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DEVELOPMENT IN SOIL ENGINEERING: AN ART OF REVIEW WITH DETERMINATION OF CONSOLIDATION PROPERTIES AND SHEAR PARAMETER OF DISTURBED SOIL: A CASE STUDY OF DABHI VILLAGE, MEHSANA, GUJARAT

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Abstract: *Determination of coefficient of consolidation and Direct shear tests have been performed on unsaturated disturbed and undisturbed specimens of a compacted area. Consolidation test has been performed as per IS:2720-15 (1965). A conventional direct shear apparatus was modified in order to use the axis-translation technique for direct shear tests on unsaturated soils. The testing procedure and some typical results are presented. Possibilities of potential use of soil for the construction of residential buildings, complexes have been identified for the development of area. An art of review of the improvement and development in soil engineering has been presented in simple and broad manner. Suggestions are made as to how best to handle the soil from a practical engineering standpoint. The coefficient of consolidation, shear parameters and some soil properties have been computed to better understand the soil. The probable mode of failure of soil has been determined.*

Key Words: *Consolidation, Shear strength, Soil, Soil Engineering, Standard Penetration Test.*

I. INTRODUCTION

Soil engineering is a broader term which deals with the stady of study and behaviour of soils, its types, properties, characteristics etc. Technically soil engineering is an applied science which deals with the application of principles of soil mechanics to practical problems in day to day life. It has a bigger and vast scope than soil mechanics. As it deals with all engineering problems related eith soils. The term soil basically is defined as an unconsolidated material composed of solid particles produced by disintegration of rocks. Soil at any place constitutes three in built components which are used as a unit 'SAW' i.e. Soil, Air and Water. The later two comes under the category of Voids. Voids should be as less as possible to improve the properties of soil and to increase maximum dry density.

Sometimes one more term is used i.e. Geotechnical engineering which is a broader term which includes soil mechanics, rock mechanics and geology. All these terms are used synonymously viz. Soil Engineering, Soil mechanics and foundations and Geotechnical engineering. Soil Engineering has very huge scope in civil constructions such as Retaining structures, Stability of slopes, Foundations, Underground structures, Dams, Pavement designing. Also the properties and characteristics of soil which is very important for further planning, investigation and construction of foundation is studied under soil engineering.

In this paper, efforts have been made not only to review the development in stages of soil engineering but also one live case study of Dabhi Village, Mehsana District, Gujarat's soil have been tested. The results and conclusions of the soil testing for consolidation tests and shear paramenters have been done to assess the potential use of the soil for foundation of residential buildings and community complexes.

II. DEVELOPMENT IN SOIL ENGINEERING: AN ART OF REVIEW

The improvement and development and the soil engineering can be trace to the ancient periods also. Even before 2000 B.C. soil engineering was applied in the constructions. Development in Soil Engineering can be grouped under four periods. (1) Past and Ancient Developments which has been happened before 2000 B.C. (2) From constructions, monuments after B.C. (3) From the Era of Coulomb till the Terzaghi's Era. (4) After the Contributions of Dr. Karl Terzaghi. In the first and second era, the constructed pavements in India and Egypt can be traced as an example. Also soil excavators, researchers and geologists have revealed in the excavation of Mohanjodaro & Haddappa civilization that soil has been used as a material for foundations. Heavy structures, aqueducts, brisges were built during the periods of Roman. The leaning tower of Pisa is also one example. Rialto Bridge (Venice), London Bridge (Londan) and Mousoleum Taj Mahal (Agra) were constructed.

The third Era can be depicted from the Coulomb's theory of earth pressure in 1773 till the contributions of Dr. Terzaghi. The fourth and Modern era of soil engineering development starts from year 1923-1925 when Dr. Karl Terzaghi, the Father of Soil Mechanics and Engineering published a book named Erdbaumechanic in 1925.

