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Study of Retaining wall with Reinforced Collapsible soil as backfill

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***Abstract:*--** **Collapsible soil is one of the problematic soils in geotechnical engineering. They exhibit sudden volume change and loss of strength when inundated. The present study results experimental investigations on passive earth pressure on walls retaining reinforced collapsible soil. The objective of the study is to examine the effect of soil collapse on passive earth pressure in dry and wet conditions. A laboratory model prepared for determining the decrease in passive earth pressure upon wetting induced collapse of the backfill. The collapsible soil is reinforced with geotextile for increasing the passive earth pressure coefficient. The results indicate that the inclusion of geotextile helps to reduce the collapse potential and thereby increase passive earth pressure. The spacing of geotextile is also taken as a parameter. From the results it was found that as the spacing of geotextile is directly proportional to the collapse potential and inversely proportional to the passive earth pressure coefficient.**

Index Terms:- Collapsible soil, Passive earth pressure, Retaining wall.

I. INTRODUCTION

Geotechnical engineers face a great challenge when the construction site contains collapsible soil. Collapsible soils are considered to be very strong in dry condition and lose its strength when inundated. Inundation may be due to running surface water and rising ground water. When collapsible soils are inundated, the soil undergoes loss of strength and volume reduction. This leads to variation in passive earth pressure of the soil on the retaining wall. The soil response to inundation could not be predicted beforehand. The passive earth pressure is the resisting force as per the structures design theories. When collapsible soil is used as a backfill for retaining wall it cause considerable reduction in passive earth pressure hence it is necessary to improve the passive earth pressure by improving the collapsible soil by using some conventional methods.

This paper presents experimental method for determining the decrease in passive earth pressure upon wetting induced collapse of the backfill. For improving the passive earth pressure the collapsible soil is reinforced with geotextile. From the results it was concluded that by the inclusion of geotextile, the collapse potential of the soil reduced and passive earth pressure coefficient i.e. the resisting force increased. Bell (1997) reported that the majority of naturally occurring collapsible soils are aeolian deposits. Aeolian deposits such as loess, dunes and other windblown deposits are encountered in different parts of the world. In the literature, most of research works were about with earth pressures theories for normally consolidated or over consolidated soils. Most of theories consider the angle of shearing resistance of the soil as the only parameter governing the values of the earth pressure (Terzaghi 1920; Jaky 1944). Hanna et al., (2017), investigated the at rest earth pressure acting on collapsible soil subjected to full inundation. An empirical formula is presented to predict the coefficient of at-rest earth pressure for collapsible soils at full inundation. In the present paper an experimental investigation was carried out to study the effect of geotextile inclusion in collapsible reinforcement and its effects on passive earth pressure coefficient.

2. MATERIALS USED

The soil used in the investigation is a laboratory prepared collapsible soils formed by mixing the clay mineral (kaoline) with sand at different percentages. Generally higher the clay content higher the collapse potential(Cp).Miller et al., (1998), reported that maximum collapse occurs at 18% clay content.In the present study the sand was mixed with 6%, 8%, and 10% of kaoline clay with 5%water content and compact with a constant compaction energy to attain a collapse potential of 4.2 %(soil 1), 9% (soil 2), 12.5% (soil 3) respectively.

2.1 Soil Mixture preparation

Three different mixtures of collapsible soil were prepared and used in the experiments, in order to reach different levels of collapse potential. The mixtures consisted of sand and Kaoline clay with different content values (6%, 8% and 10%) and water content of 5%.The basic properties of laboratory prepared collapsible soil also as shown in table 1.

Table1. Index properties of collapsible soil

Properties	Mix 1	Mix 2	Mix3
Specific gravity	2.68	2.67	2.67
Maximum dry density	1.8 g/cc	1.83g/cc	1.94g/cc
Optimum moisture content	12.4%	12.2%	11.4%
Soil classification	SP-SC	SP-SC	SP-SC
Cohesion	9	13	16
Angle of internal friction	40^0	38^0	34^0
Collapse potential	4.2	9	12.5

The odometer test as per the ASTM D 5333-03 carried out to determine the collapse potential of the soil sample. Table 2 shows the collapse potential values from odometer test and severity of the foundation problem suggested by (Jennings, 1975).

Table 2. –Collapse potential and severity problem for the soil

Soil mixture	Clay content	Collapse potential	Severity of foundation problem
Mix 1	6%	4.2	Moderate trouble
Mix 2	8%	9	Trouble
Mix 3	10%	12.5	Severe Trouble

Collapsible soil was placed in layers and the mixed sample was placed in the tank in four layers and compacted, keeping the same compaction energy for each layer. The unit weight of the mixture in the tank was measured by means of density cans, which were placed in a staggered scheme in the vertical direction to avoid boundary effects. At the end of each test, these cans were carefully taken out and weighed. The unit weight of the mixture was taken as the average unit weight in these cans.

