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REPORT

ON

SOIL INVESTIGATION FOR CONSTRUCTION OF RESIDENTIAL APARTMENT BUILDING AT KUMBAKONATHAN SALAI, THIRUVANAIKOVIL, TRICHY

Client

M/s. CS Housing Promoters,
Ward - C, Block - 48,
TS.NOs. 2416/7, 2416/8, 2416/9, 2416/11
Sriram Nagar,
Kumbakonam Salai,
Thiruvanaikovil,
Tiruchirappalli – 620 005.

By

Time

TIME INSTITUTE FOR MATERIALS TESTING
NO. 25, SANJEEVI NAGAR,
TRICHY - CHENNAI BYEPASS ROAD,
TIRUCHIRAPPALLI,
TAMIL NADU - 620 002.
PH: 0431 2401326

DECEMBER 2023

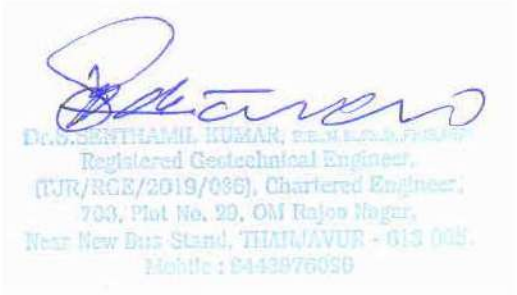
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SUMMARY

Project	:	Construction of Residential Apartment Building at Kumbakonathan Salai, Thiruvanaikovil, Trichy
Project Reference	:	Time /11/ Soil Test / December 2023
Owner	:	M/s. CS Housing Promoters, Ward - C, Block - 48, TS.NOs. 2416/7, 2416/8, 2416/9, 2416/11, Sriram Nagar, Kumbakonam Salai, Thiruvanaikovil, Tiruchirappalli – 620 005.
Type of Structure	:	R.C.C. Framed construction
Location	:	Kumbakonathan Salai, Thiruvanaikovil, Trichy
Scope	:	Geotechnical investigation for the entire area of construction
Test conducted	:	Two explanatory bore hole up to 7m & 6m depth was made and conducted standard penetration tests at every 1.5m depth. The undisturbed soil samples were collected at every 1.5m depth for laboratory test.

FINDINGS

Soil at shallow depth	:	Clay exists up to 1.5m depth
Hard stratum	:	No trace of rock exits up to 7m depth
Ground water table	:	Ground water table exists below 4.5m depth from ground level during soil Investigation



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SOIL INVESTIGATION

Time Institute for Materials Testing
टाइम इन्स्टिट्यूट चीज़े शोध केलिए
B.N. Krishnaswami, M.E., (Struct. Engg.), Ph.D., Soil & Structural Consultant, Construction Materials Testing Lab
Former Faculty, NIT, Trichy

December 07, 2023

To
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Tiruchirappalli – 620 005.

REPORT ON SOIL INVESTIGATION

(Ref: TIME/11/ SOIL TEST/ DECEMBER 2023)

Sub: Soil Investigation for construction of Residential Apartment Building at Kumbakonathan Salai, Thiruvanaikovil, Trichy – reg.,

Ref: Based on letter dated: 03.12.2023

1.1 Introduction:

It is proposed to construct a **Residential Apartment Building at Kumbakonathan Salai, Thiruvanaikovil, Trichy.** A detailed soil investigation was suggested for estimating the safe bearing capacity of the soil, so that suitable type of foundation can be decided for the proposed structure. Time Institute for Materials Testing (TIME) has been requested to undertake the soil investigation at the proposed site. The study was carried out by TIME between **04.12.2023 & 05.12.2023.** This report presents complete investigation data and discusses the results to recommend the bearing capacity values at different depths for the proposed structure.

Section 2 describes the soil profile and bore log details of two exploratory bore holes. Section 3 of this report gives the Grain size distribution curves and its analysis. Section 4 of this report presents the calculated safe Bearing capacity values of soil at various depths. Section 5 of this report reviews the test results and the recommended safe bearing capacity values for design of foundation. Section 6 of this report presents the Soil sample photos. Section 7 of this report presents site photo.

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1.2 Investigation Programme, Procedure and Data:

Investigation was carried out in two locations at the site through exploratory bore holes. Soil samples were collected from each bore hole at different depths for conducting laboratory test. Standard Penetration test was conducted at regular intervals and 'N' values were recorded. Undisturbed soil samples were collected and were preserved and transported to the laboratory for detailed identification tests. Based on the field and laboratory tests on the samples collected, the results are furnished in this report.

An exploratory bore hole was advanced from the existing ground level using truck mounted rotary drilling techniques supplemented by Betonies mud circulation. This drilling procedure with mud circulation is found most suitable for making exploratory bore hole. The mud circulation was employed through the drill rods and letting it out though the side jets provided in the cutting tool thus preventing any disturbance at the bore hole bottom. Mud circulation was used to stabilize the sides and the bottom of the bore hole, and then to bring the soil cuts to the surface. It is important to note that the mud jet is not used to cut the soils as in the case of wash boring technique. Use of drilling mud will also help in preventing the disturbance to the soil at the bore hole bottom during drilling operations. Diameter of the bore hole is about 150mm.

Bore hole was always kept full with the drilling mud so that a positive head is maintained in the bore hole thus preventing any disturbance to the soil within the test zone.

The field tests included Standard penetration test, Disturbed and undisturbed soil sampling, identification of different soil layers, Ground water table observation, complete logging of the bore hole, etc.

Laboratory investigation consisted of classification tests like grain size distribution analysis, determination of specific gravity etc. Unconfined Compression test and Direct shear was conducted on preserved soil samples. All the field and laboratory tests were conducted according to the procedures stipulated in relevant IS codes.

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1.3 Review of Field and Laboratory Results:

Sub soil Profile

The original ground level in the presently investigated area was plain terrain.

Bore Hole 1:

The natural soil below the existing ground level is Filled up soil. This layer is extended up to 1m depth. Clay exists from 1m to 1.5m depth. Fine sand with little clay mixed exists from 1.5m to 3m depth. Clay exists from 3m to 6m depth. Below which Fine sand with little clay mixed exists from 6m to 7m depth from the existing ground level. The soil stratification and its variation under present investigation are available in bore log details. The 'N' value is progressively increasing towards depth, due to the soil stratification.

