DESIGNING OF TWO STOREY BUILDING WITH ITS FOUNDATION USING TERZAGHI EQUATION

Submitted in partial fulfillment of the Degree of
Bachelor of Technology

May - 2014

Enrollment. No. - 101649
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JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY,
WAKNAGHAT

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CERTIFICATE

This is to certify that the work titled **“Designing of two storied with its foundation using Terzaghi equation”** submitted by **“Choki Dorji”** in partial fulfillment for the award of degree of B. Tech in Civil Engineering program of Jaypee University of Information Technology, Waknaghat has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

Project Supervisor

Dr. S.K Jain	**Prof. Dr.Ashok. K. Gupta**
Associate professor	Head of Department
Department of Civil Engg.	Department of Civil Engg.

Date ……………………..

DECLARATION

I hereby declare that the project work entitled **“Designing of two storied with its foundation using Terzaghi equation”** submitted to JUIT, Waknaghat is a record of an original work done by me under the guidance of **Dr. S.K. Jain** and this project work is submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering. The results embodied in this thesis have not been submitted to any other university of Institute for the award of any degree or diploma.

ACKNOWLEDGEMENT

I would like to take this opportunity to express our heart filled thanks to all the people who has directly or indirectly given a hand in making this project possible. I would especially like to thank the faculty and the staff members of the Civil Engineering Department, JUIT, Waknaghat who has always been supportive and made this project possible.

I would like to thank my project supervisor Dr. S.K Jain for giving me opportunity to do this project on such a beneficial topic for my career and guiding me throughout the whole project. Without his presence this project would not have been possible.

I would like to share my gratitude to Mr. Lav Singh for clearing all my queries regarding the design part of the project. He had been very helpful and supportive.

I offer my sincere thanks to all my colleagues, friends and family for their continuous support.

Signature of the
student

Choki Dorji
101649

Date

SUMMARY

My project that is “Designing of two storey building with its foundation” basically deals with the designing of a two storey building along with the design of its foundation. To carry out the project, we were given with different data like:

Plan of boring

Boring logs

Laboratory test data

In situ test data

Firstly considering the test data I created soil profiles along three different sections. I then created an idealized soil profile by combining and averaging the values such as depth of various sections, the densities of each section etc. For the idealized soil profile I found out different soil properties like c, ø etc.

After that I progressed to modeling of the building on STAAD PRO and analyzing it so that we can get the reactions at the base. This way we can get the actual load that would be coming on the foundation.

Thereafter different components of the building like beam, column, slab and foundation were designed. The designing was done according to design procedures given in IS 456: 2000 taking the loads as specified in IS 875. The designing would be done inclining more towards safety rather than economy and I am doing so by firstly looking into all the conditions and picking the worst case scenario. I am designing for that scenario and that section would be provided for all other parts too and this will ensure that my structure is safe on all parts.

LIST OF FIGURES:

CHAPTER 1

INTRODUCTION

For a civil engineer or civil engineering student, designing building may be his cup of tea but often problems occur when the same engineer has to deal with the geological part that is designing of foundation of the same building. Such problems mainly occur because in colleges, even though all the aspects of civil engineering such as building bridges, constructing buildings, making highways, designing foundation etc. are taught, students tend to incline towards one particular course. Moreover students take particular electives which they think they might excel in. There is nothing wrong in doing so but students tend to face difficulties later when expertise in one course is not enough. Our project is such a work in which we not only design a building but also its foundation using the loads computed that is knowledge of more than one subject is incorporated in our project.

Yet my project is a very simple one that is to build a two storey building with its foundation. I firstly study the data we have in hand. I was provided with data like bore log data, consolidation data, etc. Then we create a soil profile on which building will stand. We then find different soil parameters. Based on these soil parameters we have to find the bearing capacity and settlement criterion and later on, check whether our designed foundation is sufficient or not.

We design the two storey building by assuming data like the clear height between floors, dimension of elements and their quantity. The building is designed on STAADPRO and manual calculations are done to verify the sufficiency of the design.

In short the project mainly revolves around designing different elements of the building and verifying their adequacy by means of various methods and methodologies.

CHAPTER 2

MATERIALS, METHODS AND METHODOLOGIES

Materials

The detailed site investigation data has been provided. The site investigation involved geotechnical drilling, sampling and laboratory testing.

Data provided (Refer to appendix):

Plan of boring

Boring logs

Laboratory test data

In situ test data

Methods and Methodologies

For the design of superstructure, software like STAAD PRO and Auto cad are most likely to be used. The design method would basically be limit state method. The load computations will be done automatically by these soft wares, if not other methods may be applied.

To find bearing capacity of soil, various properties of soil are to be looked into and an idealized soil profile is be created. The formulas supplied by IS code for bearing capacity and settlement of foundation is to be programmed on C to make the calculations easier.

The soil profile and drawings such as that of reinforcement placements are to be drawn by hand on charts. Comparison between manual calculations and STAAD PRO results will also be made.

The type of foundation to support the building would be determined by rough approximate methods and if shallow foundations are recommended, design charts would be developed for sizing the spread footings for various column load ranges.

CHAPTER 3

SOIL PROFILES AND SOIL PARAMETERS

Idealized soil profile

Soil profile refers to the layers of soil horizon such as the top soil, subsoil and bed rock layer but from a geotechnical engineers perspective it is a much detailed illustration of different layers formed by different type of soil such as clay, silt, sand etc.

Looking into the data of bore logs given, we created three soil profiles by analyzing for various features like depth, water table, stratum description and other information. We took step by step procedure as follows:

1. Selecting the section for which we are going to make the soil profile.

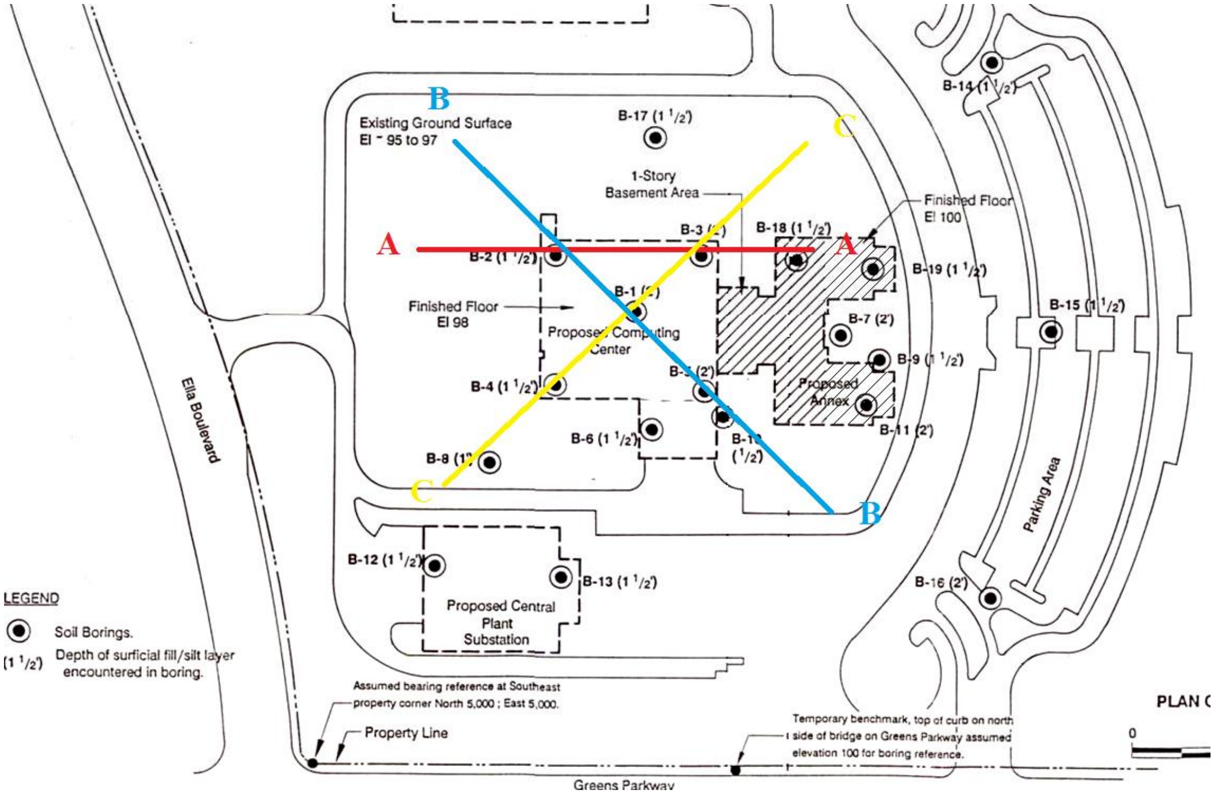


Figure 1: Plan of borings

1. Using a ruler to measure the distance between two consecutive bore holes along the section that we have chosen.

Taking the scale given in the plan and finding the exact distance between the bore holes.