In the 1773, Coulomb, a French Engineer gave theory of earth pressure on retaining walls, then he has also contributed in research work of shear parameters (c and Ø, phi) and wedge theory (1776). In 1856, Darcy gave the law of permeability of soils. Rankine (1857) gave the theory of earth pressure considering plastic equilibrium. Culmann (1866) gave general graphical solution for the earth pressure. O Mohr (1871) gave rupture theory of soils. In 1874, Rehbann (Poncelett) gave graphical method for computation of earth pressure based on Coulomb's theory. In 1885, Boussinesq gave theory of stress distribution. In 1906, Muler Breslau principle was developed. Martson (1908) gave theory for load carried by underground conduits. In 1911, Atterberg categorized consistency. Fellinius (1913) studied stability of slopes. In 1916, Patterson gave friction circle method for the stability of slopes. L Prandtl gave theory on plastic equilibrium which becomes base for soil bearing computations. This covers the third era of soil engineering development. After this era the modern era starts where Dr. Karl Terzaghi has mentioned that it is the effective stress which governs the bearing capacity and stability of slopes not the total stress. Resal (1910) and Bell (1915) extended the Rankine's earth pressure theory.

The Fourth and Modern Era of soil engineering development starts from the year 1923-1925 when Dr. Karl Terzaghi, the father of Soil Mechanics published his books *Erdbaumechanic* in year 1925. In 1933, Proctor did pioneering work in compaction of soil. In 1948, Taylor worked on Consolidation, shear strength and stability of slopes. Weavwe (1934) and Khosla (1934) solved some practical soil problems. Casagrande (1948) Classified soils, and also worked on earth masses and consolidateion. Skempton (1942, 1954) worked on pore pressure, effective stress, bearing capacity etc., Hvorslev (1949) worked on subsurface exploration and shear strength of remoulded clay. Meyerhoff G. G. (1951) studied the bearing capacity of shallow and deep foundation. Bishop (1955) studied the stability of finite slopes. R.B. Peck in 1967, 1974 worked on overburden SPT corrections. Also the work on overburden SPT Correction was done by Bazarra in 1974. Even after this the researchers and geologists are trying to come out with the soil problems and try to solve with the available theories and also some theories have been developed too. Bell's (1915), Teng and W.B. Hansan (1953) have done a lot of contributions in soil mechanics and foundations.

III. DETERMINATION OF CONSOLIDATION PRESSURE OF DISTURBED SOIL

THEORY:

The test has been performed as per IS:2720 (Part XLI)-1977 and IS:2720-15 (1965). Follwing parameters can be obtained by this test.

1. Voids ratio and coefficient of volume change.
2. Coefficient of consolidation.

3. Coefficient of permeability.

PROCEDURE:

a) **Preparation of specimen from representative soil sample.**

Soil is compacted at the desired w.c. and density, in a separate large mould and then the specimen is cut by inserting the specimen ring into the mould by pressing with hands and carefully removing the material around the ring. Trim the sample smooth and flush with the top and bottom of the ring from outside and weight . Keep three specimens from the soil trimmings for w.c. determination.

b) **Preparation of mould assembly and sample saturation.**

1. Saturate the porous stone either by boiling in distilled water for about 15 minutes or by keeping them submerged in distilled water for 4 to 8 hours.

2. Assemble the consolidometer with tile soil specimen and porous stone at top and bottom of the specimen, providing a filter paper between the soil specimen and the porous stone. Position the pressure pad centrally on tile top porous stone.

3. Mount the mould assembly on the loading frame and center it such that the load applied is axial.

4. Connect the mould assembly to the water reservoir and the sample is allowed to saturate.
5. The level of water in the reservoir should be at about the same level as the soil specimen.
6. Apply an initial seating load to the assembly. The magnitude of this load should be allowed to stand until there is no change in dial gauge reading for two consecutive hours, or for maximum of 24 hours.

