JIMMA UNIVERSITY

GRADUATE STUDES

INSTITUTE OF TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING

ENGINEERING PROPERTIES OF KOBO TOWN SOIL, NORTHERN-ETHIOPIA ESPECIALLY ON EXPANSIVE SOIL

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APPROVED BY BOARD OF EXAMINERS;

INTERNAL EXAMINER ________________ ______________

Signature date

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LIST OF SYMBOLS

L/sec………………liter per second

AWDSW………… amhara water works and supervision works

AASHTO…………American Association of state high way and transport officials

a.m.s.l.………….....average mean sea level

MCM…………….. Million cubic meters

USCS…………….. Unified soil classification method

PL…………………plastic limit

PI…………………. plastic index

LL………………….liquid limit

KPA………………. kilo Pascal

ABSTRACT

The Raya Kobo town is characterized by kola climate, low rain fall distribution and the area have high amount of ground water found at average depth of 60 meters and discharge 50 l/sec. average seasonal ground water level fluctuation at kobo town is 5 to 23 meters.

In the town kobo expansive soil locally called (Walka). This soil damaged many structures such as building, roads, irrigation canals and other civil engineering structures built over the soil.

This study is done with the intention of examining the index properties of expansive soils of kobo, swelling pressure and strength properties based on secondary data taken from **(AWDSW).** This secondary data can indicate problem of soils and provide helpful to estimate of the expected swelling of expansive soils(walka) of kobo town are generally black in color and have high swelling potential.

From the secondary data shown free swell and swelling pressure of kobo town expansive soils indicate that the soil can cause significant damage to light structures unless proper design and construction measures are taken those expansive soils have very high shear strength in the dry season and low in the wet season. Therefore expansive soils of kobo town soil can cause severe damage to civil engineering structures built in the area; otherwise proper counter measures are taken.

CHAPTER ONE

INTRODUCTION

1.1 GENERAL

“Soil mechanics” is that branch of science which studies the structure properties and the reaction or behavior of soil under loading and the changing weather conditions. The studies of engineering properties of soil are to furnish some general principles to supplement and guide the practical experience and free judgment and of the engineer. Soil is the naturally occurring loose or soft deposit forming part of the earth’s crust, produced as a result of weathering or disintegration or decomposition of rock formations, or decay of vegetation, intermingled together. Therefore it is good enough to know the engineering properties of soil that comes from different kinds of material by forming different kinds of process with many years.

Soil may change its behavior through time, with different factors such as weather and loading history. One of the types of soil changes its properties in different condition is expansive soil. Expansive soils are generally found in arid and semiarid regions. Those soils undergo volumetric changes up on wetting and drying and causing ground heave and settlement problems. The presence of montmorillonite clay in those soils imparts them high swell- shrink potentials (chan, 1988).

The amount of swell is a function of dead weight on the expansive clay. Heavy loads resist heave and up lift, while lighter loads cannot resist leading to differential. A common problem with lightly loaded structures on expansive soil is differential heave caused water pending.

Expansive soil is difficult used in construction purpose such as buildings, Highways, airfields and different construction types. Therefore expansive soil in Ethiopia exists in different region and it is better to study its properties for different regions.

1.2 objectives

1.2.1 General objective

- The main objective of this project is to determine the engineering properties of kobo town soil, northern Ethiopia especially on expansive soil.

1.2.2 Specific objective

- To know the kobo town soil is expansive or not,
- To enumerates the properties and behaviors of kobo town expansive soil,
- To know the adverse effect of kobo town expansive soil and
- To recommend type and method of construction.

1.3 organization of the thesis

The thesis is organized with five chapters. Chapter one is the introduction of expansive soil problems, objective and scope of the study, Chapter two is the origin and formation of clay minerals, properties and classification of expansive soil, Chapter three is the environmental and geological information of study area, Chapter four shows classification and type of kobo expansive soil using different classification methods and Chapter five is recommendation and conclusion.

Chapter two

Literature review

2.1 The origin of expansive soil

2.1.1 Parent material

The parent materials that give rise to expansive soil are classified into two. The first group comprises the basic igneous rocks, which are low in silica, generally about 45% to 25% and rich in metallic base such as pyroxenes, amphiboles, biotitic and olivine. Such rocks include the gabbros, basalts and volcanic glass. The second group includes sedimentary rock that contains montmorillonite as a constituent. These include shales and claystone, and limestone and marls rich in magnesium.