- ❖ Scale for the given plan:
  - ► Vertical scale

    1 cm= 70.58ft
  - ► horizontal scale

    1cm= 21.51m

2. Choosing an appropriate scale(both horizontal and vertical) for our drawing sheet.

- ❖ Scale for our drawing sheet
  - ► Vertical scale

    1cm = 2ft
  - ► Horizontal scale

    1cm =10ft

3. Drawing the bore log data on the sheet.

4. After all data has been plotted, some rough indication of the profile will come into picture.

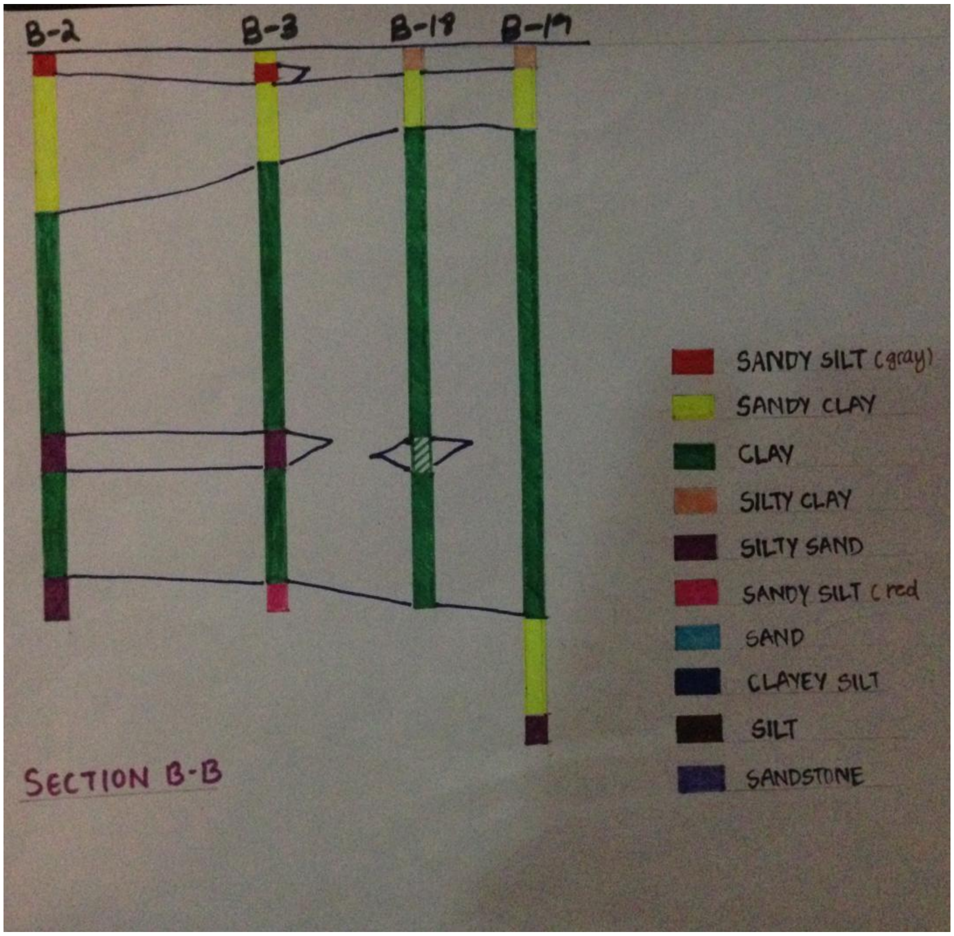


Figure 2: Soil profile of Section B-B

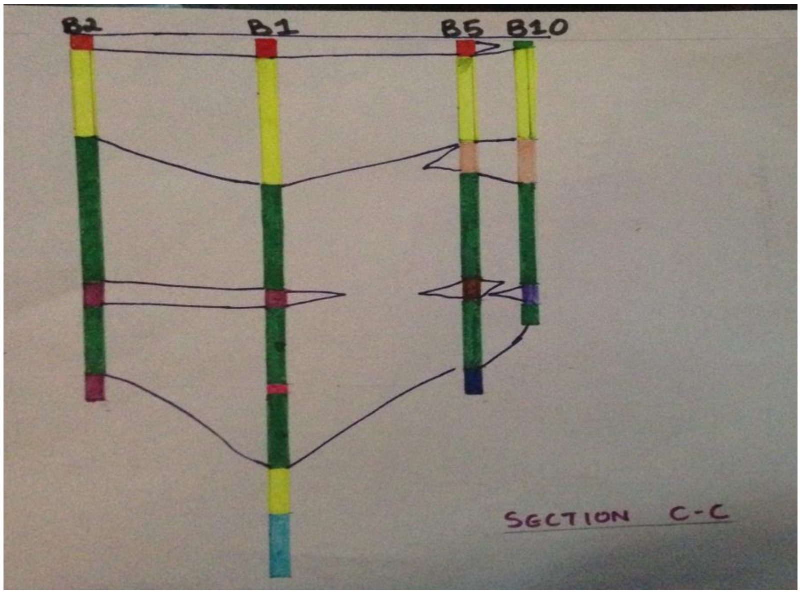


Figure 3: Soil profile of section C-C

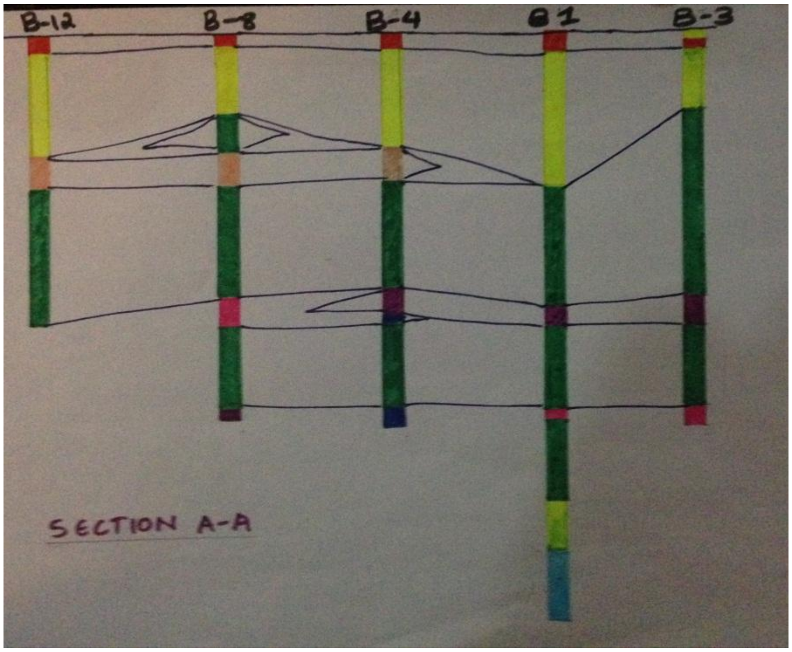


Figure 4: Soil profile of section A-A

5. Joining all the layers having same soil type and creating lenses too. This was done for all the three sections that we have chosen.

6. When all the three sections are done, an idealized soil profile is created by comparing and averaging the values of depth in each section and ignoring all the insignificant layers like lenses and all.

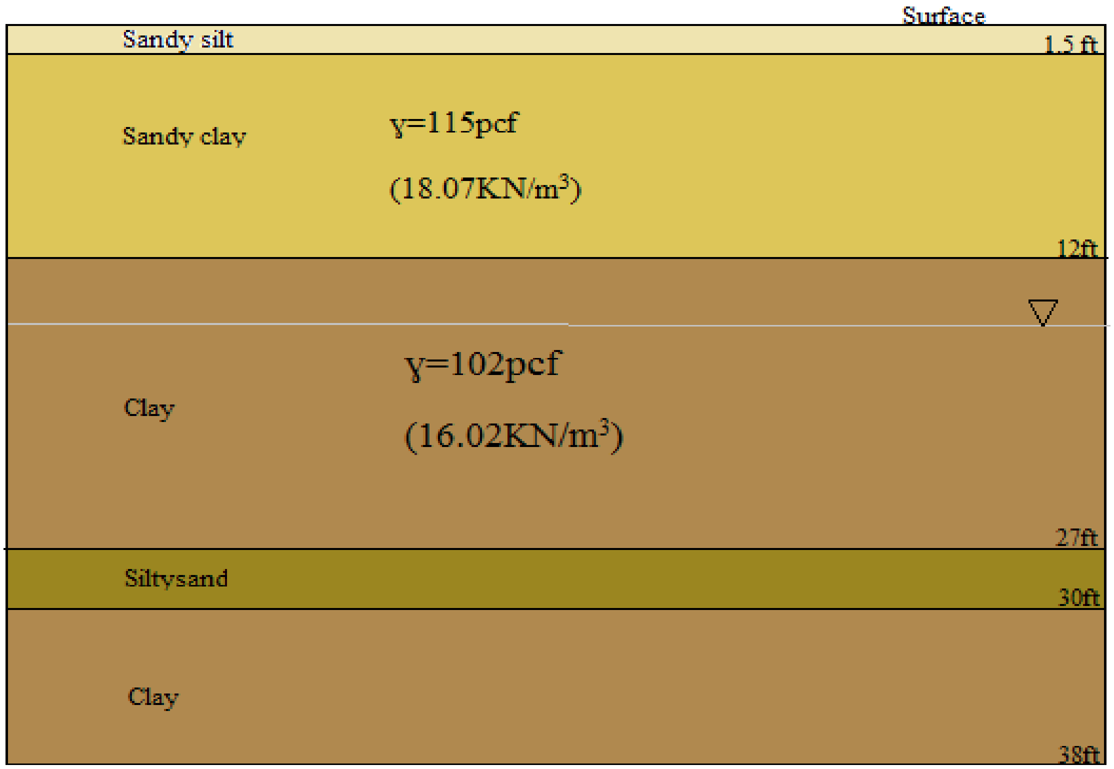
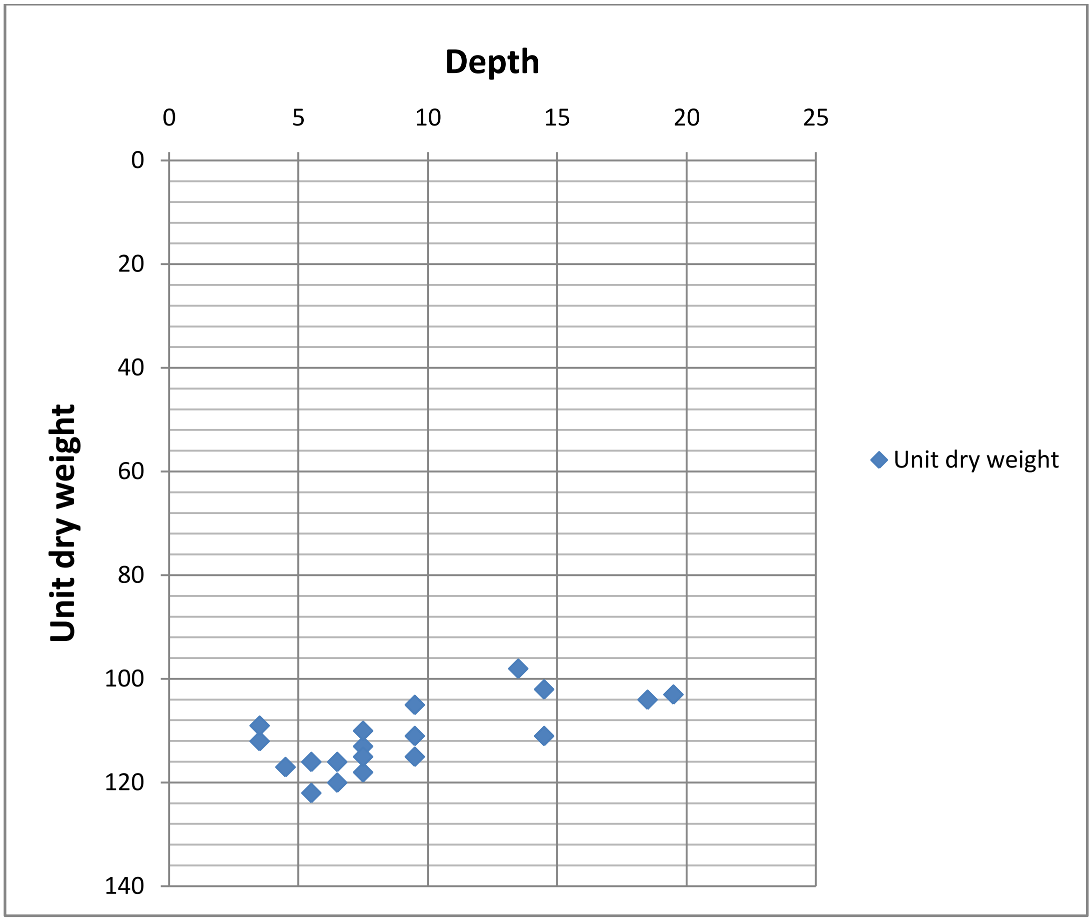


Figure 5: Idealized soil profile

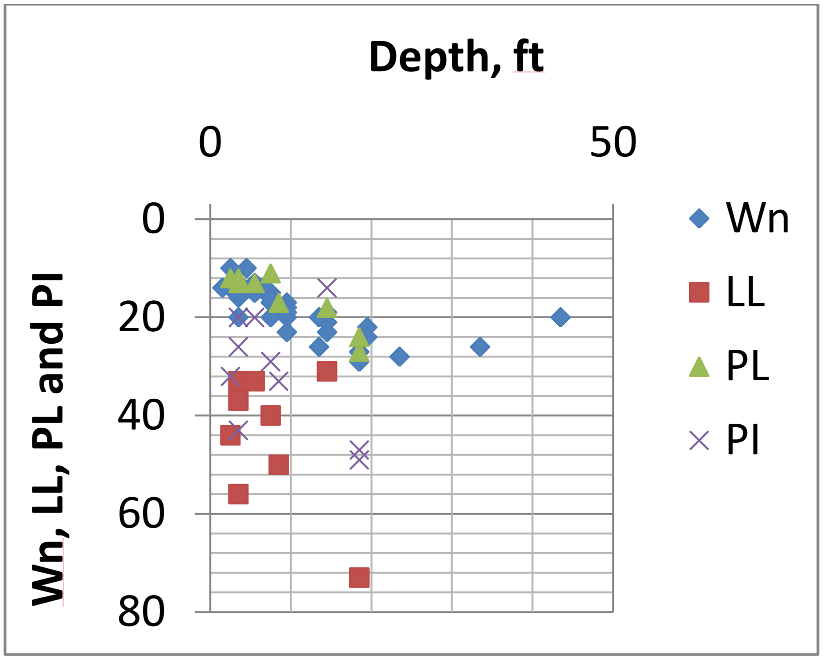
7. The depth of each layer is found by arithmetically averaging all the similar layers in each section. Some of the matchless soil layers and lenses are ignored.

Soil Parameters:

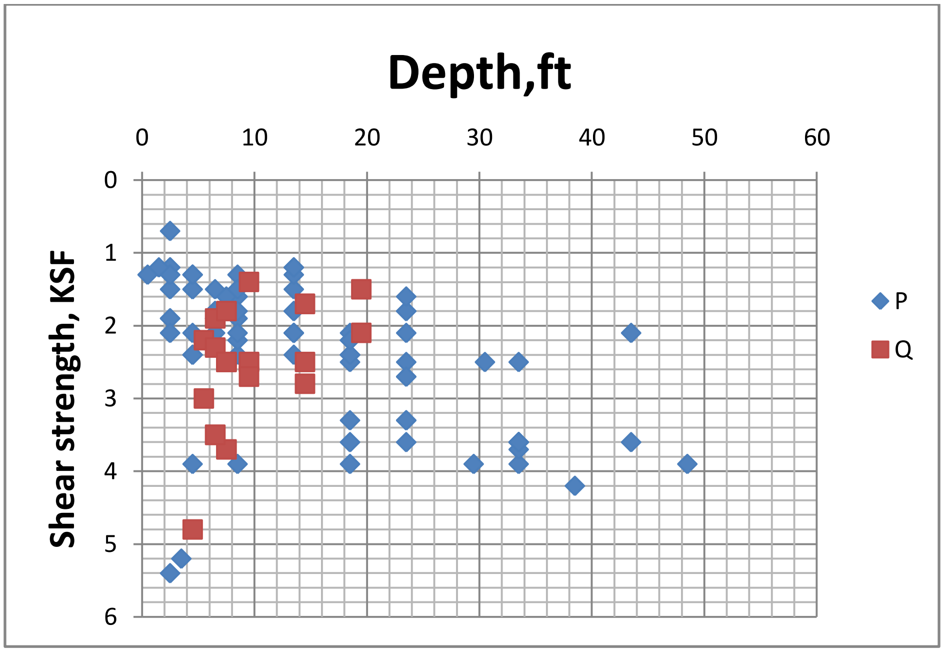
The computations of soil parameters are done by drawing the graph of each parameter against depth. After the graph is drawn, the value of different soil parameters like density, liquid limit, shear strength, etc. for each layer in the idealized soil profile are found by drawing the best fit line.



Graph 1: Depth v/s depth



Graph 2: Depth v/s liquid limit, plastic limit, plasticity index and water content



Graph 3: Depth v/s shear strength

CHAPTER 4

TYPES AND SELECTION OF FOUNDATION

Types of Foundation

Foundations can be classified into two general categories:

1. Shallow foundation

When the D/B ratio is less than 2

2. Deep foundation

When the D/B ratio is more than 2

There are further many other types or subdivisions of both shallow and deep foundations based on different functions, method of building, shape, etc.

In case of our building we are going with a shallow foundation because it’s only two storey high and shallow foundation will suffice to support the loads coming on it. But checks will be done to make sure the foundation provides enough safety and is able to bear the load of superstructure effectively.

General requirements of foundations

Foundations have to satisfy three basic criteria for a satisfactory performance. They are:

a) Location and depth criterion
b) Shear failure criterion or bearing capacity criterion
c) Settlement criterion

Location and depth criterion

The location and depth of foundation is taken such that there is no adverse effect because of factors such as lateral expulsion of soil from beneath the foundation, seasonal volume changes like due to freezing and thawing and presence of adjoining structure.

The depth of our foundation is initially being taken as 1.5m so that the foundation lies in the clay layer and gets enough bearing and friction from it.