Bore Hole 2:

The natural soil below the existing ground level is Filled up soil. This layer is extended up to 1m depth. Fine sand with clay mixed exists from 1m to 2m depth. Clay exists from 2m to 2.8m depth. Sand exists from 2.8m to 4m depth. Below which Clay with sand mixed exists from 4m to 6m depth from the existing ground level. The soil stratification and its variation under present investigation are available in bore log details. The 'N' value is progressively increasing towards depth, due to the soil stratification.

Ground Water Table

Ground water table exists below 4.5m depth from ground level during soil investigation

Shear Strength

Standard Penetration test blow counts 'N' is measured at different levels in the bore hole. Mainly these 'N' values are used to assess the shear strength of different soil layers.

Cohesive layers: The classification of 'N' values in moderate to high plasticity medium clay deposits developed by Terzaghi is used for estimating the unconfined compression strength and untrained shear strength of clay and sandy clay layers. The consistency between the N values and the liquidity index values is reviewed while assigning undrained shear strength for soft to medium clay layers.

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Non - Cohesive Layers: The sand layers towards depth are of residual type and suitable modifications are made to take care of the presence of plastic fines in the residual soil. Conventional method of estimating the angle of shearing resistance ϕ corresponding to the relative density and the grain size distribution as per the classification suggested by Peck and suitably modified by the R.K. Hough to account for the influence of grain size distribution is adopted here.

Laboratory Tests:

The Collected soil samples were tested as per relevant procedure in IS codes. The following parameters are evaluated.

1) **Natural Moisture Content**: This test is conducted in all disturbed samples to find the water content in soil samples as per **IS 2720 (Part 2): 1973**
2) **Specific Gravity:** This test is conducted in all disturbed soil samples to find specific gravity of soil as per **IS 2720 (Part 3): 1980**
3) **Density:** This test is conducted in all disturbed soil samples to find Bulk density and Dry density of soil as per **IS 2720 (Part 8): 1983**
4) **Sieve Analysis: This test is conducted to identify and classify the samples** as per **IS 2720 (Part 4) : 1985**
5) **Direct Shear Test:** This test conducted in coarse grained soil to find the angle of shearing resistance of the soil as per **IS 2720 (Part 13):1986**
6) **Unconfined Compression Test**: This test conducted in Clay soil to find Cohesion of the soil as per **IS 2720 (Part 10):1995**

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1.4 Recommended Safe bearing capacity values at different depths

Bore Hole	Depth (m)	Safe Bearing Capacity (t/m^2)
BH – 1	1.50	0.84
	3.00	1.69
	4.50	2.54
	6.00	2.54
	7.00	1.69

BH – 2	1.50	4.24
	3.00	6.79
	4.50	7.64
	6.00	7.64

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1.5 Conclusions:

The scope of foundation is purely the decision of the structural engineer. However, the following suggestion are furnished for your reference.

1. There are two types of foundation as Open foundation and Deeper foundation.
2. Under Open foundation, there are four types like Isolated, Combined, Raft and Mat Foundation.
3. Under Deeper foundation, it is only Pile foundation. Under which condition we can prefer Open foundation or Pile foundation?
4. I In general, to have Open foundation for any type of loading via Light load / Heavy load, symmetrically spaced columns or unsymmetrically spaced columns, it is preferable to have SBC as 20t/m^2 and above at 3m depth and it should continue to increase as proceed down, further it should not increase and decrease after 3m depth to satisfy the settlement criteria.
5. Based on the existing soil condition in this location all the above condition to provide Open foundation is not satisfied.
6. **Hence it is Suggested to provide Cast in situ Friction Pile foundation.**
7. The Pile load carrying capacity values like bearing resistance, Uplift force and Side Thrust for various diameter of Piles up to 7m depth are presented herewith for your reference.

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1.6 Recommended pile load capacity Values

Based on the variation of the existing soil profile and usage of M25 grade of concrete, the pile load capacity has been calculated and presented as below.

S. No.	Bore Hole no.	Pile Dia. (mm)	Depth (m)	Bearing Resistance (tonne)	Uplift Resistance (tonne)	Lateral thrust (tonne)
1	BH – 1 & BH – 2	400	7	10.1	7.7	2.1
		450		11.6	8.7	2.5
		500		13.1	9.8	2.8
		600		16.2	11.9	3.5

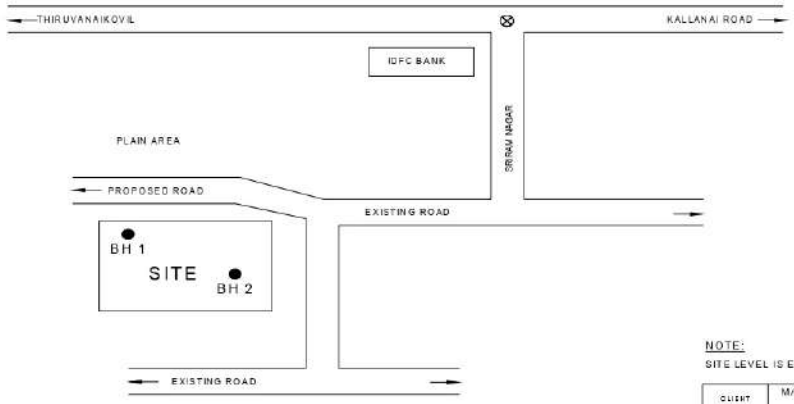
For Time Institute for Materials Testing

07th December 2023

Dr. B.N. Krishnaswami.

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SITE LOCATION PLAN



SITE PLAN

LEGEND:

● BORE LOG LOCATION

⊗ SITE LOCATION

NOTE:

SITE LEVEL IS EQUAL TO THE ROAD LEVEL

CLIENT	M/s. CS Housing Promoters, Sriram Nagar, Kumbakonam Salai, Thiruvanaikovil, Tiruchirappalli – 620 005.	
SOIL CONSULTANT	TIME Institute for Materials Testing No.26, Sanjeevi Nagar, Trichy - Chennai Bypass road, Trichy - 620002. PROJECT - 0431 - 2601526(10 PH)	
DATE OF SURVEY	04.12.2023 & 05.12.2023	TITLE PLAN OF BORE HOLE AND SITE DETAILS AT KUMBAKONAM SALAI, THIRUVANAIKOVIL, TRICHY
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BORE LOG DETAILS