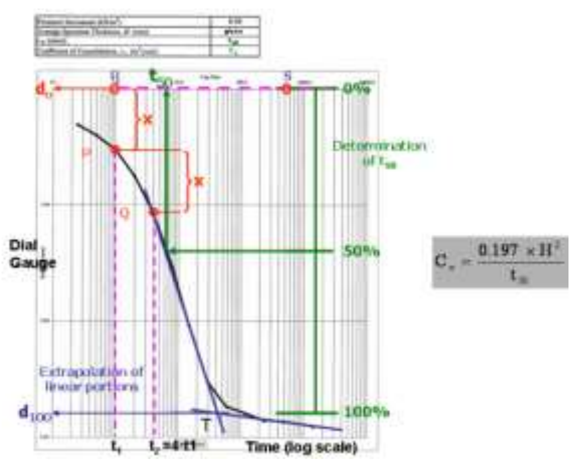
c) **Consolidation test:**

1. Note the final dial reading under the initial seating load. Apply first load of intensity 10 KN/m^2 and start the stop watch simultaneously with loading. Record the dial gauge readings at various time intervals indicated in observation table 1. The dial gauge readings are taken until 90% consolidation is reached. Primary consolidation will generally reached within 24 hours.
2. At the end of the period , specified above , take the dial reading and time reading. Apply load increment and take dial reading at various time intervals. Repeat this procedure for successive load increments..
3. After the last loading is complete. Reduce. the load to half of the value of the last load and allow it to stand for 24 hours. Reduce the load further in steps of 1/4th of previous intensity till an intensity of 10 KN/m2 is reached. Take the final readings of the dial gauge.
4. Reduce the load to the initial setting load. Keep it for 24 hours and note the final dial reading.
5. Quickly dismantle the specimen assembly and remove the excess surface water on the soil specimen by blotting. Weigh the ring with consolidation specimen. Dry the soil specimen in oven and determine its dry weight.

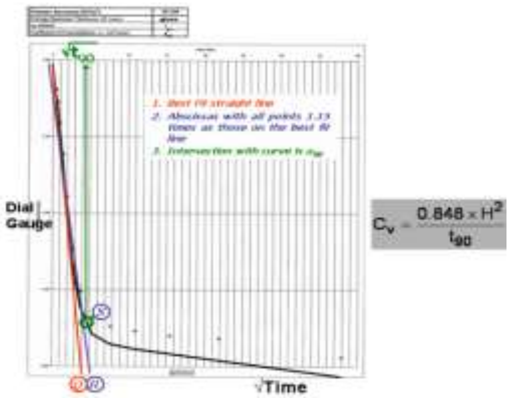
Determination of coefficient of consolidation (C) from laboratory data

The coefficient of three graphical procedure are used

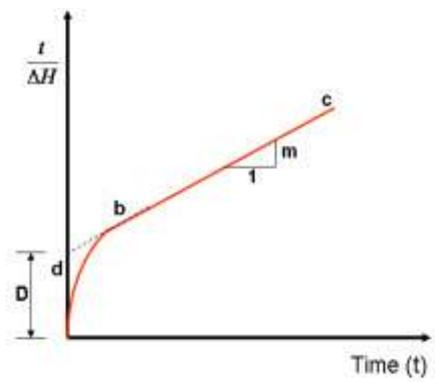
1. Logarithm of time method
2. Square root of time method
3. Hyperbola method (Sridharan and Prakash, 1985)



(a)



(b)



(c)

Figure:1- (a) Logarithm of time method, (b) Square root of time method, (c) Hyperbola method

Diameter of ring is 60 mm, Height of the ring is 20 mm, Area of ring = 2827.43 mm^2. Volume of ring is 56548.66 mm^3.

Table:1- Observation Table for Consolidation test using consolidometer (Sample readings for reference)

		Dial Gauge Reading			Dial Gauge Reading
Pressure Intensity	**Kg/ m^2**		**Pressure Intensity**	**Kg/ m^2**	
Elapsed Time (min)	**$(t)^{0.5}$**	**1.2**	**Elapsed Time (min)**	**$(t)^{0.5}$**	**1.2**
0	0	100	25	5	46.05
0.25	0.5	90	30.25	5.5	45.8
1	1	82	36	6	45.1
2.25	1.5	75	42025	6.5	45.05
4	2	70	49	7	44.95
6.25	2.5	69	64	8	43.9
9	3	58	81	9	41.5
12.25	3.5	51.5	100	10	40.9
16	4	48.7	121	11	39.9
20.25	4.5	47.1	1440	37.94	38