Changes can be made if the depth was found to be inadequate.

Shear failure criterion or bearing capacity criterion

The foundation is provided with adequate factor of safety against shear failure or soil rupture.

Allowable bearing pressure is the maximum intensity of loading that can be imposed on the soil with no possibility of shear failure or the possibility of excessive settlement. The Indian Standard Code (IS: 6403-1981) refers to allowable bearing pressure by the name allowable bearing capacity.

For calculating the bearing capacity for our idealized soil profile, a program in C was made based on the formulas given in IS: 6403. The code is as given:

```
//Program to compute Bearing capacity//


#include<stdio.h>
#include<conio.h>
void main()
{
ints,tof;
float c,qu ,nc ,nq, b, nγ, q;
clrscr();
printf("\n Type of soil:\n");
printf("\n For cohesive soil press 0\n");
printf("\n For non-cohesive soil press any key other than 0\n");
scanf("%d",&s);
printf("\n Enter the type of soil failure\n");
printf("\n For local failure press 0\n");
printf("\n For general failure press any key other than 0\n");
scanf("%f",&tof);
printf("\n Enter the value of c\n");
scanf("%f",&c);
printf("\n Enter the value of nc\n");
scanf("%f",&nc);
printf("\n Enter the value of q\n");
```

```
scanf("%f",&q);
printf("\n Enter the value of n_q\n");
scanf("%f, &n_q");
printf ("\n Enter the value of n_γ\n");
scanf ("%f, &n_γ");
printf ("\n Enter the value of b\n");
scanf ("%f", &b);
if (s!=0 &&tof!=0)
{
q_u =(c*n_c)+(q*(n_q-1))+(0.5*b*n_γ);
printf ("\n The value of  ultimate bearing capacity q_u is:%f",q_u);
}
if (s!=0 &&tof==0)
{
q_u=(0.67*c*n_c)+(q*( n_q -1))+(0.5*b*n_γ);
printf("\n The value of ultimate bearing capacity q_u is:%f", q_u);
}
If(s==0 &&tof==0)
{
q_u =(q*( n_q -1))+(0.5*b* n_γ);
printf("\n The value of ultimate bearing capacity is q_u: %f", q_u);
}
getch();
}
```

CHAPTER 5

DESIGN OF SUPERSTRUCTURE

The project is continued with the design of superstructure .Basically, it will be a two-storey building that will be modeled and analyzed using STAAD PRO.

Dimension

The building will have following dimension:

- Cross section of the building: 60x60m
- Length of the beam:10m
- Height of the column: 5m
- Plinth level: 1.5m
- Cross section of the beam (Used in STAAD PRO) : 400x400mm
- Cross section of the column(Used in STAAD PRO): 500x500mm

Various loads acting on the superstructure

1. Imposed load or Live Load
2. Dead Load
3. Wind Load

Imposed load/Live load

Imposed loads are the minimum loads which should be taken into consideration for the purpose of structural safety of the building. This load is assumed to be produced by the intended use or the occupancy of the building including weight of the movable partition, distributed and concentrated loads, loads due to impact and vibration and dust load but excluding wind load, seismic load, snow load etc.

Imposed load in our case is taken on the basis of occupancy. Our building isa commercial building.

From IS 875-part 2, we took the imposed load for commercial building as $\underline{5kN/m^2}$.

NOTE: (We have not taken snow and rain load, so to compensate these loads and to accommodate processes like expansion of concrete etc. We have taken the same maximum value of imposed load even on the roof top.)

Dead load

Dead load includes the weight of all the permanent components of the building including walls, partitions, columns, floors, roofs, finished and fixed permanent equipment and fittings that are integral part of the building. Unit weight of the building materials is taken in accordance with IS: 875-part 1.

Regarding input of dead load in STAAD PRO, it can be done automatically but for the manual considerations we use the following method:

Unit weight of concrete: 25kN/m^3

Dead load of an element: 25x section of element

Wind load

Wind load is applied to take in account the static and dynamic effects of wind forces on the structures. Wind load will be estimated taking in account the variation in the wind speed with time. The effect of wind on the structure is determined by the combined action of external and internal pressures acting upon it.

Wind load is calculated in accordance to the IS: 875-part3.Firstly, design wind speed is calculated using the following formula:

$$V_z = V_b * k_1 * k_2 * k_3$$

Where,

V_z =design wind speed at any height z in m/s;

k_1=probability factor;

k_2=terrain height and structure size factor;

k_3=topography factor;

V_b= basic wind speed.

Using above formula and evaluating the values of k2, k3 and Vb, the value of design speed can be calculated. The wind pressure is given by

P_z=0.6 V_z^2

The plan of boring given to us is from Houston, Texas. The wind map of Houston is as shown below:

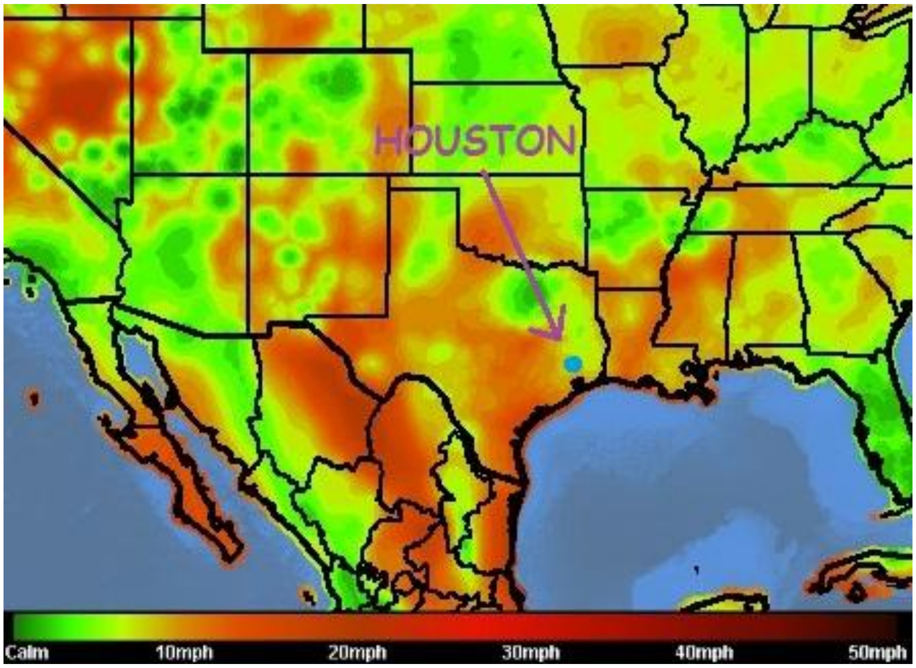


Figure 6: Wind speed map of Texas

From the figure we got the average wind speed of Houston as around 8mph which is 3.575 m/s.

We took the Terrain Category as 3 and Class as C and we computed the wind intensity in excel sheet as follows

Height(m)	K_1	K_2	K_3	V_b(m/s)	V_z(m/s)	P_z(kN/m2)
10	1	0.82	1	3.575	2.932	0.0052
15	1	0.88	1	3.575	3.146	0.0059
20	1	0.91	1	3.575	3.253	0.0064
25	1	0.96	1	3.575	3.432	0.0071

The mentioned loads were taken and a building was modeled, analyzed and some elements designed on STAAD PRO.

Design and analysis on STAAD PRO:

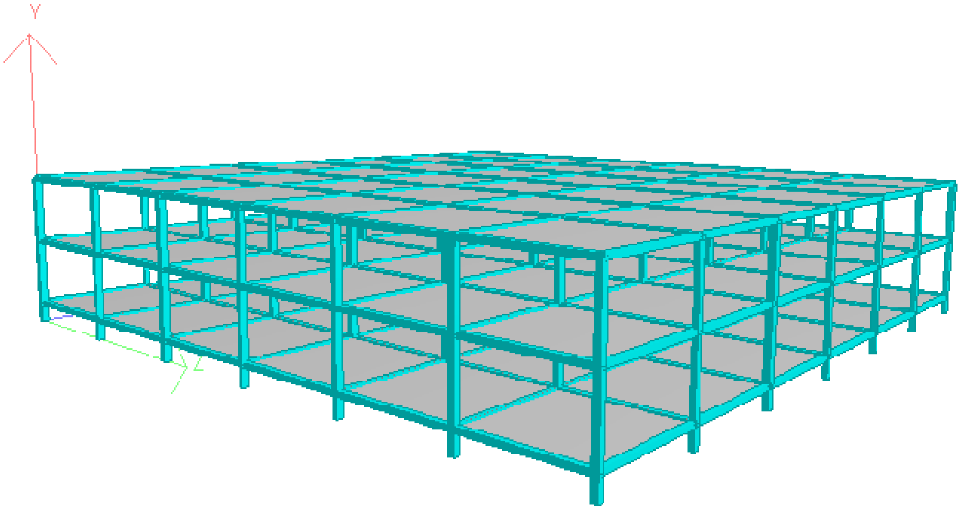


Figure 7: 3D model of the 2 storey building

Different loadings given on the building

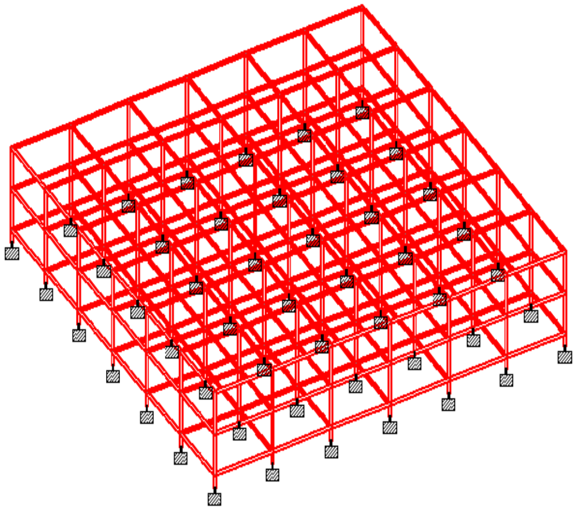


Figure 8: Dead load

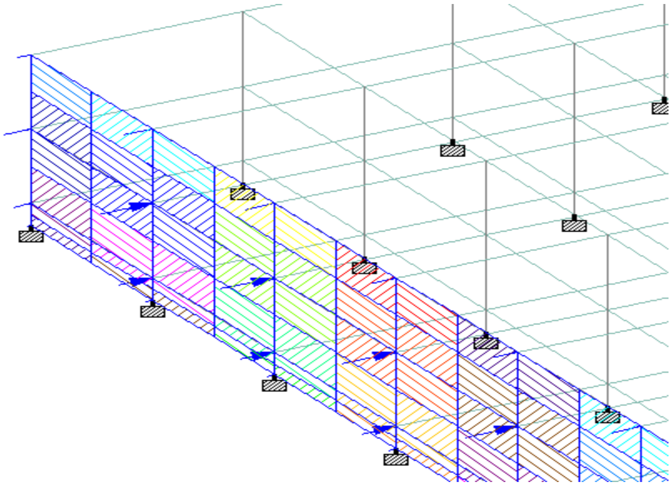


Figure 9: Wind load

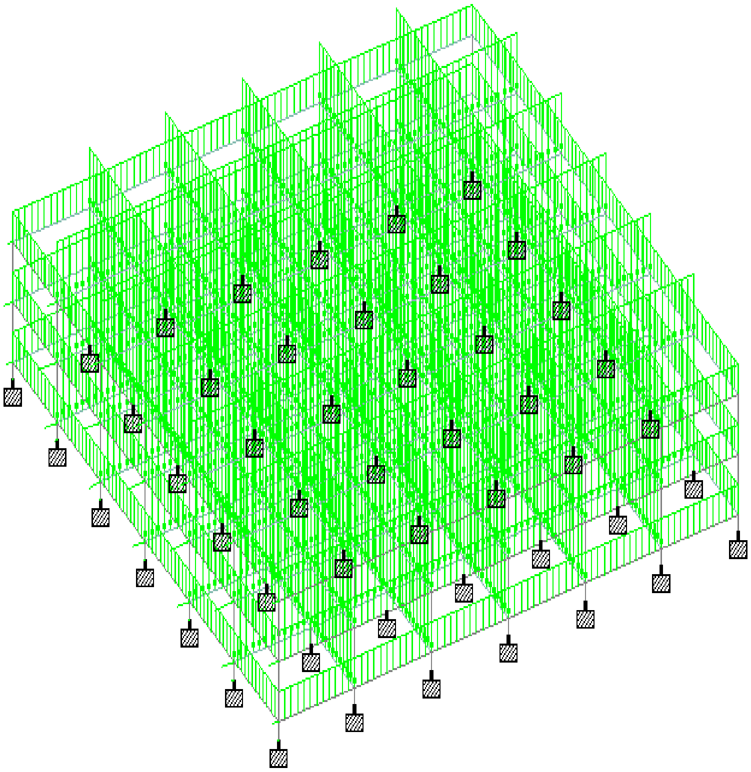
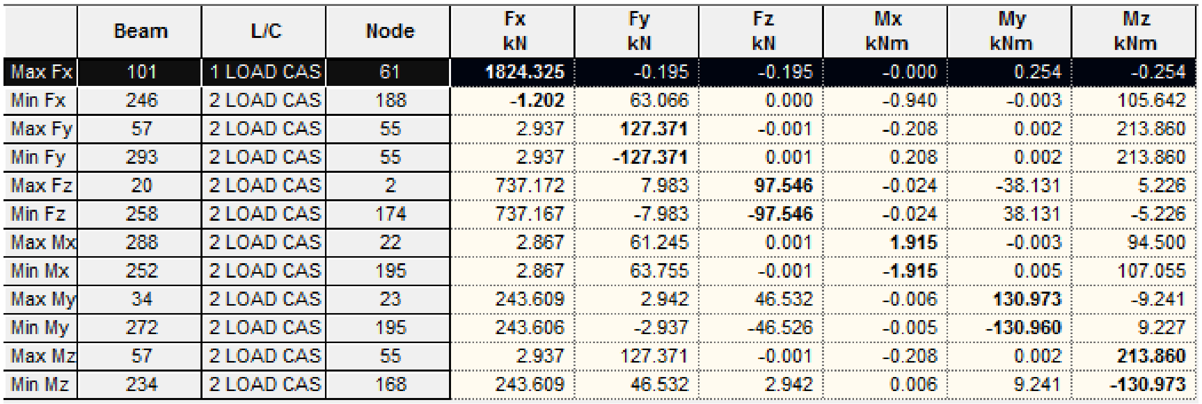