2.2 Weathering and climate

The weathering process by which clay is formed includes physical, biological and chemical process. The most important weathering process responsible for the formation of montmorillonite is the chemical weathering, which include hydrolysis, hydration, oxidation, carbonation and solution, of parent rock mineral which generally consists of ferromagnesium mineral, calcic feldspars, volcanic glass, volcanic rocks and volcanic ash. The formation is aided in alkaline environment, presence of magnesium ion and lack of leaching. Such condition is favorable in semi-arid regions with relatively low rain fall or seasonal moderate rainfall particularly where evaporation exceeds precipitation. Under these conditions enough water is available for the alteration process but the accumulated cations will not be removed by rainwater.

2.3 Identification and classification of expansive soils

The classification and identification of expansive soil using two methods that is by visual and laboratory investigation.

2.3.1 Visual identification

Soils that can exhibit high swelling potential can be identified by filed observation. Important observation includes (chen, 1988, nelson 1992).

- Usually have a color of black or gray
- Wide or deep shrinkage cracks
- High strength at dry condition and low strength at wet condition
- Cut surfaces have a shining appearance
- Appearance of cracks in nearby structures arid and semi arid areas faces problems due to large variations in rain fall and temperature

2.3.2 Laboratory identification

Methods to identify expansive soils in the laboratory can be categorized in to three methods

- Mineralogical identification
- Indirect method
- Direct method

2.4 Classification methods

The expansive soil classification have been conducted in different ways

- ✓ Classification using general method
  (Unified soil classification and AASHTO classification)
- ✓ Classification using soil index properties
  (Skemton(Mekeen,1976), kantay & Brink(Mekeen,1976) and Altmayer (Mekeen,1976)

- ✓ Classification using swelling potential

  Odometer testing (zero swell test, swell consolidation test and restrained swell test) and double odometer testing.

2.5 Mechanics of swelling

Soil volume change result from an imbalance in internal energy of the system (soil/ water/ plants/ air). Energy imbalances important in engineering result from moisture movement caused by loads, desiccation, and temperature changes. Response to a specific set of conditions is determined by the composition, structures, and geologic history of the soil. The

Largest component of volume change is that of the clay micelle which surrounds the individual clay particles in the soil. Water is forced out of the micelle by loads, desiccation, or temperature along energy gradient and reduction in volume results. When these influences are removed or reduced, the energy gradients are reversed, the available water is forced into the clay micelle and swell is produced. (Mckeen, 1976).

The natural micro scale mechanisms, which contribute the major portion of volume changes in expansive soils, are (Snethen, 1975)

Osmotic repulsion: it is a pressure gradient developed in the double-layer water due to variations in the ionic concentration in the double layer.

Clay particle attraction: as clay particles possess a net negative charge on their surfaces and edges which result in attractive forces for various cations and in particular for dipolar molecules such as water.

Cation hydration: it is physical hydration of cations substituted into or attached to the clay particles.

Capillary is a movement of water into a mass of clay particles resulting from surface tension effects of water and air mixtures in the pores of the clay mass.

The factors influencing the shrink swell potential of a soil can be considered in three different groups.

2.5.1 Soil characteristic that influence the basic nature of the internal force field. These includes

- ✓ Clay mineralogy
- ✓ Soil water chemistry
- ✓ Soil suction
- ✓ Plasticity
- ✓ Soil structures and fabrics
- ✓ Dry density

2.5.2The environment factor that influence the changes that may occur in the internal force system. These include.

- ✓ Initial moisture condition
- ✓ Moisture variation
- ✓ Climate
- ✓ Ground water
- ✓ Drainage and manmade water source
- ✓ Vegetation
- ✓ Permeability
- ✓ Temperature

2.5.3 State of stress, which include

- ✓ Stress history
- ✓ Surcharge load

CHAPTER THREE

DESCRIPTION OF THE STUDY AREA

3.1 Back ground

Kobo town is found in Amhara region Northern part of Ethiopia lies between 12˚09’ 67“ N, 39˚ 37’ 48” E and at average of elevation of 1509 meters above sea level .It is 930 km far from Jima town. The town shares the boundary from the North 15 km away Tigray region and from the East 50 km away Afar region. The climate condition of the town is kola and its average temperature is reaches 30˚c.

