4% while the average maximum dry density is approximately 2.0 g/cm$^3$. The results indicates that the range of optimum moisture content from a minimum of 10.3% to a maximum of 13.5% and the range of maximum dry density from 1.78 g/cm$^3$ to 2.18 g/cm$^3$ as a show in Figure 7 and Figure 8.

### 4.6 Permeability

Laboratory falling head and constant head permeability tests was carried out for cohesive and noncohesive soil samples and the test was performed in general accordance with ASTM Test Method D 2434. The results indicates that coefficient of permeability was varied from (0.0012-0.05) cm/sec as shown in Figure 9. The wide variety in the permeability of soil is according to the wide variety in soil type and formation within the studied area. Results indicate that the permeability of soil is ranged from poor to high in different areas in Koya city, high to medium degree of permeability for non-cohesive soil that directly affected by the percent of sand and fines and low permeability for cohesive soil.

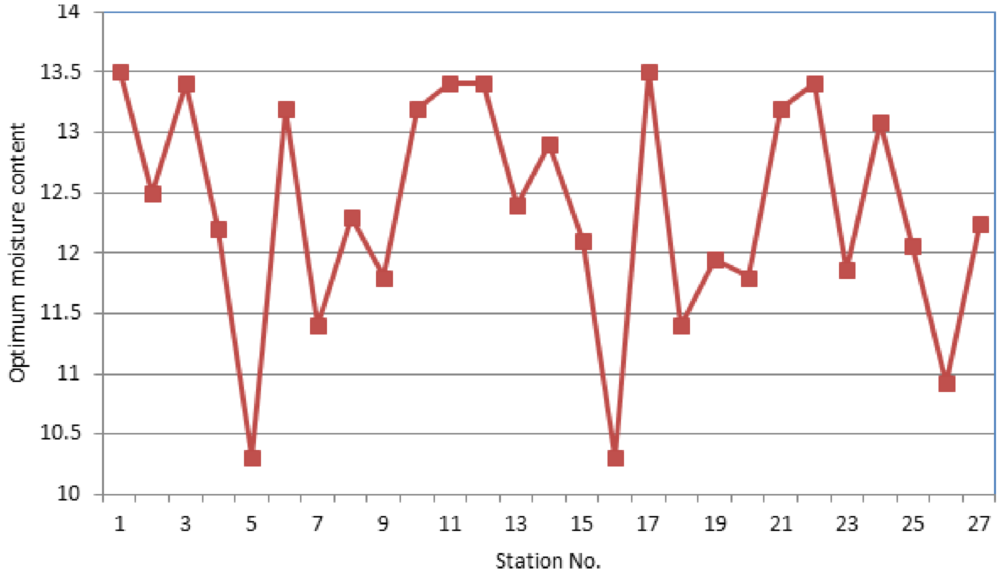


**Figure 7**. Optimum moisture content at different stations within Koya city

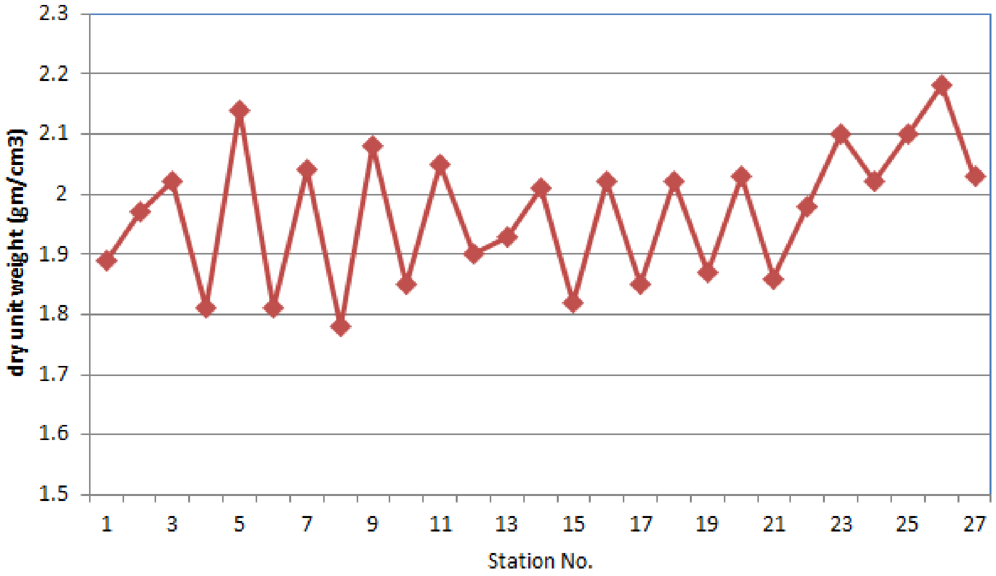


**Figure 8**. Optimum moisture content at different stations within Koya city

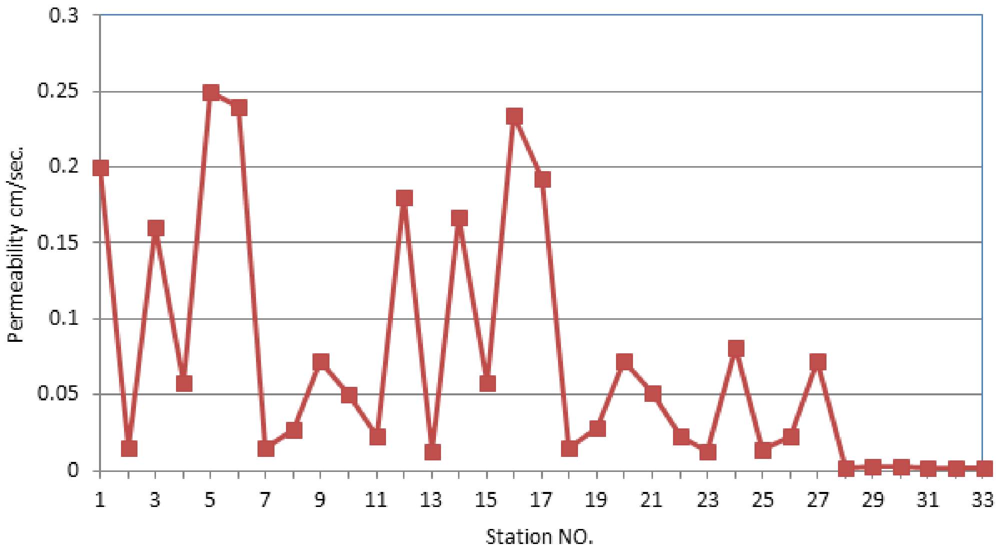


**Figure 9**. Coefficient of permeability for each station within Koya city

# 5. Conclusion

Based on the results obtained through this assessment the following can be concluded:

1. Grain size analysis and hydrometer analysis showed that there is high variety in the percentage of gravel, sand and fines from station to another, the losses in fines from some station and increase of then in anther stations depend on erosion of the fine and transmission of them with moved water.
2. There are nine groups of soil were recognized according to the unified soil classification system.
3. The results indicated that the range of specific gravities was from a minimum of 2.3 to a maximum of 2.86.
4. The results indicated that the clayey soils recognized within the tested area have poor clay activity so these soils have low swelling tendency.
5. The compaction tests for noncohesive soils showed that the average values of optimum moisture content in different location of Koya city is 12.4% while the average maximum dry density is approximately 2.0 g/cm$^3$.
6. The results showed that there is wide variety in the permeability of soils according to the wide variety in soils types and formations within the studied area.

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