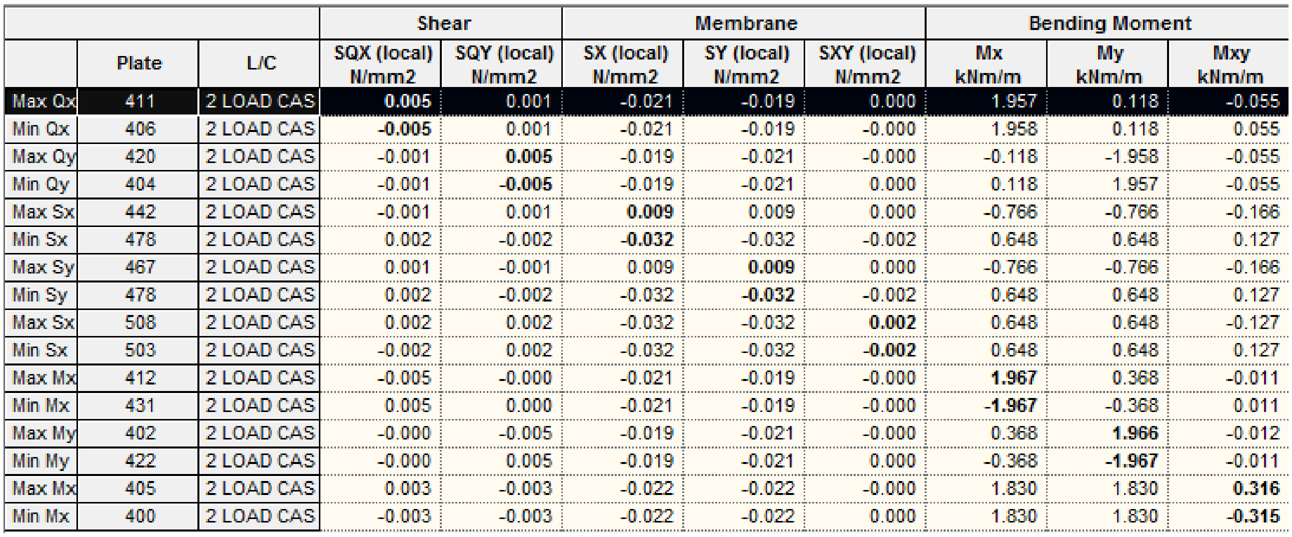
Figure 10: Combined load

Summary of beam analysis (Both horizontal and vertical):



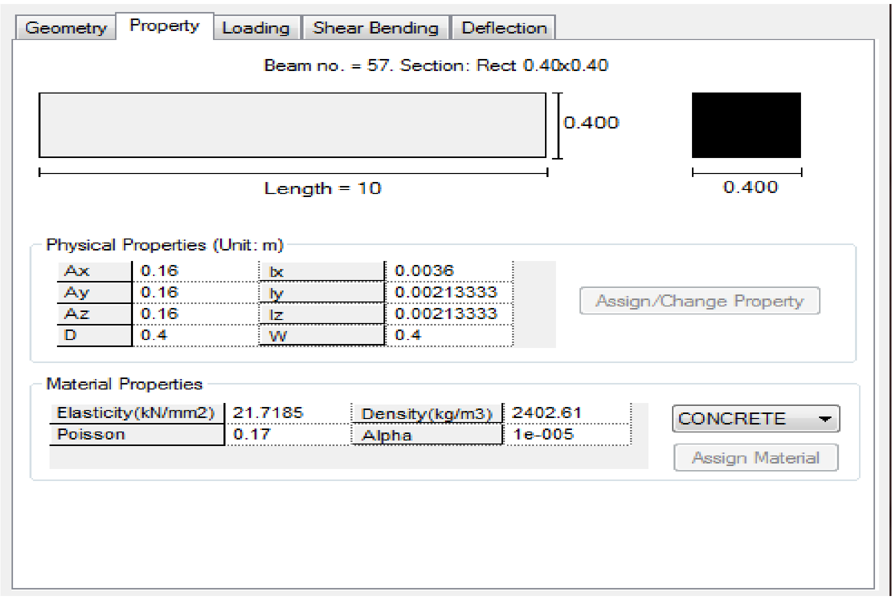
	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	101	1 LOAD CAS	61	1824.325	-0.195	-0.195	-0.000	0.254	-0.254
Min Fx	246	2 LOAD CAS	188	-1.202	63.066	0.000	-0.940	-0.003	105.642
Max Fy	57	2 LOAD CAS	55	2.937	127.371	-0.001	-0.208	0.002	213.860
Min Fy	293	2 LOAD CAS	55	2.937	-127.371	0.001	0.208	0.002	213.860
Max Fz	20	2 LOAD CAS	2	737.172	7.983	97.546	-0.024	-38.131	5.226
Min Fz	258	2 LOAD CAS	174	737.167	-7.983	-97.546	-0.024	38.131	-5.226
Max Mx	288	2 LOAD CAS	22	2.867	61.245	0.001	1.915	-0.003	94.500
Min Mx	252	2 LOAD CAS	195	2.867	63.755	-0.001	-1.915	0.005	107.055
Max My	34	2 LOAD CAS	23	243.609	2.942	46.532	-0.006	130.973	-9.241
Min My	272	2 LOAD CAS	195	243.606	-2.937	-46.526	-0.005	-130.960	9.227
Max Mz	57	2 LOAD CAS	55	2.937	127.371	-0.001	-0.208	0.002	213.860
Min Mz	234	2 LOAD CAS	168	243.609	46.532	2.942	0.006	9.241	-130.973

Summary of slab analysis:



			Shear		Membrane			Bending Moment		
	Plate	L/C	SQX (local) N/mm2	SQY (local) N/mm2	SX (local) N/mm2	SY (local) N/mm2	SXY (local) N/mm2	Mx kNm/m	My kNm/m	Mxy kNm/m
Max Qx	411	2 LOAD CAS	**0.005**	0.001	-0.021	-0.019	0.000	1.957	0.118	-0.055
Min Qx	406	2 LOAD CAS	**-0.005**	0.001	-0.021	-0.019	-0.000	1.958	0.118	0.055
Max Qy	420	2 LOAD CAS	-0.001	**0.005**	-0.019	-0.021	-0.000	-0.118	-1.958	-0.055
Min Qy	404	2 LOAD CAS	-0.001	**-0.005**	-0.019	-0.021	0.000	0.118	1.957	-0.055
Max Sx	442	2 LOAD CAS	-0.001	0.001	**0.009**	0.009	0.000	-0.766	-0.766	-0.166
Min Sx	478	2 LOAD CAS	0.002	-0.002	**-0.032**	-0.032	-0.002	0.648	0.648	0.127
Max Sy	467	2 LOAD CAS	0.001	-0.001	0.009	**0.009**	0.000	-0.766	-0.766	-0.166
Min Sy	478	2 LOAD CAS	0.002	-0.002	-0.032	**-0.032**	-0.002	0.648	0.648	0.127
Max Sx	508	2 LOAD CAS	0.002	0.002	-0.032	-0.032	**0.002**	0.648	0.648	-0.127
Min Sx	503	2 LOAD CAS	-0.002	0.002	-0.032	-0.032	**-0.002**	0.648	0.648	0.127
Max Mx	412	2 LOAD CAS	-0.005	-0.000	-0.021	-0.019	-0.000	**1.967**	0.368	-0.011
Min Mx	431	2 LOAD CAS	0.005	0.000	-0.021	-0.019	-0.000	**-1.967**	-0.368	0.011
Max My	402	2 LOAD CAS	-0.000	-0.005	-0.019	-0.021	-0.000	0.368	**1.966**	-0.012
Min My	422	2 LOAD CAS	-0.000	0.005	-0.019	-0.021	0.000	-0.368	**-1.967**	-0.011
Max Mx	405	2 LOAD CAS	0.003	-0.003	-0.022	-0.022	-0.000	1.830	1.830	**0.316**
Min Mx	400	2 LOAD CAS	-0.003	-0.003	-0.022	-0.022	0.000	1.830	1.830	**-0.315**

Design of beam (No.57)



Beam no. = 57. Section: Rect 0.40x0.40

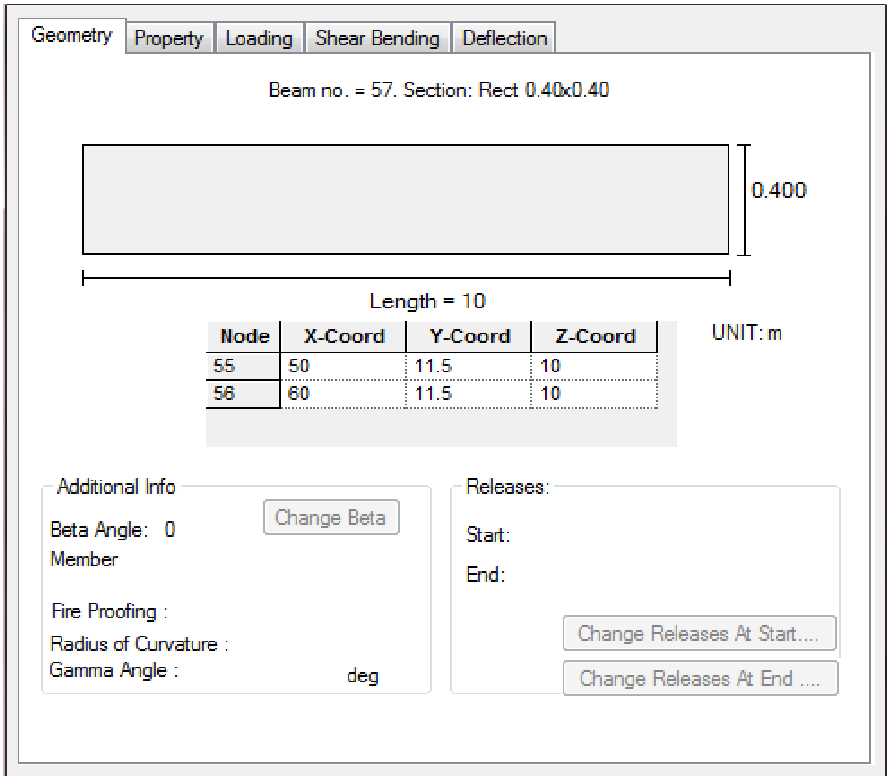
Length = 10

Physical Properties (Unit: m)

Ax	0.16	Ix	0.0036
Ay	0.16	Iy	0.00213333
Az	0.16	Iz	0.00213333
D	0.4	W	0.4

Material Properties

Elasticity(kN/mm2)	21.7185	Density(kg/m3)	2402.61
Poisson	0.17	Alpha	1e-005



Beam no. = 57. Section: Rect 0.40x0.40

Length = 10

Node	X-Coord	Y-Coord	Z-Coord
55	50	11.5	10
56	60	11.5	10

UNIT: m

Additional Info

Beta Angle: 0

Member

Fire Proofing :

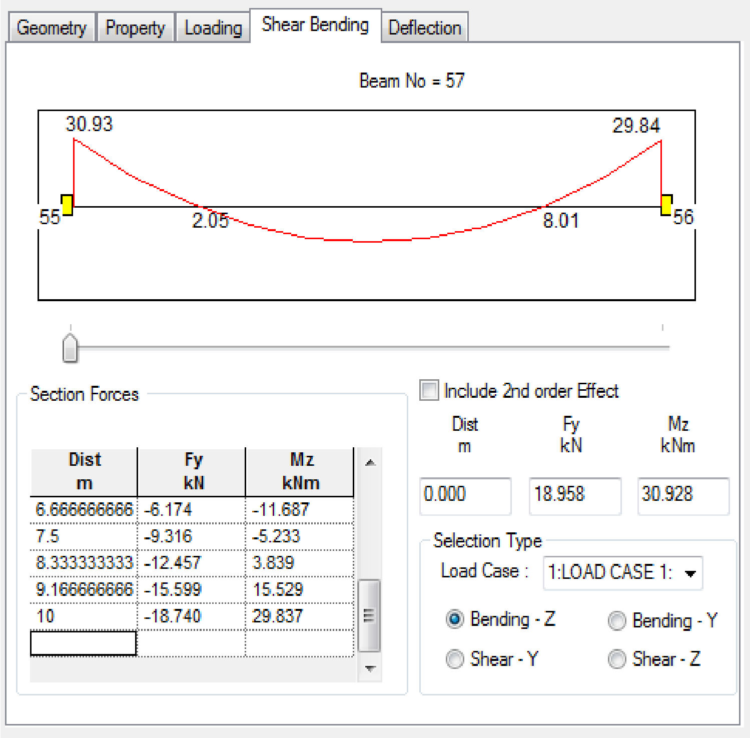
Radius of Curvature :