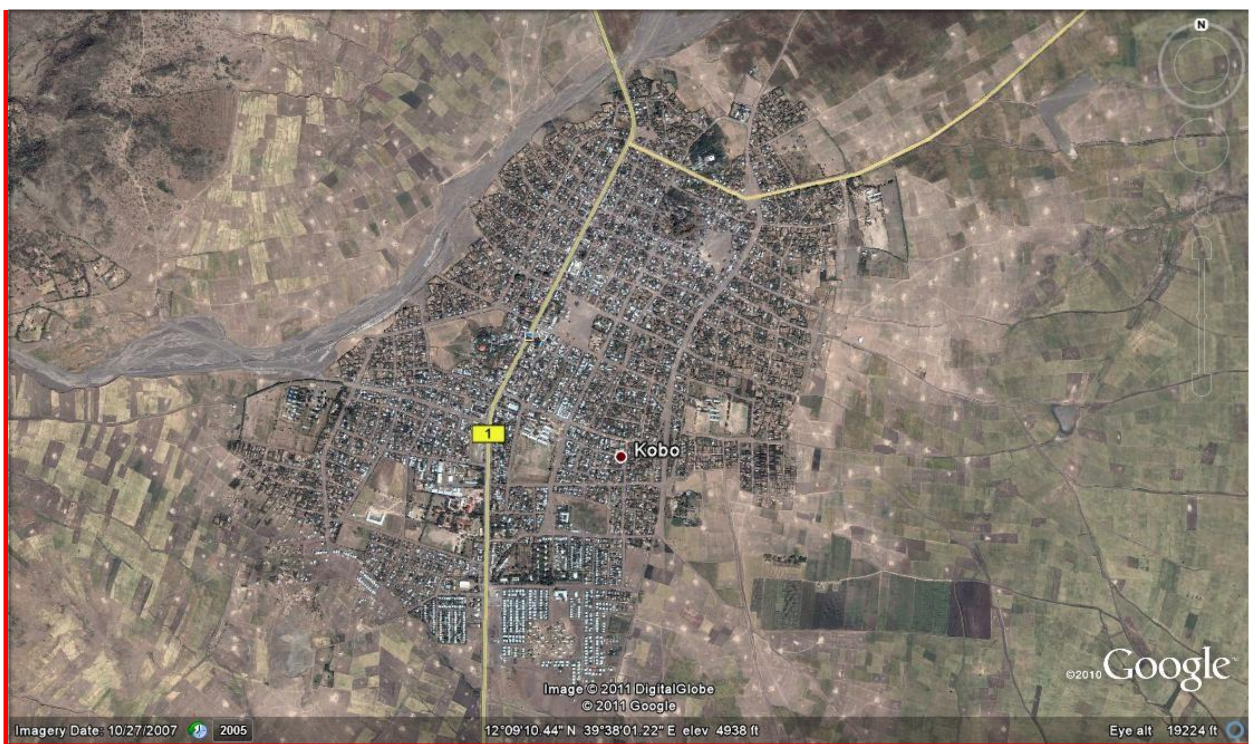

Figure 3.1 topography map of the town (source Google earth)