2.2 BORE LOG DETAILS FOR BORE HOLE 1

Project : Report on soil investigation for Construction of Residential Apartment Building
Location : Kumbakonathan Salai, Thiruvanaikovil, Trichy
Started on : 04.12.2023 **Ended on** : 04.12.2023
Depth of G.W.T : 4.5m
Type of Boring : Calyx drilling
Site Level : Equal to the road level

Lithology of Bore Hole			SPT Data					Graphical representation of penetration Resistance ('N' Value)
Depth below G.L. (m)	Profile	Soil Description	Depth of SPT (m)	0-15cm	15-30cm	30-45cm	N Value	0 20 40 60
0 - 1m		Filled up soil						
1m - 1.5m		Clay						
1.5m - 3m		Fine sand with little clay mixed	**1.5**	1	2	2	**4**	
3m - 6m		Clay	**3.0**	2	2	3	**5**	
			4.5	2	2	4	**6**	
			6.0	3	3	3	**6**	
6m - 7m		Fine sand with little clay mixed	**7.0**	3	3	2	**5**	

Bore terminated at 7m depth from the existing ground level

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2.3 BORE LOG DETAILS FOR BORE HOLE 2

Project : Report on soil investigation for Construction of Residential Apartment Building
Location : Kumbakonathan Salai, Thiruvanaikovil, Trichy
Started on : 05.12.2023 **Ended on** : 05.12.2023
Depth of G.W.T : 4.5m
Type of Boring : Calyx drilling
Site Level : Equal to the road level

Lithology of Bore Hole			SPT Data					Graphical representation of penetration Resistance ('N' Value)
Depth below G.L. (m)	Profile	Soil Description	Depth of SPT (m)	0-15cm	15-30cm	30-45cm	N Value	0 20 40 60
0 - 1m		Filled up soil						
1m - 2m		Fine sand with clay mixed	**1.5**	6	5	3	**8**	
2m - 2.8m		Clay						
2.8m - 4m		Sand	**3.0**	4	7	4	**11**	
4m - 6m		Clay with sand mixed	**4.5**	6	6	6	**12**	
			6.0	5	6	6	**12**	

Bore terminated at 6m depth from the existing ground level

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2.4 Summary of Engineering Geo Properties

Natural Moisture Content:

The natural water content also called the natural moisture content is the ratio of the weight of water to the weight of the solids in a given mass of soil. This ratio is usually expressed as percentage.

$$W = [(W2-W3)/(W3-W1)] \times 100$$

Where,

W_1 = Weight of container gm

W_2 = Weight of container +wet soil gm

W_3 = Weight of container +dry soil

Bulk Density:

The total, or wet, density of soil, $_t$, is the ratio of the total mass of soil to its total volume and can be defined as follows:

$$\gamma_{bulk} = M / V$$

Where

M_t = Total Mass of soil

V_t = Total Volume

Dry Density:

The soil dry density, $_b$, is the ratio of the mass of the solid phase of the soil (i.e., dried soil) to its total volume (solid and pore volumes together) and is defined as follows:

$$\gamma_{dry} = M_b / V_b$$

Where

M_b = Total Mass of dried soil

V_b = Total Volume

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Specific gravity:

Specific gravity is the ratio of the weight of a given volume of a material at a standard temperature to the weight of an equal volume of distilled water at the same stated temperature.

The specific gravity G of the soil = $(W_2 - W_1) / [(W_4 - W_1)-(W_3-W_2)]$

Where

W_1 = Weight of density bottle
W_2 = Weight of density bottle + dry soil
W_3 = Weight of bottle + dry soil + water at temperature
W_4 = Weight of density bottle + Water

Void Ratio:

Soil void ratio (e) is the ratio of the volume of voids to the volume of solids:

$$e = (Vv) / (Vs)$$

Where
Vv is the volume of the voids (empty or filled with fluid),
Vs is the volume of solids.

Porosity:

Soil porosity (η) , which is defined as the ratio of the volume of voids to the total volume of the soil.
The porosity and the void ratio are inter-related as follows:

$$\eta = (1 - (\gamma_d/G_s))*100$$

$$e = \eta/(1-\eta) \;\&\; \eta = e / (1+e)$$

Where
γ_d = Dry Density
G_s = Specific gravity

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Summary of Engineering Geo Properties for Bore Holes 1 & 2

Bore hole No.	Depth (m)	Soil Description	Natural Moisture Content (%)	Bulk Density (gm/cc)	Dry Density (gm/cc)	Specific gravity	Porosity (%)	Void Ratio
Bore Hole 1	1.5	Fine sand with little clay mixed	18.56	1.87	1.58	2.62	40	0.66
	3.0	Clay	20.45	1.81	1.50	2.61	42	0.74
	4.5		20.30	1.83	1.52	2.61	42	0.72
	6.0		20.05	1.84	1.53	2.61	41	0.70
	7.0	Fine sand with little clay mixed	18.60	1.89	1.59	2.62	39	0.64
Bore Hole 2	1.5	Fine sand with clay mixed	19.25	1.86	1.56	2.62	40	0.68
	3.0	Sand	19.28	1.92	1.61	2.63	39	0.63
	4.5	Clay with sand mixed	19.10	1.88	1.58	2.62	40	0.66
	6.0		18.90	1.89	1.59	2.62	39	0.65

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2.5 Summary of Laboratory Test Results for Bore Holes 1 & 2

Bore hole No.	Depth (m)	Soil Description	Atterberg limits			Gravel (%)	Coarse sand (%)	Medium Sand (%)	Fine sand (%)	Silt (%)	Clay (%)
			Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)						
Bore Hole 1	1.5	Fine sand with little clay mixed	-	-	-	0.0	6.1	15.8	62.5	6.2	9.4
	3.0	Clay	28.7	22.5	6.2	0.0	0.0	7.3	29.8	5.9	57.0
	4.5		29.3	22.8	6.5	0.0	0.0	8.9	29.2	6.1	55.8
	6.0		29.5	22.7	6.8	0.0	0.0	10.2	28.3	6.3	55.2
	7.0	Fine sand with little clay mixed	-	-	-	0.0	9.4	19.2	56.5	5.8	9.1
Bore Hole 2	1.5	Fine sand with clay mixed	29.4	23.0	6.4	0.0	9.3	18.2	43.9	4.1	24.5
	3.0	Sand	-	-	-	0.0	15.1	39.2	35.1	6.0	4.6
	4.5	Clay with sand mixed	30.5	23.4	7.1	0.0	10.6	21.9	28.6	4.2	34.7
	6.0		30.8	23.3	7.5	0.0	11.2	22.7	28.3	3.5	34.3

