DEEP FOUNDATIONS INSTITUTE
DFI
FINDING COMMON GROUND

Deep Foundations Institute of India

Students outreach initiative "Groundwork"

Laying Foundation for the Next Generation Foundation Practitioners

Problem solving competition – Level 2

Submit before end of 10 October 2021 @ activities@dfi-india.org

The competition is meant to introduce field problems to the students to improve the analytical skill.
There are FIVE problems stated in the following sheets, and any THREE problems shall be attempted.
Up to maximum five students can group together to submit one set of solutions.
One group can submit only one set of solutions.
One student can be part of only any one group.
The solution sets shall be prepared using wide screen PPT, each problem covered in two to three sheets (as far as possible).
There is no participation fee for this competition. Each participating student will receive a participation certificate. All participating students will automatically become DFI student member with access to several technical reference material.

The authors of these two solutions will get free registration for the full conference. Merit certificates shall be presented to all the students submitting the best two solution sets.
If there are identical solution sets, those may be excluded from the competition.
Any questions about the competition can be asked to activities@dfi-india.org. Visit www.dfi.org/India2021 for the conference details and other contact information.

Students are encouraged to look for suitable reference material and relevant IS codes for guiding to the solutions.

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Details of the Students (all details are required)

Sl No	Full Name	Programme	Year of completion	Roll No	Institution	Regn*
Name of the Reference Faculty						
Email and phone number of the Faculty						
Contact details of one of the students						
Date of submission						

Regn* - All the participants shall register GoToWebinar link of DFI of India. Registration is free. https://attendee.gotowebinar.com/register/5797868161383527181. It is suggested that all the students register at this link for future communication

PROBLEM 1

Estimation of Pile Capacity

Problem:

Shown is the subsoil conditions of a construction site. The SPT N values are close to N_{55} to N_{60}. Driven cast-in-situ piles of 500mm diameter need to be constructed to support an industrial structure. The piles shall be 18.0m long from the ground level. Also provided the pile driving record for 18.0m long pile. Ground water table is at 1.50m below ground.

Solutions required:

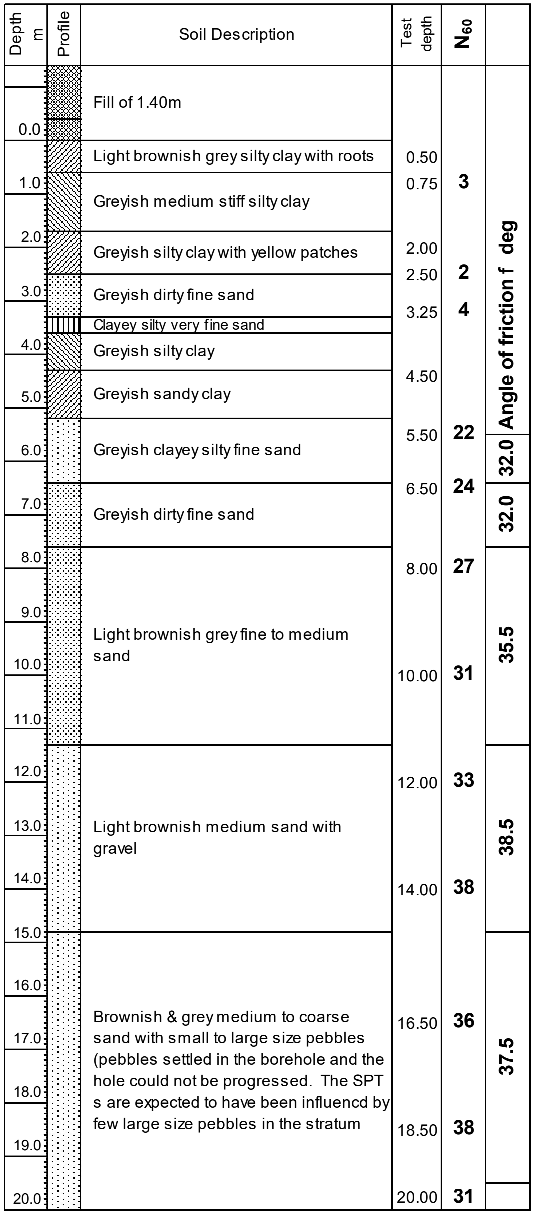
Solution 1: Estimate the ultimate compression capacity of 500mm diameter driven cast-in-situ pile driven up to 18.0m depth.