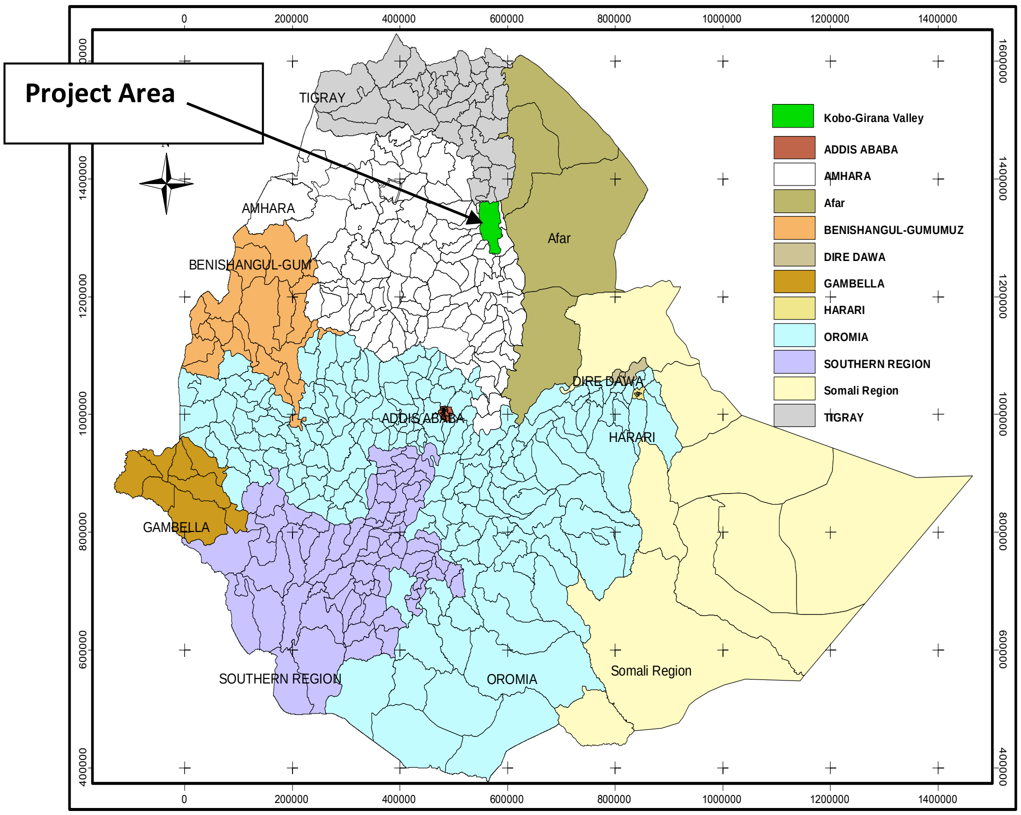

FIG. 3.1: LOCATION MAP OF THE PROJECT AREA

Figure 3.2 project area from the map of Ethiopia. Source Amahara water design and supervision works (AWDSW)

3.2 Climate

The town kobo with average of 1500meters a.m.s.l . As shown the table below a mean rain fall is 703.43 mm of the rain fall arrives in the months of July and august month.

Table 3.1 monthly rain fall of kobo town Source Amhara water design and supervision works (AWDSW)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1996	**47.37**	**0.00**	**51.04**	75.40	133.30	52.50	147.40	205.00	66.70	18.00	63.50	0.00	**860.22**
1997	0.00	0.00	42.50	57.60	47.80	51.50	110.60	94.40	37.40	169.20	49.30	0.00	**660.30**
1998	53.90	32.30	24.10	38.90	11.70	3.80	326.10	311.80	50.90	6.10	0.00	0.00	**859.60**
1999	20.30	0.00	33.50	48.20	11.70	2.20	226.30	315.90	0.00	0.00	0.00	0.00	**658.10**
2000	0.00	0.00	1.50	76.10	42.00	5.20	226.70	268.00	48.70	87.80	24.10	83.40	**863.50**
2001	0.00	0.00	70.60	13.00	**27.70**	**8.40**	**187.45**	**220.65**	**30.90**	**9.90**	**5.00**	**1.25**	**574.85**
2002	**80.55**	**0.00**	**19.90**	**88.05**	2.90	99.70	296.00	116.60	16.00	0.00	66.60	41.20	**827.50**
2003	41.20	32.70	34.80	32.80	11.00	129.30	247.50	41.80	0.00	0.00	42.80	29.90	**643.80**
2004	29.90	0.00	28.10	3.00	25.90	116.20	162.40	9.20	74.20	35.50	10.20	8.30	**502.90**
2005	8.30	0.00	34.00	125.60	2.80	125.20	190.90	23.20	8.70	64.80	0.00	0.00	**583.50**
Mean	**28.15**	**6.50**	**34.00**	**55.87**	**31.68**	**59.40**	**212.14**	**160.66**	**33.35**	**39.13**	**26.15**	**16.41**	**703.43**
St.Dev	**27.46**	**13.70**	**18.53**	**36.82**	**38.92**	**53.83**	**66.43**	**118.47**	**26.83**	**54.72**	**27.08**	**27.74**	**136.86**
Coef.Va	**0.98**	**2.11**	**0.55**	**0.66**	**1.23**	**0.91**	**0.31**	**0.74**	**0.80**	**1.40**	**1.04**	**1.69**	**0.19**
R. Coef.	**0.48**	**0.11**	**0.58**	**0.95**	**0.54**	**1.01**	**3.62**	**2.74**	**0.57**	**0.67**	**0.45**	**0.28**	