2.2 Reinforcement details

The geotextile used in the present investigation is non woven needle punched type. For the study two spacing were selected. Collapsible soil filled in the tank in layers, for the first set geotextile with 150mm spacing adopted. Each layer is compacted as per the calculated compaction energy. The test repeated for all the three mixes. Then the next spacing 100mm is selected and the process repeated. The horizontal load and the corresponding displacement were noted.

3. EXPERIMENTAL PROGRAM

The experimental set up consisting of testing tank, retaining wall and water distribution system. The inner dimensions of tank were 1000mmx200mmx500mm length width and depth respectively. One of the longitudinal sides of the tank was made of Plexiglas sheets which were transparent to observe the movement of the soil behind the wall accordingly, the failure mechanism. The lateral sides of the tank were aluminum alloy channels. The tank was laterally braced using steel angles to prevent the deflection of the tank during loading. The bracing system job was to support the loading system in order to ensure the horizontal direction of the loading system Fig. 2.

To simulate the rise of the ground water level, 10 thin- tubes were connected to the bottom of the tank. The tubes were receiving water from an elevated water tank and remained connected and open throughout the testing procedures.

For simulating Retaining wall a metal plate was placed on the upper part of the tank. The dimensions of the plate were 200mm x 215mm x 20 mm width, depth and thickness, respectively. The retaining wall was allowed to move horizontally, but no rotation was permitted. In order to simulate the plane strain condition in the sand mass, the width of the plate was kept the same as the width of the testing tank.

The plate was held using a stopper in the tank and lateral load is applies to the retaining wall using pneumatic setup. Compressed air for working of the pneumatic set up was supplied by the air compressor. The high pressured compressed air coming out of the air compressor was regulated and making a constant pressure using pressure regulator. And then its flow was regulated using flow control valve. And this regulated compressed air was passed to pneumatic air cylinder. The rod coming out of the cylinder is used to load the retaining wall. In lateral loading test, the load was applied at the side of wall in middle position. The applied load was measured using proving ring of 2.5kN capacity which was fixed at the end of rod of the air cylinder. During test, the displacement of the retaining wall was measured using dial gauge of 25mm capacity which was placed in the side of the tank. The schematic arrangement is as shown in Fig.1.

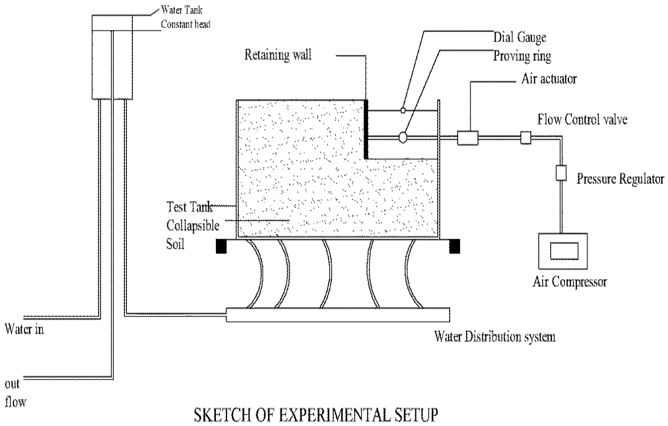

Fig.1. Schematic diagram of the test set up

In the present investigation collapsible soil was used as backfill material for the retaining wall. The collapse of the soil was achieved by inundation at the bottom of the testing tank. A water distribution system was built to simulate this condition. An elevated tank is connected to the testing tank by a plastic tube, which was branched into 10tubes, through which the water was charged to the bottom of the test tank, simulating the rise of groundwater table. The water level in the water tank was kept constant during the inundation process, water was charged from a water source and an overflow pipe was fixed inside the water tank that kept the water at a constant level. During the time that the water was allowed to flow in the water tank, this connection valve was kept closed. After the level of water started to have a constant flow, the valve was opened so that the water can pass through 10 thin tubes at the bottom of the testing tank inundating the soil.

During the inundation process the transparent thin tubes were monitored to prevent the entry of air bubbles in the system. When the test was finished and after the soil had been taken out of the tank, the tubes were cleaned with water to prevent any clogging in the system. For the inundated samples, a layer of slightly crushed stone was placed at the bottom of the testing tank to ensure an even distribution of the water throughout the test.