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2.6 Shear Strength Parameters for Different layers of Bore Holes 1 & 2

Bore Hole No.	Depth below G.L. (m)	Soil Description	N	Cohesion 'c' (t/m^2)	Shear Strength 'Ø' (in degrees)
Bore Hole 1	1.5	Fine sand with little clay mixed	4	-	26.58
	3.0	Clay	5	2.10	-
	4.5		6	2.80	-
	6.0		6	3.08	-
	7.0	Fine sand with little clay mixed	5	-	26.84
Bore Hole 2	1.5	Fine sand with clay mixed	8	3.49	27.36
	3.0	Sand	11	-	27.88
	4.5	Clay with sand mixed	12	4.88	28.14
	6.0		12	5.30	28.39

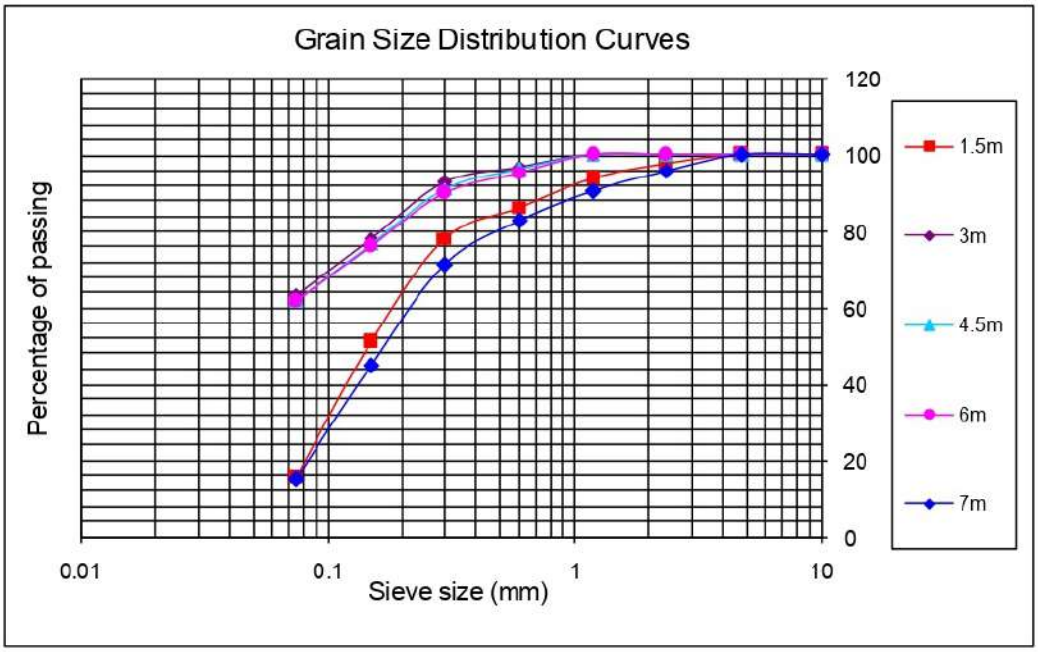
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GRAIN SIZE ANALYSIS

3.1 TEST REPORT ON SIEVE ANALYSIS OF SAMPLE

Bore Hole – 1 @ 1.5m to 7m

SIEVE SIZE	PERCENTAGE OF PASSING				
	1.5m Depth	3m Depth	4.5m Depth	6m Depth	7m Depth
10 mm	100	100	100	100	100
4.75 mm	100.0	100.0	100.0	100	100
2.36 mm	97.7	100	100	100	95.7
1.18 mm	93.9	100	100	100	90.6
600 micron	86.3	96.9	96.2	95.5	82.7
300 micron	78.1	92.7	91.1	89.8	71.4
150 micron	51	78.1	76.8	76	45.1
75 micron	15.6	62.9	61.9	61.5	14.9



Description	1.5m Depth	3m Depth	4.5m Depth	6m Depth	7m Depth
Fineness modulus	1.774	0.694	0.740	0.772	1.996

Observation:

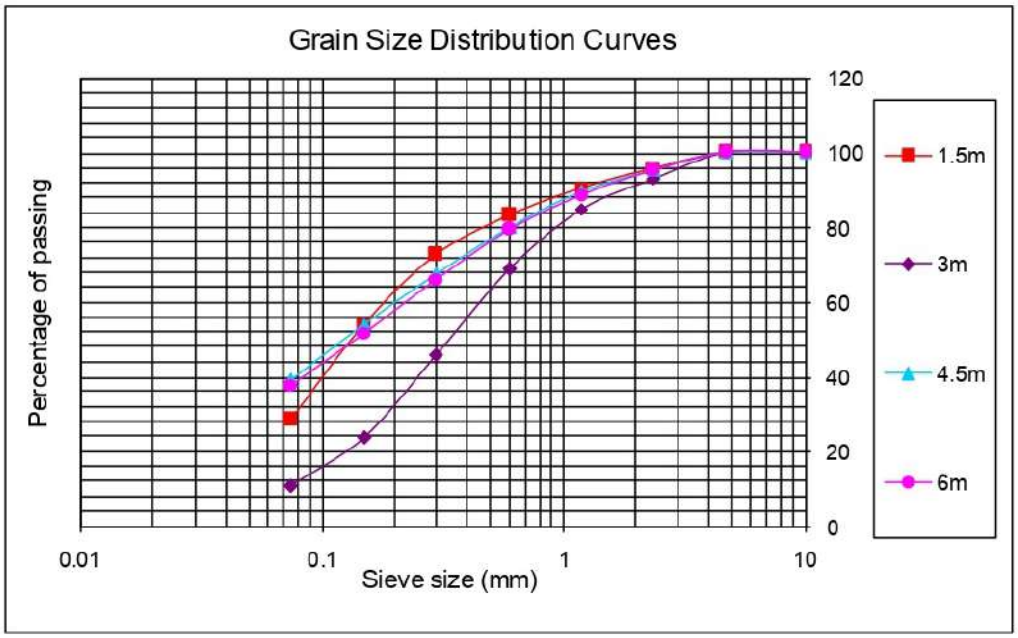
The inference from the graph shows that the Fine sand with little clay mixed exists at 1.5m depth, clay exists up to 6m depth and Fine sand with little clay mixed exists at 7m depth.