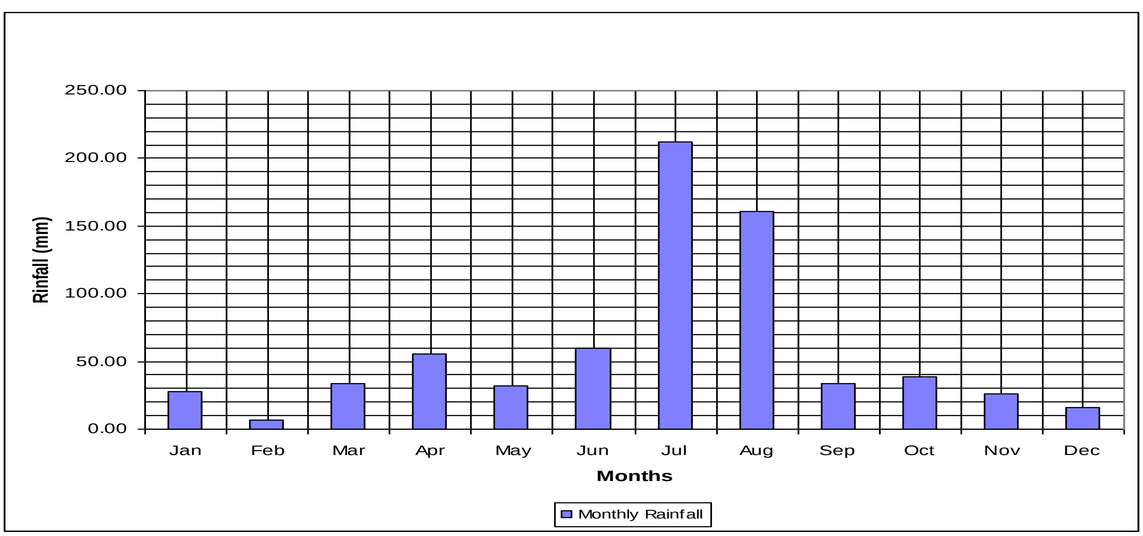

Figure 3.3 kobo mean monthly rain fall. Source Amhara water design and supervision works (AWDSW)

- Potential annual evaporation at show the table below at kobo is 277.65 mm Source- Amhara water design and supervision works (AWDSW)

Table 3.2 Kobo Sub-basin Potential Evapotranspiration Source- Amhara water design and supervision works (AWDSW)

Month	MaxTemp (deg.C)	MiniTemp (deg.C)	Humidity (%)	Wind Spd. (Km/d)	SunShine (Hours)	Solar Rad. (MJ/m2/d)	ETo (mm/d)
January	26.1	12.5	60.2	155.5	7.8	18.3	3.92
February	28.1	12.6	56.2	174.5	7.8	19.7	4.63
March	29.5	15.3	46.4	184.9	8.1	21.5	5.44
April	30.5	16.4	49.7	178.0	8.2	22.2	5.60
May	32.8	16.5	41.4	164.2	8.3	22.0	5.86
June	34.2	17.8	31.7	183.2	6.3	18.7	6.04
July	32.2	18.1	39.3	187.5	5.7	17.9	5.62
August	30.5	16.3	51.8	146.9	5.9	18.4	4.81
September	30.9	14.9	52.9	108.0	6.6	19.3	4.52
October	29.6	13.0	42.2	114.9	8.5	21.1	4.63
November	28.2	11.8	40.8	127.0	8.4	19.4	4.27
December	26.8	10.6	40.4	131.3	8.5	18.7	4.02
Average	**29.9**	**14.7**	**46.1**	**154.7**	**7.5**	**19.8**	**4.95**

3.3 Geology and ground water

The study area covers part of the Raya Valley which is generally believed to have a relatively high potential for groundwater resources.. The total project areas annual rechargeable groundwater potential is estimated to be 170 MCM (KGVDP, Hydrogeology Feasibility Report). Source **AWDSW**

The geology of the area is constituted predominantly by basalts and recent sediments. These are thick successions of strongly weathered basalts without clear stratification. The recent sediments are deposited in grabens formed in the escarpment zone as a result of extensive faulting and subsidence during the development of the rift system. They consist of lacustrine, alluvial and colluvial deposits. Source **AWDSW**

CHAPTER FOUR

The index tests

4.1 General

The laboratory investigation was conducted with AWDSW. And I am taken the results obtained from AWDSW and attached at the back.