Gamma Angle : deg

Releases:

Start:

End:



Section Forces

Dist m	Fy kN	Mz kNm
6.666666666	-6.174	-11.687
7.5	-9.316	-5.233
8.333333333	-12.457	3.839
9.166666666	-15.599	15.529
10	-18.740	29.837

☐ Include 2nd order Effect

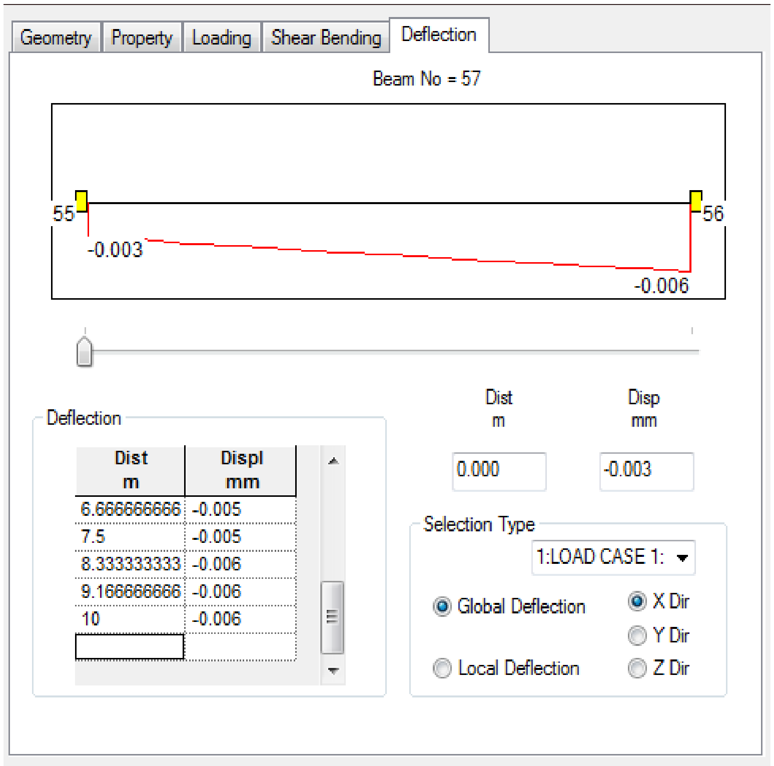
Dist m	Fy kN	Mz kNm
0.000	18.958	30.928

Selection Type

Load Case : 1:LOAD CASE 1:

● Bending - Z ○ Bending - Y

○ Shear - Y ○ Shear - Z



Deflection

Dist m	Displ mm
6.666666666	-0.005
7.5	-0.005
8.333333333	-0.006
9.166666666	-0.006
10	-0.006

Dist m	Disp mm
0.000	-0.003

Selection Type

1:LOAD CASE 1:

● Global Deflection ● X Dir

○ Y Dir

○ Local Deflection ○ Z Dir

Figure: Shear bending and deflection

Design of slab(No.412):

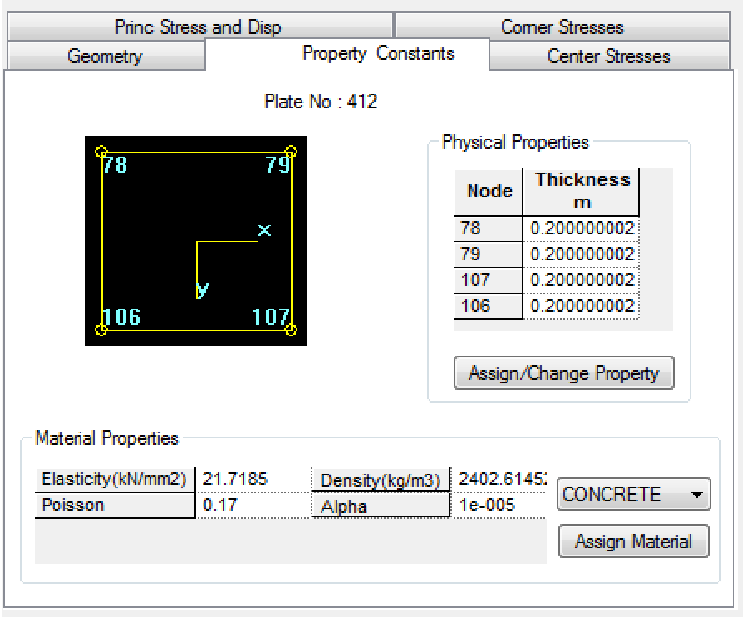


Plate No : 412

Physical Properties

Node	Thickness m
78	0.200000002
79	0.200000002
107	0.200000002
106	0.200000002

Material Properties

Elasticity(kN/mm2)	21.7185	Density(kg/m3)	2402.6145
Poisson	0.17	Alpha	1e-005

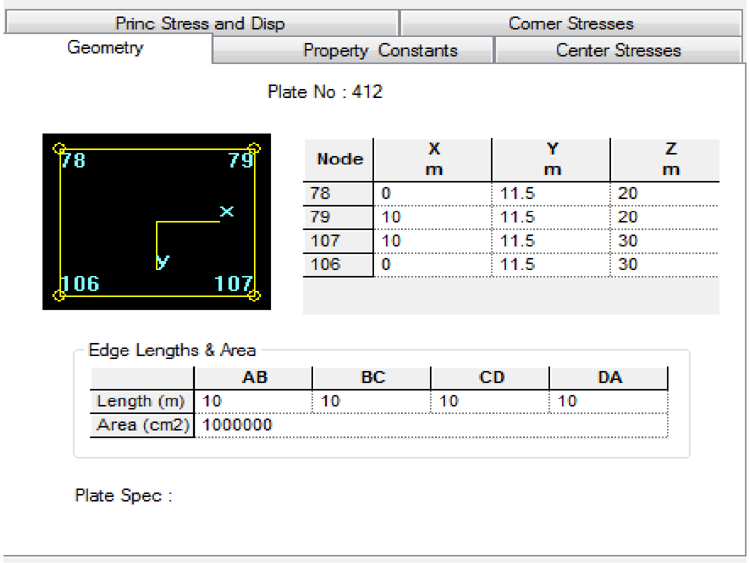


Plate No : 412

Node	X m	Y m	Z m
78	0	11.5	20
79	10	11.5	20
107	10	11.5	30
106	0	11.5	30

Edge Lengths & Area

	AB	BC	CD	DA
Length (m)	10	10	10	10
Area (cm2)	1000000			

Plate Spec :

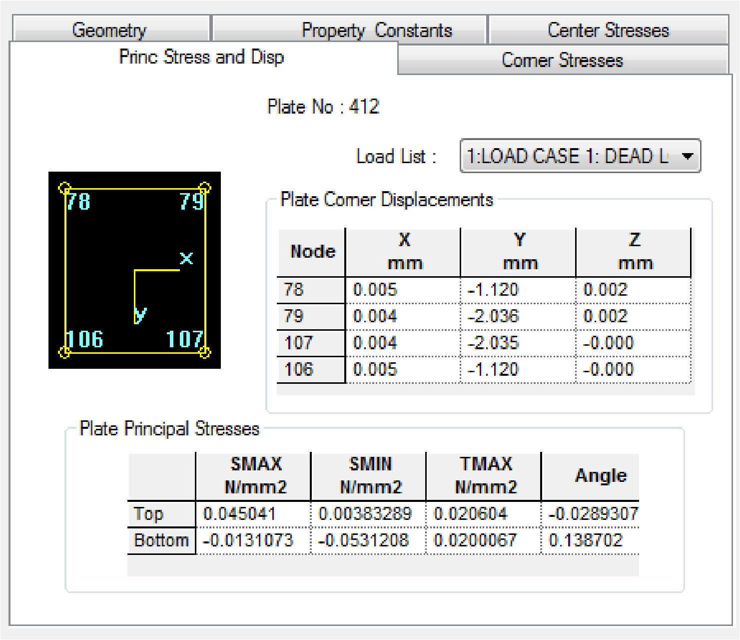


Plate No : 412

Load List : 1:LOAD CASE 1: DEAD L

Plate Corner Displacements

Node	X mm	Y mm	Z mm
78	0.005	-1.120	0.002
79	0.004	-2.036	0.002
107	0.004	-2.035	-0.000
106	0.005	-1.120	-0.000

Plate Principal Stresses

	SMAX N/mm2	SMIN N/mm2	TMAX N/mm2	Angle
Top	0.045041	0.00383289	0.020604	-0.0289307
Bottom	-0.0131073	-0.0531208	0.0200067	0.138702

CHAPTER 6

BEARING CAPACITY USING TERZAGHI EQUATION

In geotechnical engineering, bearing capacity is the capacity of soil to support the loads applied to the ground. It is the maximum contact pressure between the foundation and soil which shouldn't produce shear failure in the soil. Ultimate bearing capacity(qu) is the value of bearing stress which causes a sudden catastrophic settlement of the foundation (due to shear failure). There are three modes of failure that limit bearing capacity general shear failure, local shear failure and punching shear failure.

Its calculated from an equation that incorporates appropriate soil parameters (e.g. shear strength, unit weight) and details about the size, shape and founding depth of the footing. Terzaghi (1943) stated the ultimate bearing capacity of a strip footing as three term expression incorporating the bearing capacity factors N_c, N_q and N_{Υ} which are related to the angle of friction (φ).

$q_u = 1.3\ c_u N_c + q\ N_q + 0.4\ \Upsilon\ B\ N_{\Upsilon}$

Where c_u is the undrained cohesion, q is the vertical effective stress and B is the width or the diameter of the foundation.

For cohesive soils

$\Phi=0$,where $N_c = 5.7$, $N_q =1$ and $N_{\Upsilon} = 0$

For square footings

$q_u = 1.3\ c_u\ N_c + q\ N_q + 0.4\ \Upsilon\ B\ N_\gamma$

For circular footings

$q_u = 1.3\ c_u N_c + q\ N_q + 0.3\ \Upsilon\ B\ N_\gamma$

So equation becomes

$q_{nu} = 1.3\ c_u N_c$

6.1 CALCULATION OF BEARING CAPACITY

For calculating q_u first calculate the c_u value from graph 3

$c_u = c_{avg}$ (weighted average values)

$c_{avg} = C_1\ H_1 + C_2\ H_{2\ldots\ldots\ldots\ldots\ldots} / \Sigma H_n$

$= 2.6 * 2.16 + 2.2 * 0.34 / 2.16 + 0.34$

$= 2.6$ ksf i.e. 125 kN/m^2

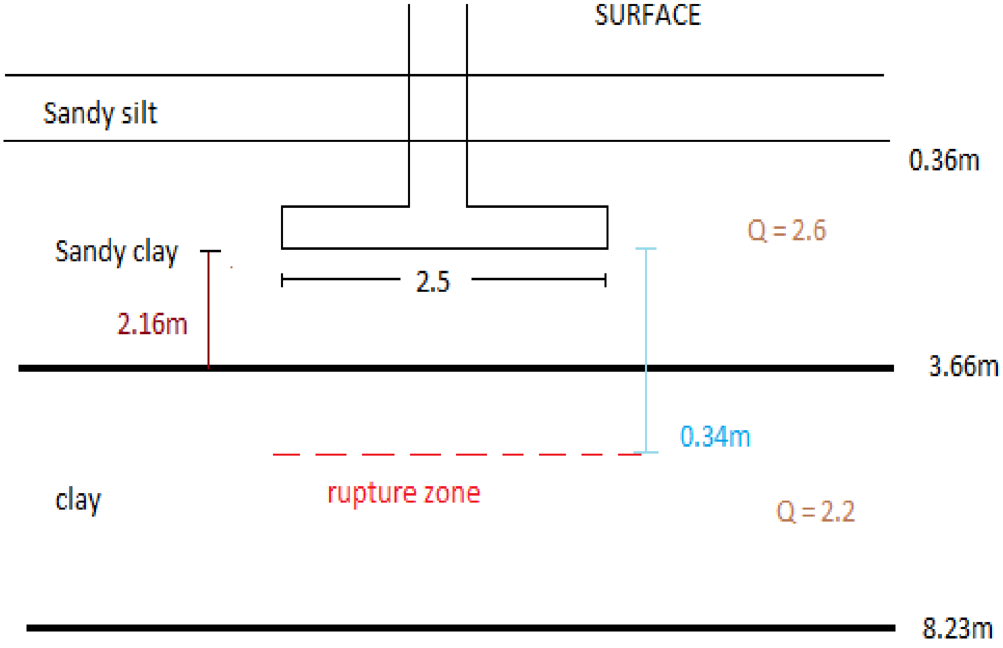


Figure: 11 C_u weighted average value

As Q, the test result for unconsolidated- undrained triaxial. C_u value as taken from graph (the best fitted line of Q according to its depth)

q_{nu} = 1.3 * 125 * 5.7

= 926.25 kN/m^2

Safe bearing capacity S_{bc}

= q_{nu}/f.o.s

= 926.25/3

= 310 kN/m^2 approximately

CHAPTER 7

LOADS ON SUPERSTRUCTURE

7.1 FROM THE ANALYSIS IN STAAD PRO FOR DIFFERENT NODES

Node	F_x (kN)	F_y (kN)	F_z (kN)	M_x(kN.m)	M_y (kN.m)	M_z(kN.m)
85	108.66	960.805	0.000	0.000	0.000	-42.269
86	-15.930	1825.432	-0.000	0.000	0.000	9.061
87	-1.549	1791.060	0.002	0.001	0.000	1.826
88	-0.076	1797.039	-0.007	-0.003	0.000	0.099
89	1.383	1791.059	0.004	0.002	-0.000	-1.622
90	15.751	1825.432	-0.000	0.000	0.000	-8.850
91	-108.80	960.906	0.001	0.000	0.000	42.452
4	-0.057	960.859	108.763	42.370	-0.000	0.091
32	-0.085	1825.440	-15.832	-8.948	-0.000	0.103
60	-0.087	1791.056	-1.463	-1.721	0.000	0.104
116	-0.084	1791.061	1.462	1.721	0 .000	0.102
144	-0.085	1825.424	15.834	8.949	0.000	0.103
172	-0.057	960.854	-108.762	-42.369	0.000	0.091