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3.2 TEST REPORT ON SIEVE ANALYSIS OF SAMPLE

Bore Hole – 2 @ 1.5m to 6m

SIEVE SIZE	PERCENTAGE OF PASSING			
	1.5m Depth	3m Depth	4.5m Depth	6m Depth
10 mm	100	100	100	100
4.75 mm	100.0	100.0	100.0	100
2.36 mm	95.9	93.1	95.5	95.1
1.18 mm	90.7	84.9	89.4	88.8
600 micron	83.1	68.8	80.1	79.3
300 micron	72.5	45.7	67.5	66.1
150 micron	54.2	23.8	54.2	51.8
75 micron	28.6	10.6	38.9	37.8



Description	1.5m Depth	3m Depth	4.5m Depth	6m Depth
Fineness modulus	1.750	2.731	1.744	1.811

Observation:

The inference from the graph shows that the Fine sand with clay mixed exists at 1.5m depth, sand exists at 3m depth and Clay with sand mixed exists up to 6m depth.

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CALCULATION
OF
SAFE BEARING CAPACITY

4. CALCULATION OF SAFE BEARING CAPACITY

4.1 Safe bearing capacity calculation based on settlement and Shear

Safe Bearing Capacity calculations based on settlement consideration (SPT value):

Safe Bearing Capacity calculations for shallow foundation will vary based on the width of foundation.

For example, in the case of Individual footing such as isolated, combined etc., we are supposed to use the formula as mentioned below. (Using Teng's Modified formula)

$$q_{na} = 51.4 \times (N-3) \times \left(\frac{B+0.3}{2B}\right)^2 \times R_w \times C_d$$

Where,

q_{na}	=	Net safe bearing capacity of soil (kN/m^2) (for 2.5cm permissible settlement as per Terzhagi & Peck)
N	=	Corrected SPT values
B	=	Width of foundation (m) (let us assume 2m)
R_w	=	Correction factor for water table level
C_d	=	Correction factor for depth of embedment

For Bore Hole 1 @ 3m depth SPT 'N' Value = 5

$\Rightarrow$ **q_{na} = 51.4 x (5 - 3) x ((2 + 0.3)/(2 x 2))^2 x 0.5 x 1 = 16.99 kN/m^2**

$\therefore$ **q_{na} = 1.69 t/m^2**

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Safe Bearing Capacity calculations based on Unconfined Compression Test (UCC):

As Per IS 6403:1981

Net safe bearing capacity of the soil,

$$q_{ult} = C\,N_c\,S_c\,d_c\,i_c + q\,(N_q - 1)\,S_q\,d_q\,i_q + 0.5\,B\,\gamma\,N_\gamma\,S_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where

C	=	Cohesion in Kgf/cm^2
N_c, N_q, N_γ	=	Bearing Capacity Factors
S_c, S_q, S_γ	=	Shape Factors
d_c, d_q, d_γ	=	Depth Factors
i_c, i_q, i_γ	=	Inclination Factors
q	=	Effective surcharge at the base level of foundation in Kgf/cm^2
	=	γ x d
B	=	Width of footing, diameter of circular footing in cm
γ	=	Bulk unit weight of soil in Kgf/cm^3
W'	=	Correction factor for location of water table

At 3m depth (Bore Hole 1), the Soil profile is Clay

If	Φ	=	0 (assumed)
	N_c	=	5.14
	N_q	=	1
	N_γ	=	0 (Zero)
and Cohesion C		=	2.10 (based on laboratory test)

Applying these parameters in the equation No. 1

$$q_{ult} = C\,N_c\,S_c\,d_c\,i_c + q\,(N_q - 1)\,S_q\,d_q\,i_q + 0.5\,B\,\gamma\,N_\gamma\,S_\gamma\,d_\gamma\,i_\gamma\,W'$$

$$= C\,N_c\,S_c\,d_c\,i_c + q\,(1 - 1)\,S_q\,d_q\,i_q + 0.5\,B\,\gamma\,0\,S_\gamma\,d_\gamma\,i_\gamma\,W'$$

$$= C\,N_c\,S_c\,d_c\,i_c + 0 + 0$$

$$q_{ult} = C\,N_c\,S_c\,d_c\,i_c$$

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Where S_c = Shape factor which is equal to 1

d_c = $1 + 0.2 \frac{df}{B} \sqrt{Nq}$

= $1 + 0.2 \frac{1.6}{1.8} \sqrt{\tan 2(45+\emptyset/2)}$

= 1.028 (hence considered the minimum value as 1)

= 1

i_c = $(1 + \alpha/90)^2$

Where α = inclination of the load to the vertical in degree which is equal to zero

i_c = 1

Therefore q_{ult} = $C\ N_c\ S_c\ d_c\ i_c$

= 2.10 x 5.14 x 1 x 1 x 1

= 10.794 t/m^2

Applying factor of safety as 3

Then allowable bearing capacity

$q_{allowable}$ = 10.794 / 3

= 3.60 t/m^2

Safe Bearing Capacity calculations based on shear consideration (Direct Shear):

As Per IS 6403:1981

At 3m depth (Bore Hole 2)

Proving Ring capacity 200kg = 966.2 division

Area of the shear box = 6cm x 6cm = 36cm^2

Normal Stress (kg/cm^2)	No. of Division	Stress
0.5	23	0.132
1.0	69	0.397
1.5	115	0.661

Stress = Load / Area

= (200/966.2) * 23* (1/36) = 0.132

Ø = $\tan^{-1}$ (0.661-0.132) = 27.88°

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Net safe bearing capacity of the soil (for general shear failure as per IS 6403:1981)

$$q_{ult} = C N_c S_c d_c i_c + q (N_q - 1) S_q d_q i_q + 0.5 B \gamma N_\gamma S_\gamma d_\gamma i_\gamma W'$$

Where

C	=	Cohesion in t/m^2
N_c, Nq, N_γ	=	Bearing Capacity Factors (From Table 1 of IS 6403 – 1981)
S_c, S_q, S_γ	=	Shape Factors (From Table 2 of IS 6403 – 1981)
d_c, d_q, d_γ	=	Depth Factors
i_c, i_q, i_γ	=	Inclination Factors
q	=	Effective surcharge at the base level of foundation in t/m^2
B	=	Width of footing, diameter of circular footing in m
γ	=	Bulk unit weight of soil in t/m^3
W'	=	Correction factor for location of water table