Hint:

In the case of driven cast-in-situ pile, a thick steel tube is placed over a dispensable (sacrificial) steel shoe and driven into the ground using 3 tonne to 5 tonne drop hammer. After driving to 18.0m depth, reinforcement steel is lowered into the steel tube and then concrete with high slump is poured into the tube. The steel tube is withdrawn once it is filled with concrete. The steel shoe remains at the final driving depth. The concrete is allowed to set in place. Ref IS 2911 Part 1, Section1, IS 2911 Part 4.

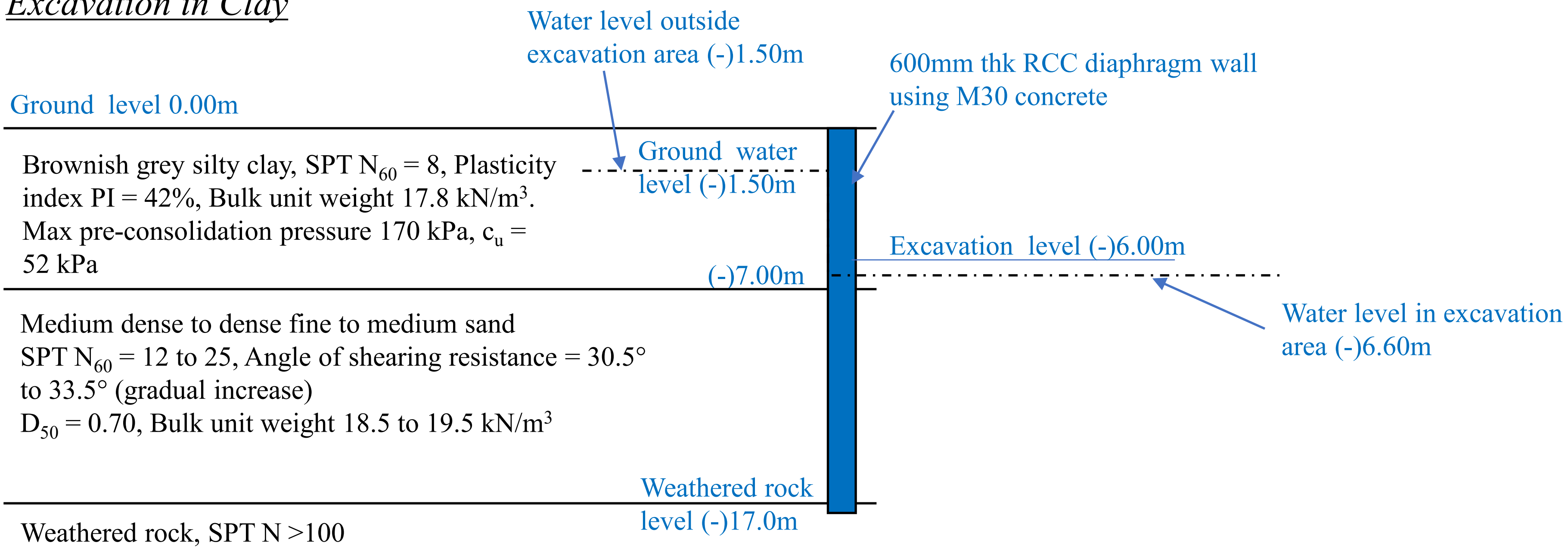
Bulk unit weight of the soil layers may be selected based on the SPT N values. Possible range is 17.0 kN/m^3 (top clayey soil layers) to 20.0 kN/m^3 (for bottom sand layer).

The end bearing resistance may be 80% to 85% of average static cone resistance at the pile base. The side friction from the top 5.20m clayey soil may be neglected. Side friction and base resistance (end bearing) shall be estimated separately.



PROBLEM 2

Excavation in Clay



Water level outside excavation area (-)1.50m

600mm thk RCC diaphragm wall using M30 concrete

Ground level 0.00m

Brownish grey silty clay, SPT N_{60} = 8, Plasticity index PI = 42%, Bulk unit weight 17.8 kN/m^3. Max pre-consolidation pressure 170 kPa, c_u = 52 kPa

Ground water level (-)1.50m

Excavation level (-)6.00m

(-)7.00m

Water level in excavation area (-)6.60m

Medium dense to dense fine to medium sand
SPT N_{60} = 12 to 25, Angle of shearing resistance = 30.5° to 33.5° (gradual increase)
D_{50} = 0.70, Bulk unit weight 18.5 to 19.5 kN/m^3

Weathered rock level (-)17.0m

Weathered rock, SPT N >100

Problem:

Shown in the figure is the subsoil conditions of a construction site. Excavation up to (-)6.0m is made after constructing a 600mm thick RCC diaphragm wall up to (-)17.5m, penetrating 500mm into weathered rock. Static water levels during excavation is (-)1.50m and (-)6.60m respectively outside and inside excavation area. Excavation is gradual and completed in 10 days.