Table 1

COLUMN DESIGNED FROM STAAD PRO

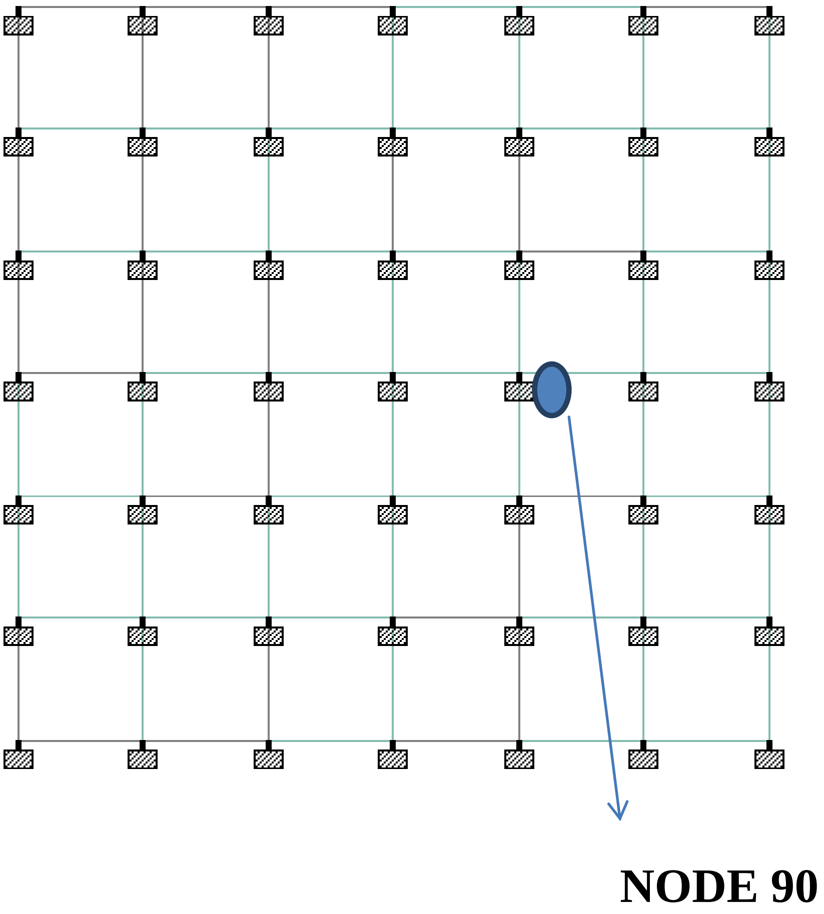


Figure: 12

Taking node 90 for futher designing of footings in which its loads in various direction and moment are given in figure.11. According to its load it is the maximmum load coming to the substructure i.e foundation. And its moments are ignored as its very neglible.

CHAPTER 8

FOOTINGS ON SHALLOW FOUNDATIONS

Footings ' belong to the category of shallow foundations (as opposed to deep foundations such as piles and caissons) are used when soil of sufficient strength is available within a relatively short depth below the ground surface; otherwise deep foundations are used

Shallow foundations comprise not only footings but also rafts which support multiple columns on a large plan area. It has a large plan area in comparison with the cross sectional area of the columns it supports.

8. 1 ISOLATED FOOTING

For ordinary structure located on firmly soil, it usually suffices to provide a separate footing for every column. Such footing is called an isolated footing.

It is generally square or rectangular in plan; other shapes are resorted to under special circumstances. The footing basically comprises a thick slab which may be flat, stepped or sloped (on the upper surface)

8.2 TYPES OF FOOTING

a) Isolated footing (spread footing)

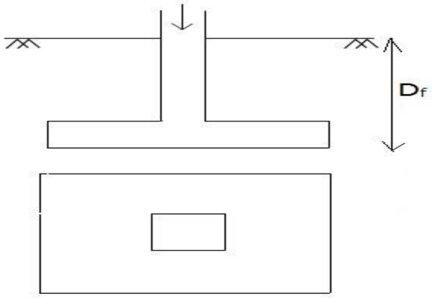


Figure : 13

b)Combined footing

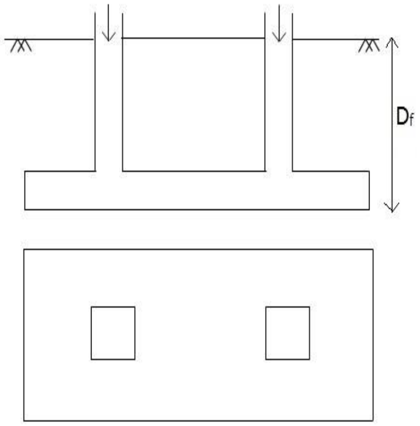


Figure: 14

c) sloping

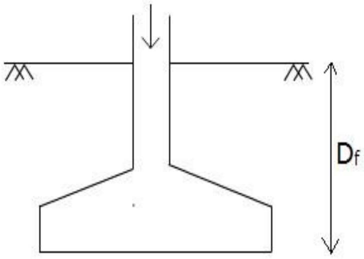


Figure: 15

d) step footing

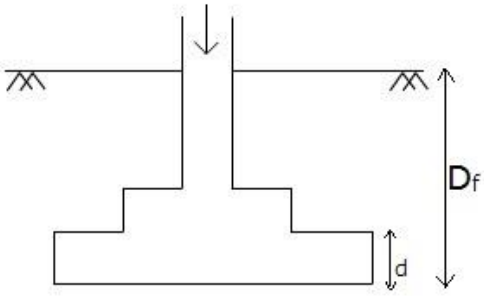


Figure: 16

c) Continuous / strip footing

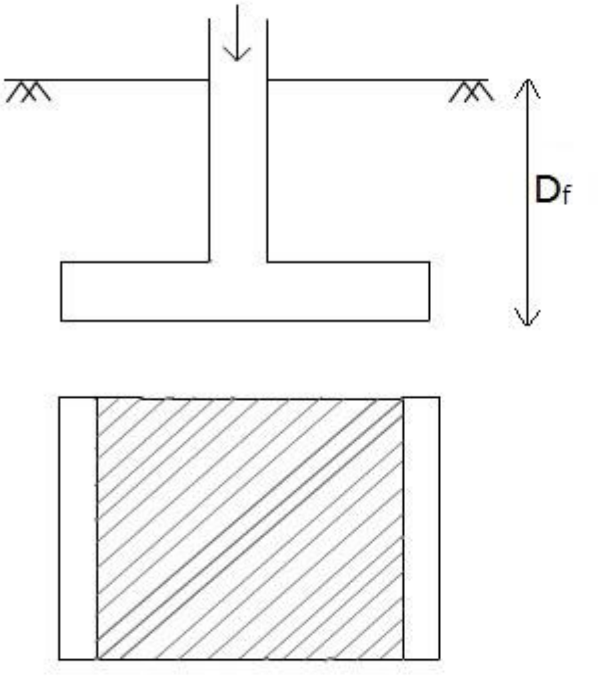


Figure : 17

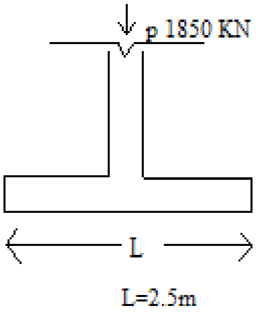
8.3 DESIGN OF ISOLATED SQUARE FOOTING

Data provided = 1850 kN

Square column = 500 * 500

Concrete M20, steel fe415

Safe bearing capacity S_{bc} = 310 kN/m^2



1. SIZE OF THE FOOTING

Total load = 1.1 * 1850

= 2035 kN

So required area = P_u / S_{bc}

= 2035 / 310 = 6.329 m^2

= 2.5m

Providing area of 2.5 * 2.5 m

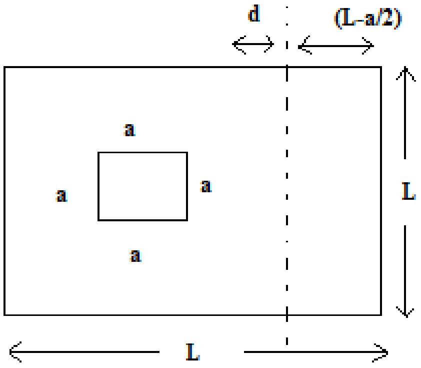
q, Net upward pressure in the soil= 1850 / (2.5 *2.5)

=296 < 311.27 (so okay)

q_u = 1.5 * 296 = 444 kN

and also factored load = 1.5 * 1850 = 2775 kN assuming factor of safety 1.5

2. DEPTH FROM ONE WAY SHEAR



Critical section at d from the face of column

$$q= P / l^2$$

shear force, V = q L ((L-a)÷2 – d)

τ_c L d =V ………….(1)

where τ_c = permissible shear stress and its value is 0.28 N/mm^2[Refer table 19. IS.456]

So the above eqn. (1) becomes when substituting ‘V’

$$d= P_u (L-a) / 2 (P_u + \tau_c L^2)$$

so $d= 2775 (2.5 – 0.5) / 2 (2775+ 280 *2.5^2)$

$$d= 600 \text{ mm}$$

3. TWO WAY SHEAR / PUNCHING SHEAR

Critical section at d/2 from face of column

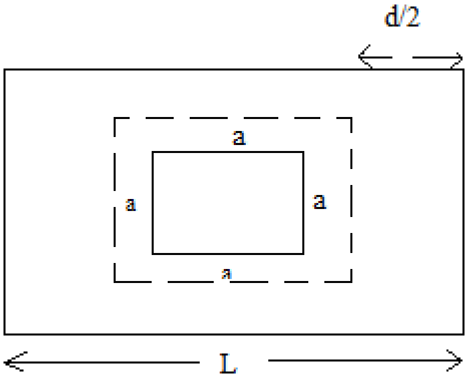
Perimeter = 4(a+d)

Considering equilibrium of forces

$P / L^2[L^2 – (a+d)^2] = 4 (a+d) d \tau_p$ where τ_p is punching shear

$\tau_p= 0.25 \sqrt{fck}$ [IS 456:2000 pg.66 cl 34.4]

$= 1.118 \text{ N/mm}^2$



As $\tau_p = P / L^2 \{ L – (a + d)^2 / 4 (a + d) d$

$= .509 \text{ N/mm}^2< 1.118 \text{ N/mm}^2$

(So okay)

4. BENDING MOMENT

Moment at force of column

$M_u = P / L^2\{ (L – a)^2 \}$

= 222 kN/m

$M_u = M_u lim.$

$M_u = 0.138 f_{ck} b d^2$ for fe 415, M_{20}

So d = 179.37 mm

Steel area $M_u = 0.87 f_y Ast d (1- Ast f_y /b d f_{ck})$

(IS : 456 G – 1.1 pg.96)

$= 2.3 * 10^{-8} Ast^2 – Ast – 1024$

So Ast = 1038.89 mm^2

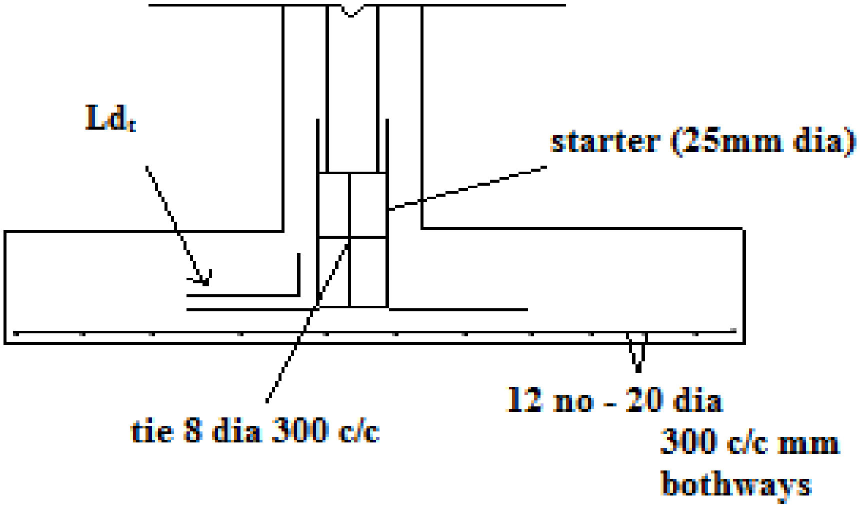
Spacing = 1000 / Ast * $\Pi / 4^2 * 20^2$

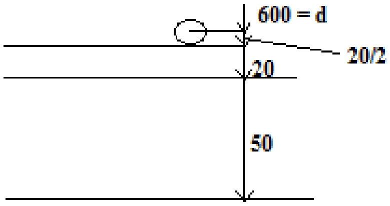
Providing 12 no – 20 φ bars

Spacing = 300 mm

For 20 φ, Ld = 940 mm from SP – 16

5. PLAN OF FOOTING





So overall depth = 600 + 50 + (20 / 2) + 20

= 680 mm

6. SUMMARY OF THE DESIGN

As depth designed in one way and two way shear is safe without shear reinforcement. And also depth in bending moment is safe without compression settlement.