At 3m depth (Bore hole 2), the Soil profile is Sand

If	C	=	0 (Since no Cohesion)
	Φ	=	27.88° (based on laboratory test)
Therefore	N_c	=	26.143;
	N_q	=	15.116;
	N_γ	=	17.512

Applying these parameters in the above equation

$$q_{ult} = C N_c S_c d_c i_c + q (N_q - 1) S_q d_q i_q + 0.5 B \gamma N_\gamma S_\gamma d_\gamma i_\gamma W'$$

Where C = 0 (Since no Cohesion)

Therefore, $$q_{ult} = q (N_q - 1) S_q d_q i_q + 0.5 B \gamma N_\gamma S_\gamma d_\gamma i_\gamma W'$$

Bearing Capacity calculation through shear density of soil 'γ'

There are two relationships of weight of soil to Volume of soil as

i) Total density or Bulk density

ii) Dry density

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Therefore, Total Bulk density, $\gamma_t = \frac{\text{Total Weight of soil}}{\text{Total Volume of soil}} = \frac{W}{V}$

Dry Density $\gamma_d = W_s/V$; Whereas W_s = Total weight of solids

In a particular case the **total density** will be known as **saturated density**, when the soil is saturated.

Another density of soil will be known as submerged or buoyant density, Y_b when the soil is submerged in water.

$Y_b = Y_t - Y_w$

Where Y_w = Density of water = 1 g/cc or 1 t/m^3

Mostly soils submerged in water are saturated.

Hence $Y_{buoyant} = Y_{sat} - Y_w$

Based on the above equations,

$Y = Y_{sat} = 1.8$ t/m^3

d = 3m

Here, $Y_b = Y_{sat} - 1 = 1.8 - 1 = 0.8$ t/m^3

Therefore, $q = Y_b \times d = 0.8 \times 3 = 2.4$ t/m^2

$S_q = S_\gamma$ = Shape factor which is equal to 1

$d_q = d_\gamma = 1 + 0.1 \frac{df}{B} \sqrt{N\emptyset}$

= 1 (Minimum value of 1 can be taken)

i_q = inclination factor $(1 - \alpha/90)^2$

Where α = inclination of the load to the vertical in degree which is equal to zero

i_q = 1

B = Width of footing (2m)

W' = 0.5

Applying in the above equation

$q_{ult} = q (Nq - 1) S_q d_q i_q + 0.5 B \gamma N_\gamma S_\gamma d_\gamma i_\gamma W'$

$= 2.4 \times (15.116 - 1) \times 1 \times 1 \times 1 + 0.5 \times 2 \times 1.8 \times 17.512 \times 1 \times 1 \times 1 \times 0.5$

$= 49.639$ t/m^2

Applying factor of safety as 3

Then allowable bearing capacity

$q_{na} = 49.639 / 3$

$= 16.55$ t/m^2

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Settlement Calculations as per IS – 8009 (Part – 1) 1976

1. Soil Strata at 3m depth from EGL = Clay
2. The allowable bearing capacity value based on shear calculation = 36 kN/m^2 ≈ 40 kN/m^2
   (as Per IS 6403 – 1981) at 3m depth from EGL
3. Young's Modulus, Es for Clay = 25 Mpa = 25 x 10^3 kN/m^2
   (As per "Foundation analysis and Design" by Bowles, Pg. No. 125)
4. Poisson's ratio μ = 0.4
   (As per "Foundation analysis and Design" by Bowles, Pg. No. 123)
5. Width of Foundation = 2m

Settlement $S_i = I * Q_s * B (1- \mu^2) / E_s$

Q_s = Pressure, Si = Immediate Settlement, I = Influence Factor,
B = Width of Foundation, μ = Poisson's ratio, E_s = Elastic Modulus

S_i = $(0.95 \times 40 \times 2 (1- 0.4^2) / (25 \times 10^3)$
= 0.00255m
= 2.55 mm

Settlement = 2.55 mm < 50mm. Hence safe

The maximum settlement for sand and Hard Clay as per IS 1904 -1986 will be 50mm. (Details Enclosed)

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TABLE 1 PERMISSIBLE DIFFERENTIAL SETTLEMENTS AND TILT (ANGULAR DISTORTION) FOR SHALLOW FOUNDATION IN SOILS

(*Clause* 16.3.4)

Sl No.	Type of Structure	Isolated Foundations						Raft Foundations					
		Sand and Hard Clay			Plastic Clay			Sand and Hard Clay			Plastic Clay		
		Maximum settlement	Differential settlement	Angular distortion	Maximum settlement	Differential settlement	Angular distortion	Maximum settlement	Differential settlement	Angular distortion	Maximum settlement	Differential settlement	Angular distortion
		mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
i)	For steel structure	50	·003 3L	1/300	50	·003 3L	1/300	75	·003 3L	1/300	100	·003 3L	1/300
ii)	For reinforced concrete structures	50	·001 5L	1/666	75	·001 5L	1/666	75	·002 1L	1/500	100	·002L	1/500
iii)	For multistoreyed buildings												
	a) RC or steel framed buildings with panel walls	60	·002L	1/500	75	·002L	1/500	75	0·002 5L	1/400	125	0·003 3L	1/300
	b) For load bearing walls												
	1) L/H — 2+	60	·000 2L	1/5 000	60	·000 2L	1/5 000	Not likely to be encountered					
	2) L/H — 7+	60	·000 4L	1/2 500	60	·000 4L	1/2 500						
iv)	For water towers and silos	50	·001 5L	1/666	75	·001 5L	1/666	100	·002 5L	1/400	125	·002 5L	1/400

NOTE — The values given in the table may be taken only as a guide and the permissible total settlement/different settlement and tilt (angular distortion) in each case should be decided as per requirements of the designer.

L denotes the length of deflected part of wall/raft or centre-to-centre distance between columns.

H denotes the height of wall from foundation footing.

+For intermediate ratios of L/H, the values can be interpolated.