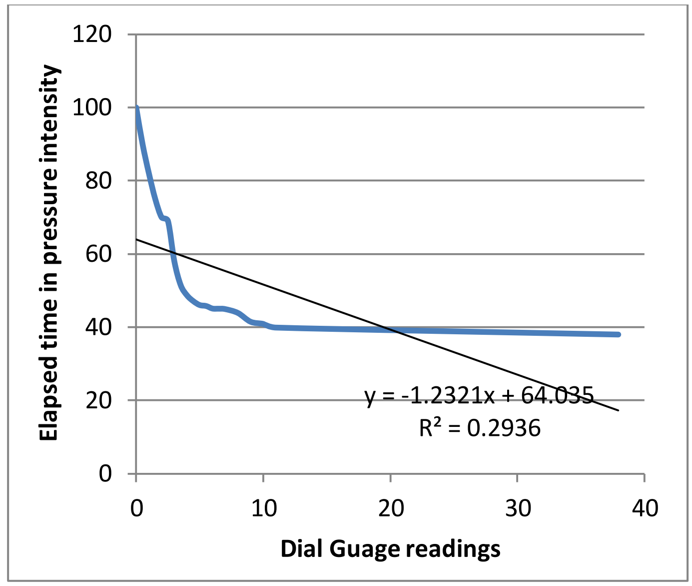


Figure:2- Relation between time elapsed in pressure intensity and Dial gauge readings

1. Logarithm of time method

$C_v = (0.197\ d^d)/t_{50}$

The value of Cv obtained by this method has been been found out equal to 0.0447.

2. Square root of time method

$C_v = (0.848\ d^d)/t_{90}$

The value of Cv obtained by this method has been been found out equal to 0.03504.

3. Hyperbola method (Sridharan and Prakash, 1985)

$C_v = 0.3\ (m\ H^2_{dr}/d)$

The value of Cv obtained by this method has been been found out equal to 0.0457.

Time rate of consolidation:

$T = (C_v * t)/ H^2$ or $t\ \alpha\ H^2 / C_v$

Therefore the time required for a given degree of consolidation is proportional to the length of the drainage path If the time required to reach a certain degree of consolidation is measured in the laboratory on a sample obtained from the field. The time taken by the field deposit of known thickness can be predicted by
using

$t_f = (H_f^2 / H_L^2)*t_L$

t_f = Time required for field consolidation
t_L = Time required for laboratory consolidation
H_f = Thickness of soil in the site
H_L = Thickness of laboratory sample

IV. DETERMINATION OF SHEAR PARAMETER OF THE SOIL

Shear box test has been used to estimate the direct shear.

MATERIAL AND EQUPMENT:

1. Shear box equipment consisting of (a) shear box 60× 60 × 24 × mm maybe tested. The box should be divided into two parts horizontally, with suitable spacing screws, (b) container for shear box (c) gird plates, two pairs, one plane and other perforated: depth of serrations to be 1.5mm porous stones, one pair, 6mm thick, (e) base plate, with cross –grooves on its top into the shear box, (f) loading pad, with a steel ball on its top.
2. Loading frame, to distribute the load from the yoke over the specimen, normal to the shear plane.
3. Set of weights for normal load.
4. Proving ring with dial gauge accurate to 0.002 mm to measure the shear force.
5. Micrometer dial gauge, two nos accurate to 0.001mm measure horizontal and vertical displacements during shear.
6. Spatula, straight edge, sample trimmer etc.
7. Stop watch.

PREPARATION OF SPECIMEN:

1. The undisturbed specimen is prepared by pushing a cutting ring of size 10 cm in diameter and 2cm high, in the undisturbed soil sample obtained from field. The square specimen of size 6cm 86cm is then cut from the circular specimen so obtained.
2. In order to obtain remolded specimen of cohesive soil, the soil may be compacted to the required density and trimmed to the required size. Alternatively, the soil may be compacted at the required density and water content directly into the shear box after fixing two halves of the shear box together by means, of the fixing screws.
3. Non – cohesive soil may be tamped in the shear box itself with the base plate and grid plate or porous stone as required in place at the bottom of the box.
4. In all the three cases mentioned above, water content and dry density of the soil compacted in the shear box should be determined.