4.2 soil chemistry

The chemical analysis of kobo expansive soils is conducted and all the samples have as shown in the table PH greater her than 7. As alkaline conditions generally favor for montomorillonte formation (Gillot J.E, 1968), the clay mineral. Therefore from soil chemistry the kobo town soil is expansive soil.

4.3 particle size distribution

Grain size provide a useful classification system for soil, by determing the distribution of particle sizes in a given soil specimen. For particle size distribution both ASSHTO an USCS define grain size ranges (Bowels, 1984).

Gravel > 2mm as ASSHTO and > 4.75mm as per USCS.

Sand 0.075- 2mm as ASSHTO and0.075- 4.75mm as per USCS.

Silt 0.002-0.075mm as per both ASSHTO and USCS.

Clay ˂0.00 2mm as per both ASSHTO and USCS.

The kobo town soil black clays have clay fraction ranges from 2-61%, silt fraction 2-76% and sand fraction 9-96%. All the soil as shown on the table is loam, silt and clay. Therefore that soil is highly expansive character.

4.4 Classification of expansive soil of kobo town

The parameters determined from expansive soil identification tests have been combined in a number of different classification schemes. But before using any soil classification system,

engineers should understand the data base from which it was derived and establish its limitations; otherwise, poor reliability and lack of confidence in the system may result. The different classification system is categorized into two:

1. General classification systems which have evolved over many years and are based largely on correlation with actual performance
2. Those devised specifically for classification of expansive soils. Theses system are based on indirect and direct prediction of swell potential, as well as combinations, to arrive at a rating

4.5 General classification system

The most widely used general classifications are

4.5.1Unified soil classification systems

In these classification system a correlation is made between swell potential and unified soil classification as follows

Category	symbol	soil classification in unified
Little or no expansion	1	GW, GP, GM, SW, SP, SM
Moderate expansion	2	GW, SC, ML, MH
High volume change	3	CL, OL, CH, OH
No rating		PT

The above classification system can be summarized as follow:

1. All clay soil and organic soils exhibit high volume change.
2. All clayey gravels and sands and all silts exhibit moderate volume changes.
3. All sands and gravels exhibit little or no expansion.

In the above classification soils rated as CL or OH may be considered as potentially expansive.

4.5.2 AASHTO classification

As shown the test results as obtained from secondary data the kobo town soil is expansive soil.

4.6 Swelling pressure tests

4.6.1 Swelling pressure

Swelling pressure is the pressure which prevents the specimen from swelling or that pressure which is required to return the specimen back to its original state. Swelling pressure values obtained from secondary data like others data. the resulting swelling pressure ranges from 37-348 kpa . Therefore the swelling pressure of kobo expansive soil is high result because of 48 kpa is the degree of expansion can be categorized as medium to high (Chen, 1988). So kobo town soil is highly expansive soil.

CHAPTER FIVE

Conclusions and recommendations

5.1 conclusions

- There are expansive soils in the town of kobo
- Kobo town is located in arid climate condition, at the time of rainy season there is a problem of expansive (heave) the soil.
- The swelling pressure of kobo expansive soil ranges from 37-348 kpa this is beyond the maximum dead load pressure that can be exerted by most lightly loaded structures.
- The adverse economic consequence of damages related to expansive soils in kobo town is substantial
- Thickness of kobo town expansive soils ranges from top surface to 6 meters. Therefore care should be made during design the buildings to minimize different settlement.

5.2 Recommendations

- ✓ Proper construction design should be taken to prevent or minimize the damage of that comes from expansive soil.
- ✓ Using selected material to fill the excavated expansive soil
- ✓ Design larger factor of safety for swelling pressure to extend the development of swelling pressure.
- ✓ Great attention should be made especially on moisture control measures.

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