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SAFE BEARING CAPACITY RESULTS

4. Calculation of Safe bearing capacity of the soil:

4.2 Safe Bearing capacity of soil based on SPT values for Bore Holes 1 & 2

Bore Hole No.	Depth (m)	SPT value	Safe Bearing capacity of soil	
			KN/m^2	t/m^2
BH – 1	1.50	4	8.49	0.84
	3.00	5	16.99	1.69
	4.50	6	25.49	2.54
	6.00	6	25.49	2.54
	7.00	5	16.99	1.69
BH – 2	1.50	8	42.48	4.24
	3.00	11	67.97	6.79
	4.50	12	76.47	7.64
	6.00	12	76.47	7.64

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4.3 Safe Bearing capacity of soil based on Shear Failure Criteria:

Through Unconfined Compression Test (UCC)

Bore Hole No.	Depth (m)	Max. Load (Div)	Max. Deformation (Div)	Cohesion (t/m^2)	Safe Bearing capacity of soil (t/m^2)
BH – 1	3.00	15	60	2.10	3.60
	4.50	20	70	2.80	4.79
	6.00	22	70	3.08	5.27
BH – 2	1.50	25	75	3.49	5.99
	4.50	35	85	4.88	8.37
	6.00	38	85	5.30	9.08

Direct Shear test for Bore Hole 1

Bore Hole No.	Depth (m)	Normal Stress (kg/cm^2)	Division	Ø (in degrees)	Safe Bearing Capacity of Soil (t/m^2)
BH - 1	1.50	0.5 1.0 1.5	23 66 110	26.58°	9.19
	7.00	0.5 1.0 1.5	23 66 111	26.84°	27.88

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Direct Shear test for Bore Hole 2

Bore Hole No.	Depth (m)	Normal Stress (kg/cm^2)	Division	Ø (in degrees)	Safe Bearing Capacity of Soil (t/m^2)
BH - 2	1.50	0.5 1.0 1.5	23 67 113	27.36°	10.22
	3.00	0.5 1.0 1.5	23 69 115	27.88°	16.55
	4.50	0.5 1.0 1.5	23 70 116	28.14°	22.85
	6.00	0.5 1.0 1.5	23 71 117	28.39°	29.46

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4.4 Comparison of Safe bearing capacity of soil through Shear and Settlement consideration:

Bore Hole no.	Depth (m)	Safe Bearing Capacity (t/m^2)		
		Shear consideration		Settlement consideration
		(UCC)	(Direct Shear)	
BH – 1	1.50	---	9.19	0.84
	3.00	3.60	---	1.69
	4.50	4.79	---	2.54
	6.00	5.27	---	2.54
	7.00	---	27.88	1.69
BH – 2	1.50	5.99	10.22	4.24
	3.00	---	16.55	6.79
	4.50	8.37	22.85	7.64
	6.00	9.08	29.46	7.64

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5. Result:

5.1 Recommended Safe bearing capacity values at different depths

Considering the lesser value of the above, the Safe Bearing Capacity, values at different depths are recommended below:

Bore Hole	Depth (m)	Safe Bearing Capacity (t/m^2)
BH – 1	1.50	0.84
	3.00	1.69
	4.50	2.54
	6.00	2.54
	7.00	1.69
BH – 2	1.50	4.24
	3.00	6.79
	4.50	7.64
	6.00	7.64

The above test data and findings are relevant and applicable only for the soil conditions existing at the test site. Any change in the soil strata observed during excavation may be reported to the laboratory, which will redefine the safe bearing capacity of the soil.

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SOIL SAMPLE PHOTOS

0



7m

Bore Hole No: 1

Depth : 0 to 7m

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0



6m

Bore Hole No: 2

Depth : 0 to 6m

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SITE PHOTO



Kumbakonathan Salai, Thiruvanaikovil, Trichy

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ANNEXURE

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Annexure - A

NATURAL MOISTURE CONTENT
(As per IS 2720 (Part - 2) - 1973)

Project Name : **Soil investigation for Construction of Residential Apartment Building at Kumbakonathan Salai, Thiruvanaikovil, Trichy**

Bore Hole No. : **1**

Depth : **3m**

Trial	Wt of container (W) gm	Wt of container +wet soil (W_1) gm	Wt of container + Dry soil (W_2) gm	Wt of Water ($W_3 = W_1-W_2$) gm	Wt of Dry Soil ($W_4 = W_2-W$) gm	Water Content (%) = $(W_3-W_4)*100$
1	21.90	50.80	45.90	4.9	24.0	20.42
2	22.00	56.20	50.40	5.8	28.4	20.42
3	20.45	55.10	49.20	5.9	28.8	20.52

Natural Moisture Content = 20.45

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Annexure - B

SPECIFIC GRAVITY TEST
(As per IS 2720 (Part - 3) - 1980)

Project Name : **Soil investigation for Construction of Residential Apartment Building at Kumbakonathan Salai, Thiruvanaikovil, Trichy**

Bore Hole No. : 1

Depth : 3m

Trial	Bottle Wt (W1) gm	Bottle + Sample (W2) gm	Bottle + Sample + Water (W3) gm	Bottle + Water (W4) gm	Specific Gravity
1	32.6	92.8	118.0	80.8	2.617
2	32.6	91.4	117.1	80.8	2.613
3	32.6	93.6	118.4	80.8	2.607

Specific gravity of Fine Aggregate = 2.61

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Annexure - C

DENSITY CALCULATION

Project Name : **Soil investigation for Construction of Residential Apartment Building at Kumbakonathan Salai, Thiruvanaikovil, Trichy**

Bore Hole No. : 1

Depth : 3m

Sl. No.	Description	Reading
1	Weight of Empty Box (gm)	630.00
2	Weight of Box + Soil (gm)	793.00
3	Weight of Soil (gm)	163.00
4	Volume of Box (cm^3)	90.00
5	**Bulk Density (gm/cm^3)**	**1.81**
6	Weight of Container (gm)	21.90
7	Weight of Container + Wet Soil (gm)	50.80
8	Weight of Container + Dry Soil (gm)	45.90
9	Moisture Content (%)	20.42
10	**Dry Density (gm/cm^3)**	**1.50**

Result

Bulk Density of Soil = 1.81

Dry Density of Soil = 1.50

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Annexure - D

POROSITY & VOID RATIO

Project Name : **Soil investigation for Construction of Residential Apartment Building at Kumbakonathan Salai, Thiruvanaikovil, Trichy**

Bore Hole No. : **1**

Depth : **3m**

Sl. No.	Description	Reading
1	Dry Density γ_d (gm/cm^3)	1.50
2	Specific gravity (G_s)	2.61
	Porosity (%)	$(1 - (\gamma d/Gs))*100$
		(1-(1.50/2.61)) x 100 = 42.52
3	**Porosity (%)**	**42**
	Void Ratio, (e)	$\eta/(1-\eta)$
		0.4252/(1-0.4252)
4	**Void Ratio**	**0.74**