Solutions required:

Estimate the forces and moments on the diaphragm wall after excavation up to (-)6.0m. All components of the forces shall be shown separately and combinedly.

Additional data:

The excavation is uniform and for short duration. Ground water table is gradually lowered as the excavation progresses. There is no seepage below the base of the diaphragm wall

PROBLEM 3

Ground Treatment- Stone Columns

Problem:

Shown here is the soil profile of an oil storage tank construction site. The entire site is to be graded with 2.0m thick fill before tank construction.

36m diameter MS tank for storing oil for 16m height needs to be constructed. The free-board above 16.0m is 1.0m. The specific gravity of the oil is 0.82. The tank will be hydrotested for the full 16.5m over a period of 30 days.

After the site grading with 2.0m thick sand layer, 800mm diameter stone columns shall be installed to a total depth of 14.50m (12.5m below NGL). The stone columns will be connected at the surface by replacing the sand with well compacted stone layer for 500mm thickness.

Solutions required:

Solution 1: Estimate the short-term settlement under 2.0m site grading assuming bulk unit weight 18.0 kN/m^3.

Solution 2: Estimate the spacing of the stone columns to ensure safe bearing capacity = 210 kN/m^2. Estimate the total settlement at the centre of the tank and periphery of the tank under hydrotest for 30 days gradual loading. Estimate the long-term settlement under the product load.

Hint:

The total load intensity at the tank base during the hydrotest is for 17.0m high water column ignoring the tank self weight. The product load is corresponding to 16.0m oil column. Critical depth for the stone column may be taken as 2.0m below the NGL. The maximum past consolidation pressure P_c of the top clay may be estimated from the undrained shear strength and index properties.

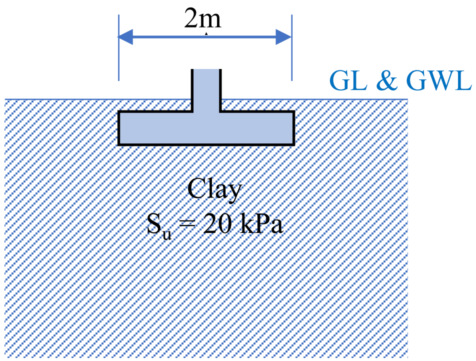
Depth, m	Soil Type	SPT N_{60} (field)	Other parameters
NGL to 3.7m	Clayey silt/silty clay	1.3m – 2 2.3m – 2 3.0m – 2	BU – 18.1 kN/m^3. S_u=c_u=25 kPa, LL – 57%, PI – 32%, NMC – 43%, FC 80 to 95%. Coefficient of consolidation c_v is 1.5 m^2 /year and c_h is 2.5 m^2/year
3.7m to 7.5m	Clayey fine sand	4.0m – 4 6.0m – 5 7.0m – 5	BU – 19.2 kN/m^3. FC 45%, D50 0.143
7.5m to 11.0m	Silty sand / fine sand	8.0m – 8 9.0m – 8 10.5m – 8	BU – 19.5 kN/m^3. FC 11%, D50 0.14
11.0m to 14.0m	Fine Sand	11.5m – 15 13.0m - 22	BU – 19.8 kN/m^3. FC 6%, D50 0.11
14.0m to 18.0m	Silty clay	14.0m – 19 15.0m – 19 15.5m – 22 17.0m – 25	BU – 19.5 kN/m^3. FC 70%, LL = 63%, PI = 38%, NMC = 33%. Consolidation parameters as for the topsoil.
18.0m to 24.0m	Fine sand	N = 21 to 22	BU – 19.8 kN/m^3. FC 7%, D50 0.185
24.0m to 30.0m	Fine sand	N = 24 to 29	BU – 19.8 kN/m^3. FC 7%, D50 0.192
Below 30.0m	Sand	N >100	BU – 21.0 kN/m^3.
The ground water table is at 1.70m below NGL. The filling sand has relative density 78% and comprises fine to medium grain size. D50 is 0.22. The SPT N of the compacted sand is 12. BU is bulk unit weight, LL is liquid limit, PI is plasticity index, NMC is natural moisture content and FC is fines content smaller than 75 microns.			