And percentage of steel is 0.15% for Fe 250

0.12% for Fe 415

- Size of the footing = 2.5m *2.5m
- Reinforcement details = 12 no. 20 φ bars
- Development length Ld_t = 940 mm
- Total factored load = 2775 kN
- Square column = 500mm * 500mm
- Concrete M_{20}, steel fe 415
- Safe bearing capacity = 310 kN /m^2
- Overall depth of the footing = 680 mm

CONCLUSION

One of things that I have learned personally from this project is to adopt a methodical approach to problem solving. From the outset of the project the aim was to design for superstructure as well as substructure. In substructure part, with each given bore log data three different sections of soil profile were created to ensure each individual sections are drawn correctly to achieve an idealized soil profile.

The aim of this project was to design a superstructure part using staad pro and designing substructure with respect to it. Knowledge of using this software greatly helped in the design of the project. Where as in substructure the foundation was designed i.e. isolated footing. These overall design analysis studied in these past years of civil engineering gave good background knowledge in both the parts. Another aspect that helped was the use of various software's in creating different drawings and the design analysis. Now having been spent the duration of the project, I would have to say that my knowledge has been greatly enhanced, as too is my understanding of various soil parameters in different bore logs and also in design analysis using the software as well as in substructure part.

Often component values had to be changed due to errors and viewing designed components such as beam, column and slab ensured that the design was economical and reasonable.

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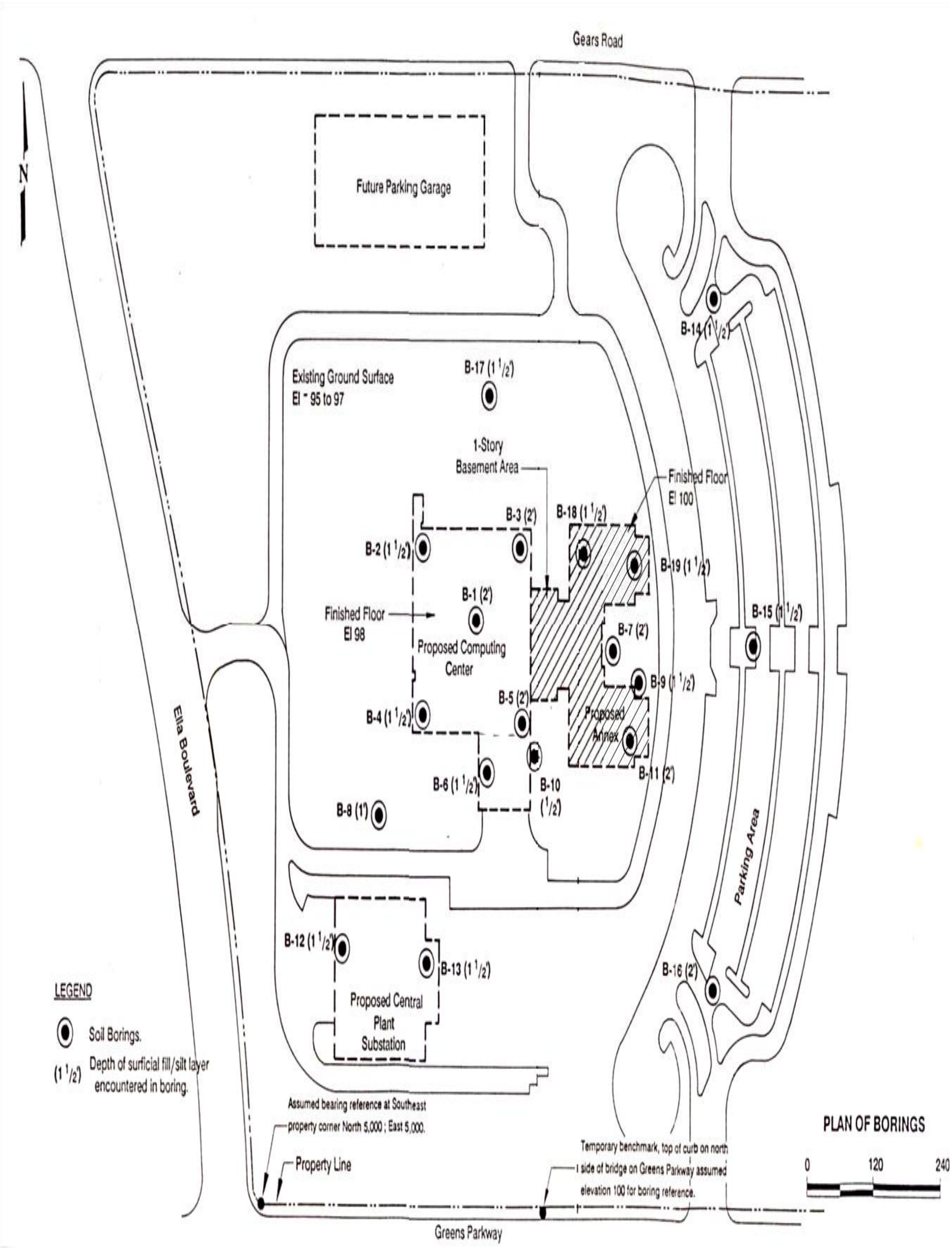
APPENDIX

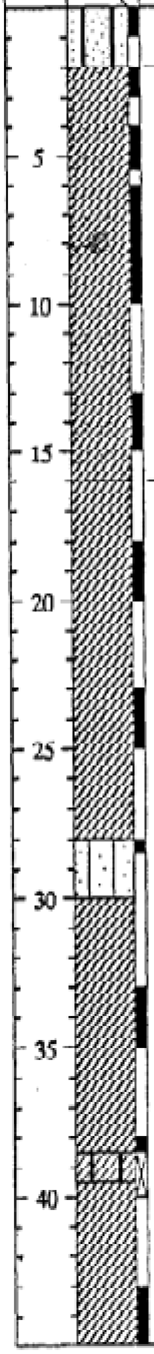


PLAN OF BORINGS

Water First Noticed: N/A
Completion Depth: 59.5'   Date: August 8, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 15.3'
Caved Depth: 16.2'
Date: August 9, 1991
Backfill: Bentonite Granules

Location: N 5538 ; E 5356
Surf El. 100.8'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1



DEPTH, FT	BLOWS PER FOOT	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
		SANDY SILT, gray, with roots								2.7+ P
		- very stiff sandy clay to 0.5'	98.8							
		SANDY CLAY, stiff, gray	2.0	14						1.2 P
		- with calcareous nodules to 12'								
		- very stiff, gray and tan below 4'								2.4 P
5		- with ferrous nodules, 4' to 12'		13					122	3.0 Q
		- with sand pockets below 6'								2.1 P
				17	40	11	29		113	
										1.5 P
				17					115	2.5 Q
10										
										2.1 P
15			84.8							
		CLAY, very stiff, red and gray, slickensided, with calcareous nodules	16.0							
				27						2.4 P
20										
		- with silt pockets below 23'								2.7 P
25										
		- silty sand layer with clay pockets and sand stone seams, 28' to 30'								
30		- with silt stone seams below 30'								
										3.6 P
35										
	19	- red silty sand layer, with clay pockets, 38' to 38.5'								
40		- red clayey silt layer, 38.5' to 39.5'								
										3.6 P

LOG OF BORING NO. 1
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-1a

Water First Noticed: N/A
Completion Depth: 59.5'   Date: August 8, 1991
Type: Wet Rotary
Logger: T. Mircles

Depth to Water: 15.3'
Caved Depth: 16.2'
Date: August 9, 1991
Backfill: Bentonite Granules

Location: N 5538 ; E 5356
Surf El. 100.8'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
	▨			CLAY, very stiff, red, slickensided	53.3 47.5							
50	▨	■		SANDY CLAY, very stiff, red and gray	48.3 52.5							3.9 P
55	░	☒	50/11"	SAND, very dense, tan, fine - with silt to 55'								
60	░	☒	50/8"		41.3 59.5							
65												
70												
75												
80												
85												

LOG OF BORING NO. 1
EXXON COMPUTING CENTER
HOUSTON, TEXAS

Water First Noticed: N/A
Completion Depth: 40.0' Date: August 9, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 15.6'
Caved Depth: 28.6'
Date: August 10, 1991
Backfill: Bentonite Granules

Location: N 5620 ; E 5249
Surf El. 100.5'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1

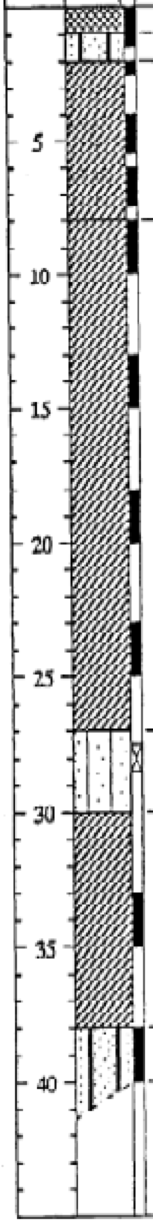
DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
				SANDY SILT, gray	99.0 1.5							
				SANDY CLAY, stiff, tan and gray								1.2 P
						16	33	13	20		112	
5				- with ferrous nodules at 4'								1.3 P
				- with calcareous nodules at 6'								1.8 P
				- very stiff below 7'		15					116	2.5 Q
				- with sand pockets below 8'								1.6 P
10					89.5 11.0							
				CLAY, very stiff, red and gray - with sand pockets to 16'								2.4 P
15						26					98	2.8 Q
				- with siltstone nodules at 18'								2.4 P
20						29	73	27	47			
				- with silt pockets below 23'								2.5 P
25					73.5 27.0							
			50/1.5"	SILTY SAND, very dense, red, with sand stone seams	71.0 29.5							
30				CLAY, very stiff, red and gray, slickensided - with siltstone nodules to 33'								3.9 P
35												3.6 P
					63.5 37.0							
			50/6"	SILTY SAND, very dense, red, fine								
40					60.5 40.0							

LOG OF BORING NO. 2
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-2

Water First Noticed: N/A
Completion Depth: 40.0' Date: August 8, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 15.9'
Caved Depth: 20.1'
Date: August 9, 1991
Backfill: Bentonite Granules



BLOWS PER FOOT	Location: N 5626 ; E 5437 Surf El. 101.1' Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1 STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
	FILL: SANDY CLAY, very stiff, gray and tan, with shell fragments	100.1 1.0							2.7+ P
	SANDY SILT, gray	99.1 2.0	14						1.9 P
	SANDY CLAY, stiff, tan and gray, with sand pockets								1.3 P
	- with ferrous nodules and calcareous nodules below 4'		15					117	2.2 Q
	- very stiff below 5'								1.8 P
	CLAY, stiff, gray and tan	93.1 8.0							2.4 P
	- with sand pockets to 16'		20						
									1.5 P
	- very stiff, red and gray, slickensided, with calcareous nodules and siltstone seams below 16'								2.2 P
			22					104	1.5* O
	- with sand pockets below 23'								3.6 P
50/9"	SILTY SAND, very dense, red, fine, with clay seams	74.1 27.0							
	CLAY, very stiff, red and gray, slickensided	71.1 30.0							3.9 P
	SANDY SILT, red, with clay seams	63.1 38.0							
		61.1 40.0							
	* Failed on slickensided plane								

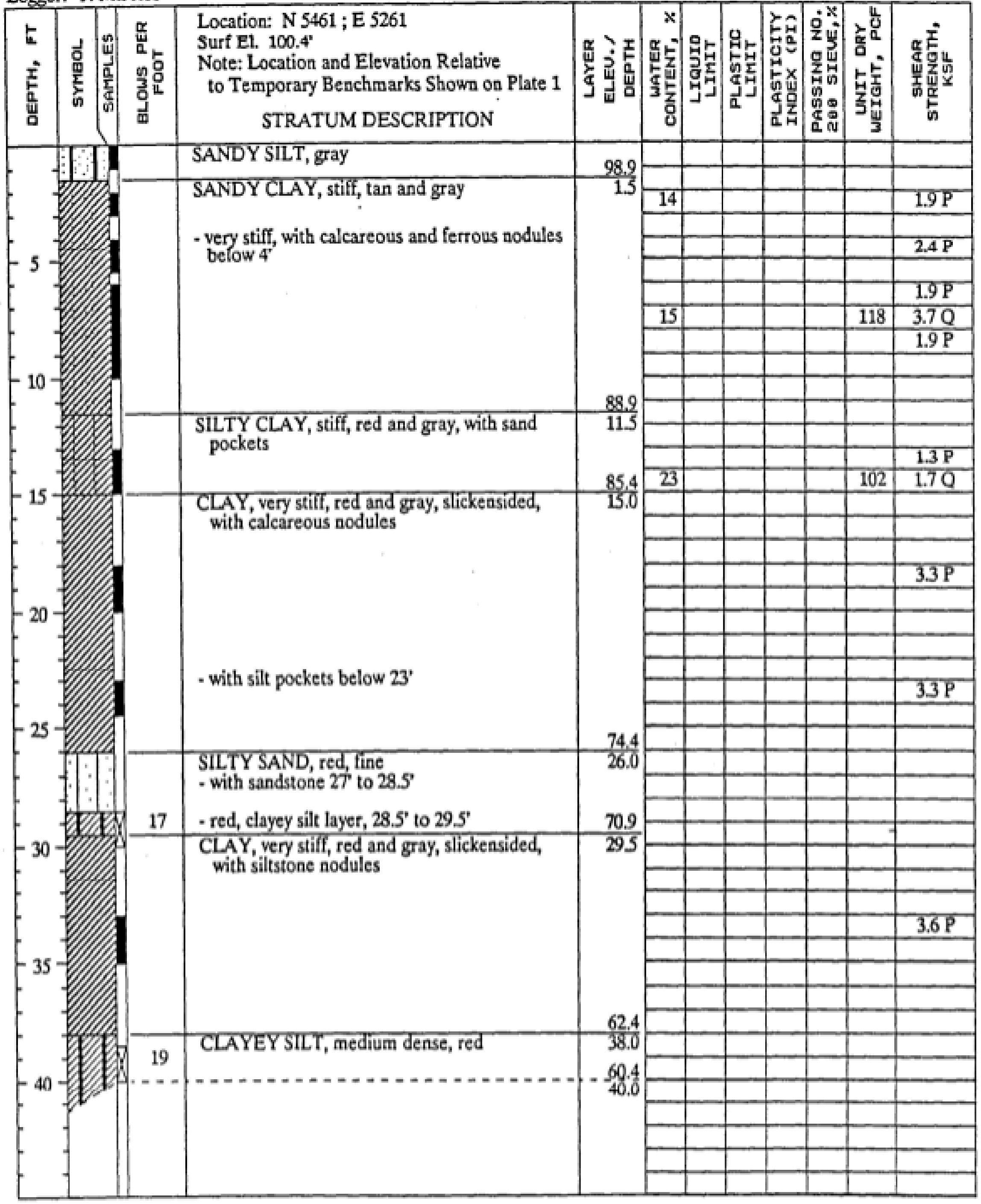
LOG OF BORING NO. 3
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-3