Fig.2.Pneumatic set up for lateral loading

4. EXPERIMENTAL RESULTS AND DISCUSSIONS

4.1 Collapsible soil with initial 5% water content

Collapsible soil with 5% initial water content three tests were conducted for mixes with clay content 6%, 8% and 10%.Load displacement curve of the three mixes were plotted. In the case of passive earth pressure on retaining wall with horizontal cohesive backfill Rankine presents the passive force per unit length of the wall as:

$$P_p = \frac{1}{2} K_p \gamma h^2 + 2C\sqrt{K_p} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,

P_P= Passive earth pressure

γ= Unit weight of soil

C= Cohesion

K_p= Coefficient of passive earth pressure

In the present investigation the horizontal force of the earth pressure is measured by the proving ring. The coefficient of passive earth pressure which can be calculated. The load displacement relation ship of three mixes in dry condition in Fig.3.

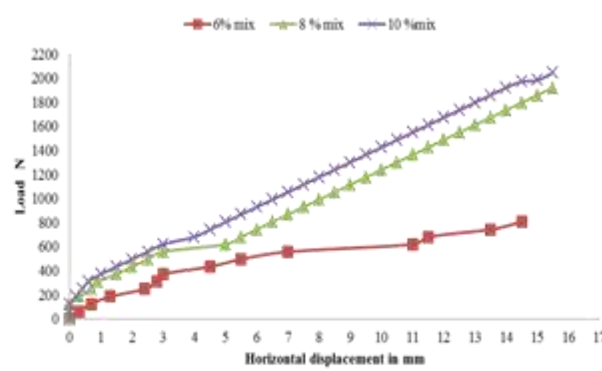

Fig.3. Load displacement curve of three mixes with 5% initial water content

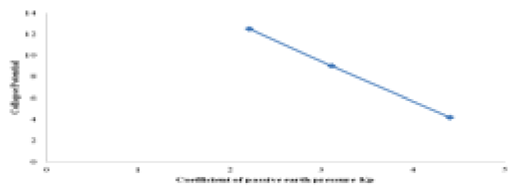

Fig.4. Variation of coefficient of passive earth pressure with Collapse potential. From Fig.4.it was observed the coefficient of passive earth pressure decreased with almost 38% from the 4.2% to 9% collapse potential. The decrease from 9% to 12.5% collapse potential is in the range of 40%.

4.2 Collapsible soil with 100% water content

The collapsible soil is known to have a loss of strength when inundated. The second set of tests performed in this investigation was performed on the soil mixtures with 6, 8 and 10% clay content but under the condition that the ground water level kept being risen until the soil became fully saturated. The increase of the moisture caused the clay bonds to weaken reducing the original soil strength. During the testing, the force applied on the retaining wall was measured as well as its horizontal displacement. Fig.5. represents the load displacement curve of the three mixes.

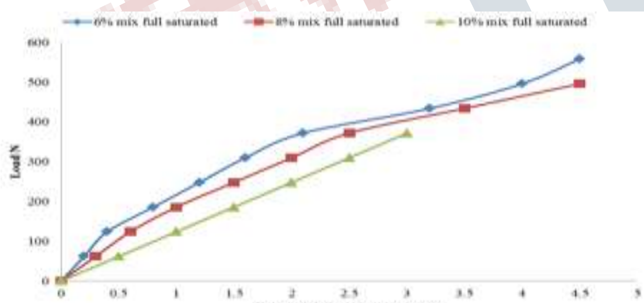

Fig.5. Load displacement curve of three mixes with 100% initial water content.

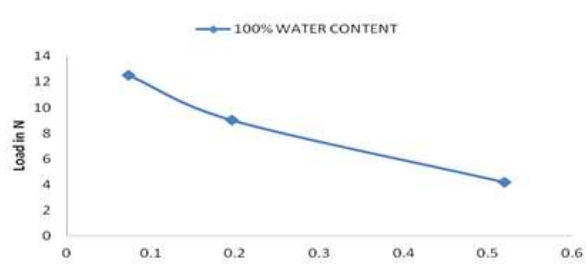

Fig.6. Variation of coefficient of passive earth pressure with Collapse potential

4.3 Effect of geotextile on soil collapse

For improving the collapse potential the backfill soil is reinforced with non woven geotextile.For that collapsible soil filled in the tank in such a way that after placing each soil layer the non woven geotextile fabric is included. Two series of tests were conducted by changing the spacing of geotextile. Two spacing selected here was 150mm and 100mm. Horizontal load applied and the corresponding deflection was noted. From results it was found that after placing geotextile the load carrying capacity of the collapsible soil was increased and collapse settlement reduced. The increase in strength is due to the reduction in permeability of the soil towards the top with the inclusion of geotextile. From the findings it was found that inclusion of geotextile improved the load carrying capacity of the soil. The increase in load carrying capacity is due to the reduction in soil collapse potential.