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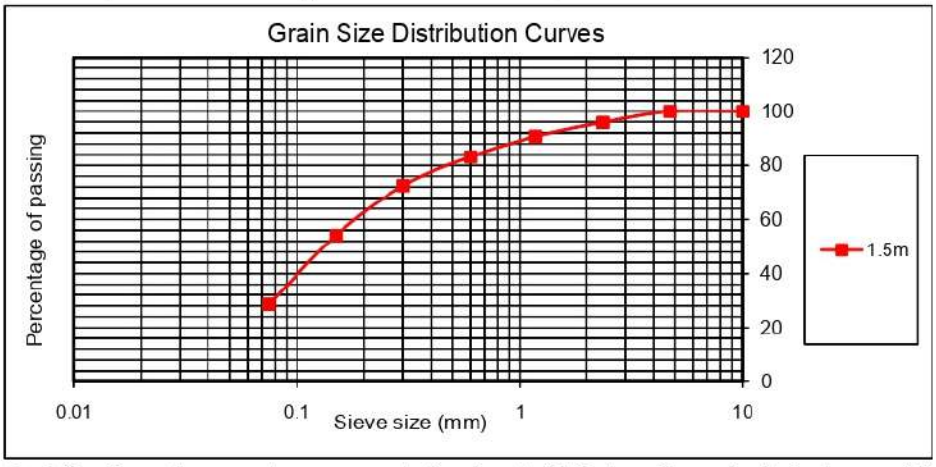
Annexure - E

FINENESS MODULUS TEST

(As per IS 2720 (Part - 4) - 1985)

Project Name : **Soil investigation for Construction of Residential Apartment Building at Kumbakonathan Salai, Thiruvanaikovil, Trichy**
Bore Hole No. : **1**
Depth : **1.5m**

Sieve size (mm)	Weight retained (gm)	Cumulative Weight retained (gm)	Percentage cumulative weight retained (gm)	Percentage of passing
10	0	0.0	0.0	100.0
4.75	0	0.0	0.0	100.0
2.36	2.3	2.3	2.3	97.7
1.18	3.8	6.1	6.1	93.9
0.6	7.6	13.7	13.7	86.3
0.3	8.2	21.9	21.9	78.1
0.15	27.1	49.0	49.0	51.0
0.075	35.4	84.4	84.4	15.6
Pan	15.6	100.0	100.0	0.0



Based on Gradation Curve, the percentge component of each materials in the soil sample obtained are as follows (As per IS 1498 - 1970).

Gravel (%)	0
Coarse Sand (%)	6.1
Medium Sand (%)	15.8
Fine sand (%)	62.5
Silt & Clay (%)	15.6

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Annexure - F

Direct Shear Test (IS 2720 - Part 13 -1986)

Bore Hole	1
Depth (m)	3m
Date of Test	07.12.2023

L.C. Of Dial Gauge	0.002
Proving ring Constant	0.206996
Area of the specimen (cm^2)	36

Trial 1

Normal Stress: 0.5 kg/cm^2

Horizontal Gauge Reading	Proving Ring Reading	Shear Deformation	Shear Stress (kg/cm^2)
0	0	0.00	0.000
50	9	0.50	0.052
100	11	1.00	0.063
150	13	1.50	0.075
200	15	2.00	0.086
250	17	2.50	0.098
300	19	3.00	0.109
350	21	3.50	0.121
400	23	4.00	0.132

Trial 2

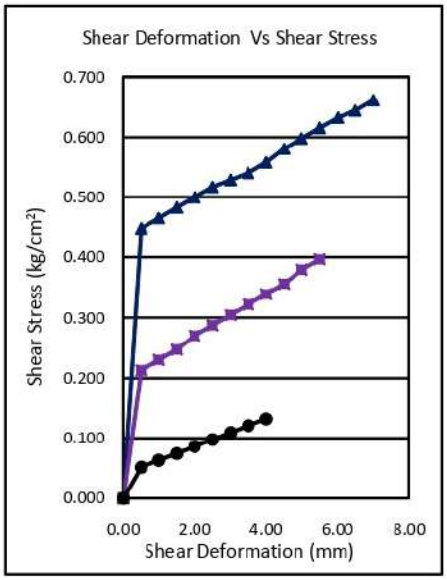
Normal Stress: 1 kg/cm^2

Horizontal Gauge Reading	Proving Ring Reading	Shear Deformation	Shear Stress (kg/cm^2)
0	0	0.00	0.000
50	37	0.50	0.213
100	40	1.00	0.230
150	43	1.50	0.247
200	47	2.00	0.270
250	50	2.50	0.287
300	53	3.00	0.305
350	56	3.50	0.322
400	59	4.00	0.339
450	62	4.50	0.356
500	66	5.00	0.379
550	69	5.50	0.397

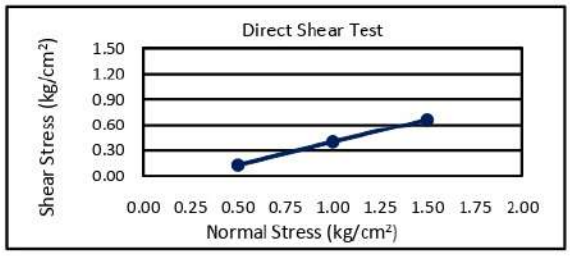
Trial 3

Normal Stress: 1.5 kg/cm^2

Horizontal Gauge Reading	Proving Ring Reading	Shear Deformation	Shear Stress (kg/cm^2)
0	0	0.00	0.000
50	78	0.50	0.448
100	81	1.00	0.466
150	84	1.50	0.483
200	87	2.00	0.500
250	90	2.50	0.517
300	92	3.00	0.529
350	94	3.50	0.540
400	97	4.00	0.558
450	101	4.50	0.581
500	104	5.00	0.598
550	107	5.50	0.615
600	110	6.00	0.632
650	112	6.50	0.644
700	115	7.00	0.661



Normal Stress (Kg/cm^2)	Proving Ring Reading at failure	Shear Stress (kg/cm^2)
0.50	23	0.132
1.00	69	0.397
1.50	115	0.661



Ø = $\tan^{-1}$ (0.661 - 0.132)

Angle of Shearing Resistance (Ø) = 27.88 °

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