PROCEDURE:

1. The shear box with the specimen plain grid plate over the base plate at bottom of specimen, and plain gird over the top of the specimen, should be fitted into position. The serration of the grid plates should be placed at right angles to the direction of shear .As the porous stone are not used in the untrained tests, plain plates of equal thickness should be placed, one at the bottom and other a top of the two grids, so as to maintain the shear plane in the sample in the middle of its thickness. Place the loading pad on the top of the plain grid plate. Both the parts of the box should be tightened by the fixing screws.
2. Put water inside the water jacket so that the sample does not get dried during the test.
3. Mount the shear box assembly on the load frame (or shearing machine). Set the lower part of the box to bear against the load jack and the upper part of the box to bear against the providing ring. Set the dial of the proving ring to zero.
4. Put the loading yoke on the top of the loading pad, and adjust the dial gauge to zero to measure the vertical displacement in the soil sample. Put proper normal weight on the hanger of the loading yoke, so that this weight plus the weight of the hanger equals the required normal load. Note the reading of the vertical displacement dial gauge.
5. Remove the locking screw so that the parts are freed to move against each other. By turning the spacing screw, raise the upper part slightly above the lower parts by about 1mm.

6. Conduct the test by applying horizontal shear load to failure or to 20 per cent longitudinal displacement, whichever occur first. The rate of stain may vary from 1 to 2.5 mm per minute. Start stop watch immediately at the start of the application of the shear load. Take the readings of proving ring dial gauge, longitudinal displacement gauge and the vertical displacement gauge at regular time interval.
7. At the end of the test, remove specimen from the box and determine its final water content. Repeat the above steps on three or four identical specimen, under varying normal loads.

Size of the bos (cm) 6 by 6cm, Tickness of the sample 6 cm, Area of the box, A (cm^2) = 36 cm^2. Proving ring constant (kg/div) = 0.318 kg.

Table:2- Observation table for box shear test (Sample reading for reference)

Sr. No.	Normal Stress (kg/cm^2)	Shear force = Proving Ring	Shear strain = S.F./A*P.C.(kg/cm^2)
(1)	(2)	(3)	(4)
1	0.7	12	0.106
2	1	18	0.159
3	1.3	24	0.212

After the analysis and experimentation, C (Cohesion intercept) has been calculated as 0. I t directly reveals that the soil is not cohesive and does not possess cohesiveness. The value of angle of shear resistance has been observed as 70 degree which is under the category of cohesive or phi soils. It can be concluded that the soils of the study area (Village-Dabhi) is absolutely cohesion less.

Wider and microscopic investigations on the soils have been also carried out to reveal the properties and characteristics of the soil such as water content, liquid limit, grain size distribution (using sieve analysis). It was obtained as a result that the obtained soil does not possess much plasticity and soil can be categorized as GP means poorly or uniformly graded gravel. The coefficient of uniformity was obtained as 2.6. And the coefficient of curvature found out to be nearly 1. The fineness was observed less than 5 percent.

As the soil is cohesion less than shrinkage and swelling is not a big problem but seepage and pore pressure may create a problem. As per Standard Penetration Test (SPT) N value has been obtained to be 43. And angle φ is greater than 36degree means the soil may be fail by general shear failure. The general shear failure occurs in dense sand, medium sand and stidd clays.

V. RESULTS AND CONCLUSION

Following findings can be summarized as an outcome of the present study,

(1) An entire review of the soil engineering research from the ancient era to the modern era has been done. The development in soil mechanics has been divided in four era's and each era has been explained. An art of review of development in soil engineering has been presented in simple, drastic and broad manner.

(2) Determination of coefficient of consolidation and Direct shear tests have been performed on unsaturated disturbed and undisturbed specimens of a compacted area. Consolidation test has been performed as per IS:2720-15 (1965). A conventional direct shear apparatus was modified in order to use the axis-translation technique for direct shear tests on unsaturated soils. The testing procedure and some typical results are presented.

(3) Possibilities of potential use of soil as a foundation for residential building, complexes have been identified. Suggestions are made as to how best to handle the soil from a practical engineering standpoint.

(4) The coefficient of consolidation has been estimated to be 0.0447, 0.03504, 0.0457 as per the three methods i.e. Logarithm of time method, Square root of time method, Hyperbola method, shear parameters and some soil properties have been computed to better understand the soil. After experiments and analysis the soil has been classified as GP means poorly graded gravels or uniformly graded gravel. The soil is cohesion less and suitable for the foundation.

(5) Friction angle is obtained to be greater than 36 degree, the soil may be fail by general shear failure and the soil is well suited for shallow foundations up to two and three floor buildings. The SPT Value has

been obtained as 43, this shows that the foundation on soil may impart on good shallow foundation.

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