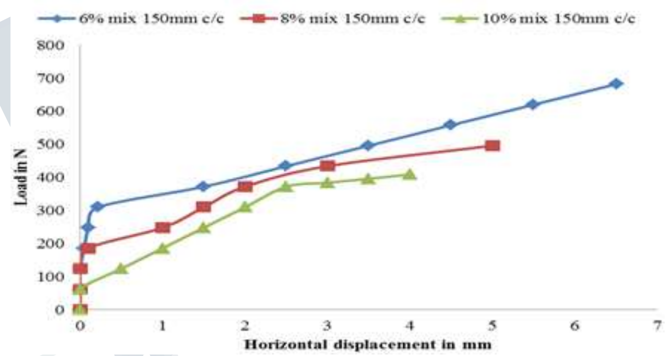

Fig.7. Load displacement curve of three mixes with 100% water content& 150mm c/c geotextile

Reduction in collapse potential occurs due to the the non woven geotextile act as barrier and it prevents the water to enter the upper layers; water slowly reaches in that layers. This helps to remain the soil strong in that region and hence less collapse of the soil occurs.

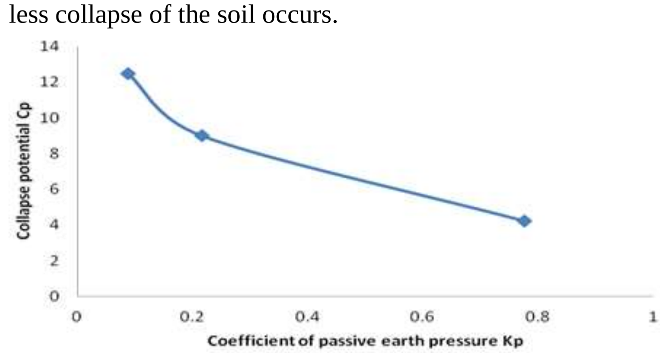

Fig.8. Variation of coefficient of passive earth pressure with Collapse potential

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From the graph it was found that for mixes the coefficient of passive earth pressure inceased about 50% with the inclusion of geotextile.

4.4 Effect of geotextile Spacing on soil collapse

The spacing of geotextile reduced to 100mm and the corresponding load test were conducted.The test results of soil mix with clay content of 6% presented in Fig.9.

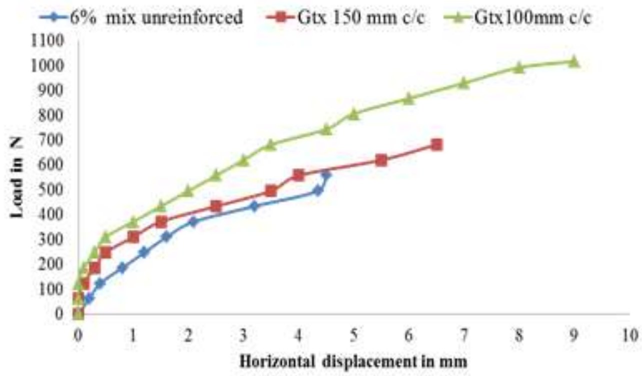

Fig.9. Load displacement curve of showing effect of Geotextile spacing

From the findings it was understood that as the spacing decreases, the more increase in passive earth pressure coefficient due to decrease in collapse potential.

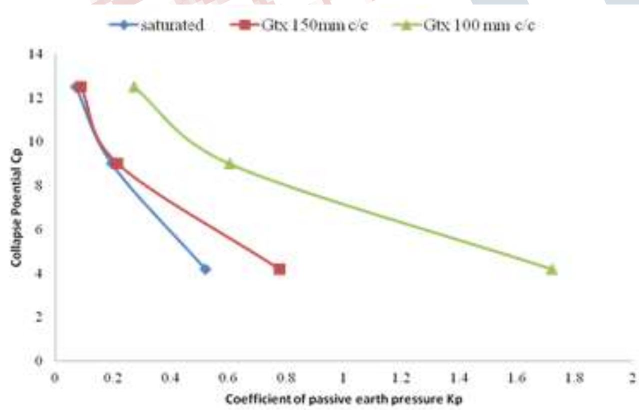

Fig.10. Variation of coefficient of passive earth pressure with Collapse potential

5. CONCLUSIONS

Increasing the clay content of the dry soil mixes increased the strength of the soil. After full saturation the collapse potential increased with increase in clay content. In case of dry soils, the coefficient of passive earth pressure decreased with the increase in clay content. But the decrease was small comparing the saturated case. After collapse, the coefficient of passive earth pressure decreased with the increase of collapse potential of the soil. With the inclusion of geotextile the coefficient of passive earth pressure coefficient increases significantly with decrease in collapse potential. As the spacing of the geotextile decreased more the increase in passive earth pressure coefficient. From the findings it was concluded that reinforcing the collapsible soil using geotextile is an economic alternative to increase the passive earth pressure coefficient.

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