PROBLEM 4

Foundation on Soft Clay

Problem:

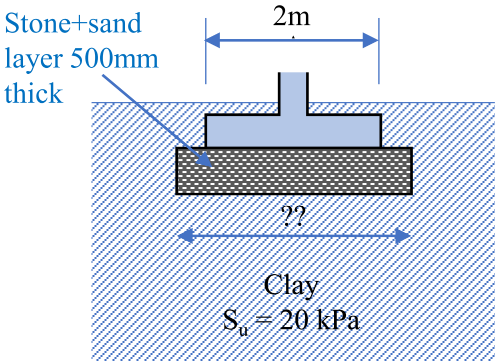
The sub-soil profile of a construction site comprises 14.0m thick clay with uniform undrained shear strength 20 kPa. The undrained modulus E_s is 8 MPa. A large storage shed needs to be constructed. The designer proposed 2.0m wide strip footing on either side of the shed to support the columns and roughly 5.5m high wall. The footings is to be placed at 0.50m below ground level. The average load intensity over the 2.0m wide footing is 200 kN/m length of the strip including the weight of the foundation.



Solutions required:

Solution 1: State whether the 2.0m wide footing at 0.50m can support the design load of 100 kPa with necessary estimations. The factor of safety against bearing capacity failure shall be 3. What is the stress increment at 0.50m depth below the foundation depth (i.e. 1.0m below NGL) under the foundation load. Draw the shape of the contact stress assuming that the footing is rigid.

Solution 2: State, with necessary estimations, whether a 500mm thick stone + sand layer below the strip footing can improve the bearing capacity to support the design load of 200 kN/m length of the strip. Please suggest the minimum width of the stone+ sand layer. The well compacted stone + sand layer can offer angle of shearing resistance 45 deg. What is the stress increment at the bottom of the stone + sand layer under foundation load. Draw the shape of the contact stress distribution assuming the footing is rigid.



Solution 3: State with necessary supporting parameters whether the clay is likely to be subjected to consolidation settlement. List down the parameters required for estimating the consolidation settlement.

Additional information and hints:

The clay is highly plastic with liquid limit 67% and plasticity index 41%. The natural moisture content before construction is 47.5%. The ground water table is 0.50m below natural ground level. The initial excess pore pressure in the clay layer is zero.

Contact stress distribution under a rigid footing is not uniform and it depends on the type of foundation soil.

For solution 2, the load dispersion in very stiff soil over weak soil is flatter.

PROBLEM 5

Load testing of Driven Cast-in-Situ Pile

Problem:

The load-settlement data obtained from a static load test on 500mm diameter driven cast-in-situ pile installed through sandy soil up to a depth of 18.0m is presented here. The pile was constructed by driving a thick steel tube placed over a sacrificial steel shoe by the impact of a 4.2m tonne drop hammer. Refer Problem 2.

The load was applied on the pile top and the settlement was observed from the micrometer gauges placed over the pile head. The concrete used in the pile is equivalent to concrete grade M30.

Each load increment was maintained for minimum one hour before applying the next load increment. Wherever the rate of settlement was large, the load was maintained for 90 minutes to 120 minutes.

The ground water table was at 1.50m below the ground level.

Solutions required:

Solution 1: Plot the load-settlement curve with load on x axis and settlement on y axis. Use the fourth quadrant. Extrapolate the maximum load capacity using any standard curve fitting procedure.

Solution 2: Make a prediction of side friction and end bearing at 12mm pile head displacement. The soil profile given in problem 1 is applicable to this problem.

Solution 3: When the soil conditions are matching with the details given in problem 1, how does the maximum load capacity estimation compare with the load test results.

Additional information and hints:

The load test was carried out using standard procedure described in IS 2911 Part 4. Extrapolation method suggested by Chin using hyperbolic curve fitting is a useful tool when the pile has moved more than 5% of the pile diameter. Please note that almost the entire side friction is mobilised during a short pile displacement while the mobilisation of full base resistance needs large displacement (solution 2).

Load settlement data from static load test using maintained load test procedure in IS 2911 Part 4

Load kN	Pile head settlement mm (average of 4)
0	0.00
250	0.59
490	1.42
710	2.60
930	3.90
1120	5.82
1300	7.82
1500	11.00
1700	14.20
1930	17.53
2120	21.33
2330	26.43
2500	33.31
2730	53.87

Note: The settlement values are marginally adjusted for the possible pressure gauge variations.