Water First Noticed: N/A
Completion Depth: 40.0' Date: August 9, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 15.2'
Caved Depth: 27.2'
Date: August 10, 1991
Backfill: Bentonite Granules

Location: N 5461 ; E 5261
Surf El. 100.4'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1



BLOWS PER FOOT	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
	SANDY SILT, gray	98.9 1.5							
	SANDY CLAY, stiff, tan and gray		14						1.9 P
	- very stiff, with calcareous and ferrous nodules below 4'								2.4 P
									1.9 P
			15					118	3.7 Q
									1.9 P
		88.9 11.5							
	SILTY CLAY, stiff, red and gray, with sand pockets								1.3 P
		85.4 15.0	23					102	1.7 Q
	CLAY, very stiff, red and gray, slickensided, with calcareous nodules								3.3 P
	- with silt pockets below 23'								3.3 P
		74.4 26.0							
	SILTY SAND, red, fine - with sandstone 27' to 28.5'								
17	- red, clayey silt layer, 28.5' to 29.5'	70.9 29.5							
	CLAY, very stiff, red and gray, slickensided, with siltstone nodules								3.6 P
		62.4 38.0							
19	CLAYEY SILT, medium dense, red	60.4 40.0							

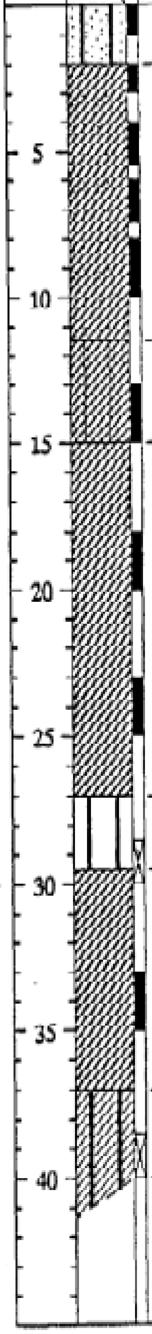
LOG OF BORING NO. 4
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-4

Water First Noticed: N/A
Completion Depth: 40.0' Date: August 9, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 15.4'
Caved Depth: 19.0'
Date: August 10, 1991
Backfill: Bentonite Granules

Location: N 5470 ; E 5444
Surf El. 100.7
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1



DEPTH, FT	BLOWS PER FOOT	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
		SANDY SILT, gray - very stiff sandy clay to 0.5'								
		SANDY CLAY, stiff, gray and tan, with calcareous nodules	98.7 2.0							1.5 P
				15						
		- very stiff, tan and gray, with ferrous nodules below 4'								1.5 P
5				14	33	13	20		120	2.3 Q
										1.8 P
										1.8 P
				18					112	2.5 Q
10										
		SILTY CLAY, stiff, red and gray	89.2 11.5							
										1.2 P
				21						
15		CLAY, very stiff, red and gray, slickensided, with siltstone nodules	85.7 15.0							
										3.6 P
20										
		- with silt pockets below 23'								3.3 P
25										
		SILT, medium dense, red, with siltstone seams	73.7 27.0							
	18									
		CLAY, very stiff, red and gray, slickensided	71.2 29.5							
30										
		- with siltstone seams, 32' to 33.5'								
										3.7 P
35										
		CLAYEY SILT, medium dense, red	63.7 37.0							
	20									
40			60.7 40.0							

LOG OF BORING NO. 5
EXXON COMPUTING CENTER
HOUSTON, TEXAS

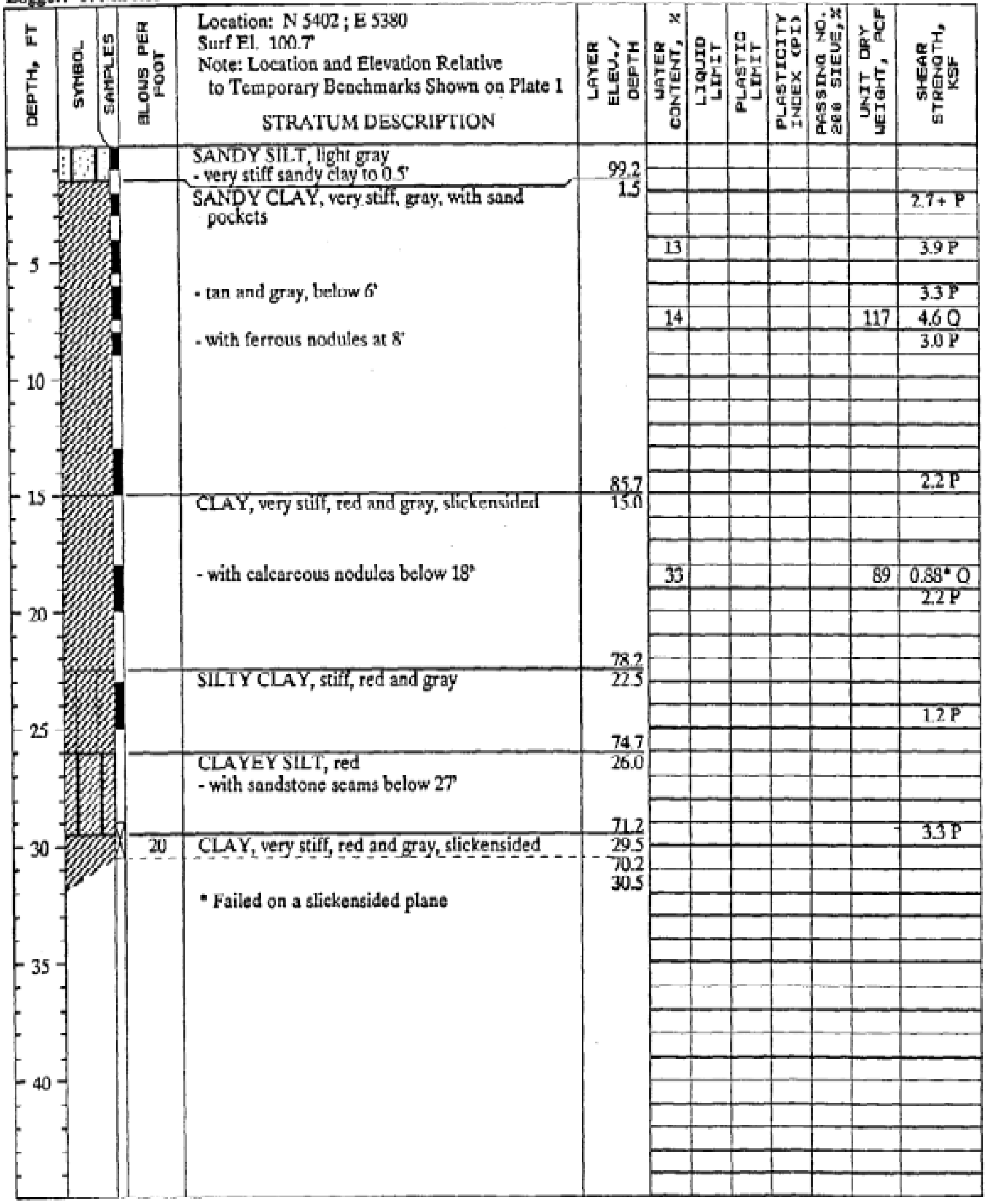
Fugro McClelland

Report No. 0401-2452

Water First Noticed: N/A
Completion Depth: 30.5'   Date: August 10, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 13.9'
Caved Depth: 20.3'
Date: August 12, 1991
Backfill: Bentonite Granules

Location: N 5402 ; E 5380
Surf El. 100.7'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1

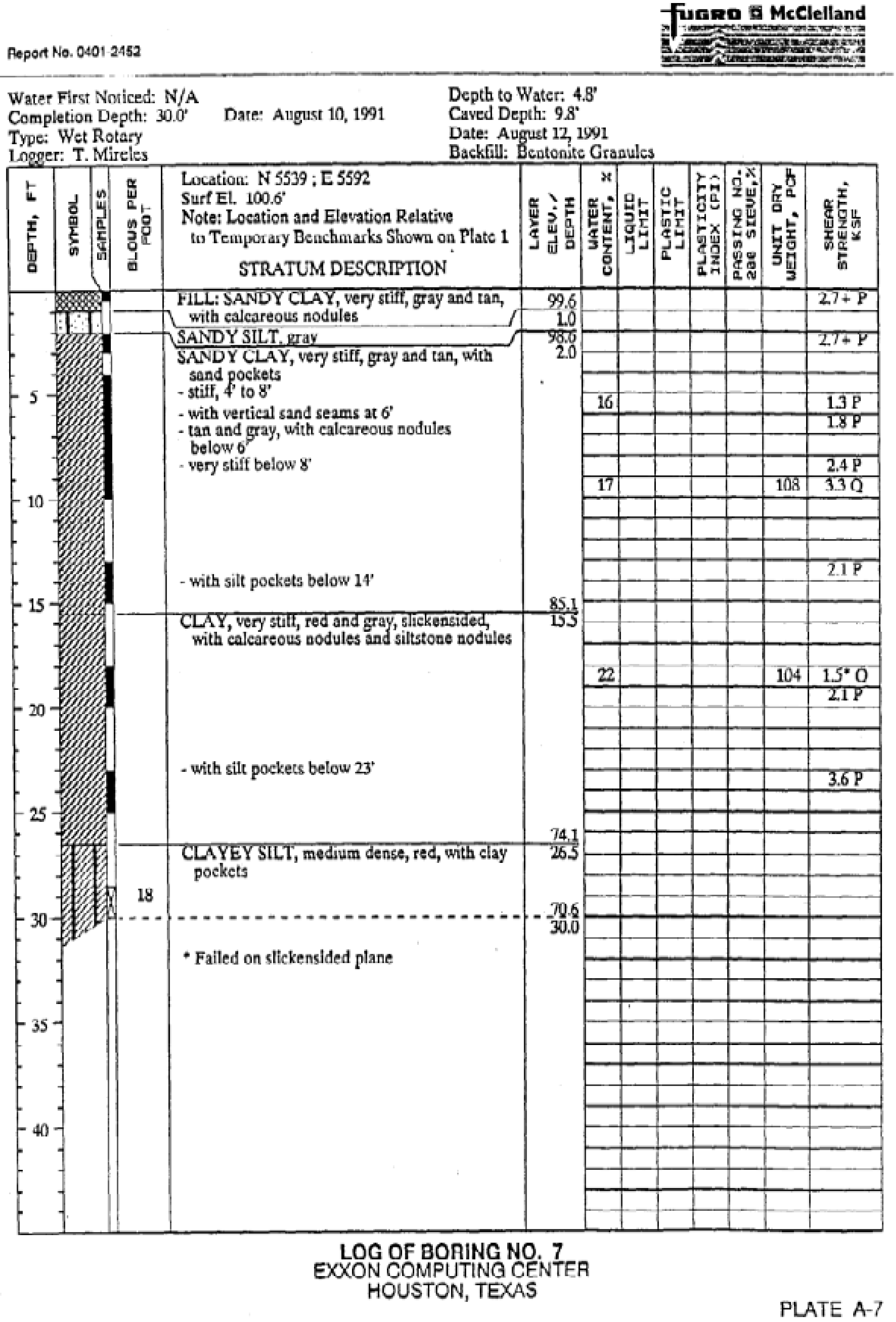


BLOWS PER FOOT	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
	SANDY SILT, light gray - very stiff sandy clay to 0.5'	99.2 1.5							
	SANDY CLAY, very stiff, gray, with sand pockets								2.7+ P
			13						3.9 P
	- tan and gray, below 6'								3.3 P
			14					117	4.6 Q
	- with ferrous nodules at 8'								3.0 P
		85.7 15.0							2.2 P
	CLAY, very stiff, red and gray, slickensided								
	- with calcareous nodules below 18'		33					89	0.88* Q
									2.2 P
	SILTY CLAY, stiff, red and gray	78.2 22.5							
									1.2 P
	CLAYEY SILT, red - with sandstone seams below 27'	74.7 26.0							
									3.3 P
20	CLAY, very stiff, red and gray, slickensided	71.2 29.5							
		70.2 30.5							

* Failed on a slickensided plane

LOG OF BORING NO. 6
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-6



Report No. 0401-2452

FUGRO McClelland

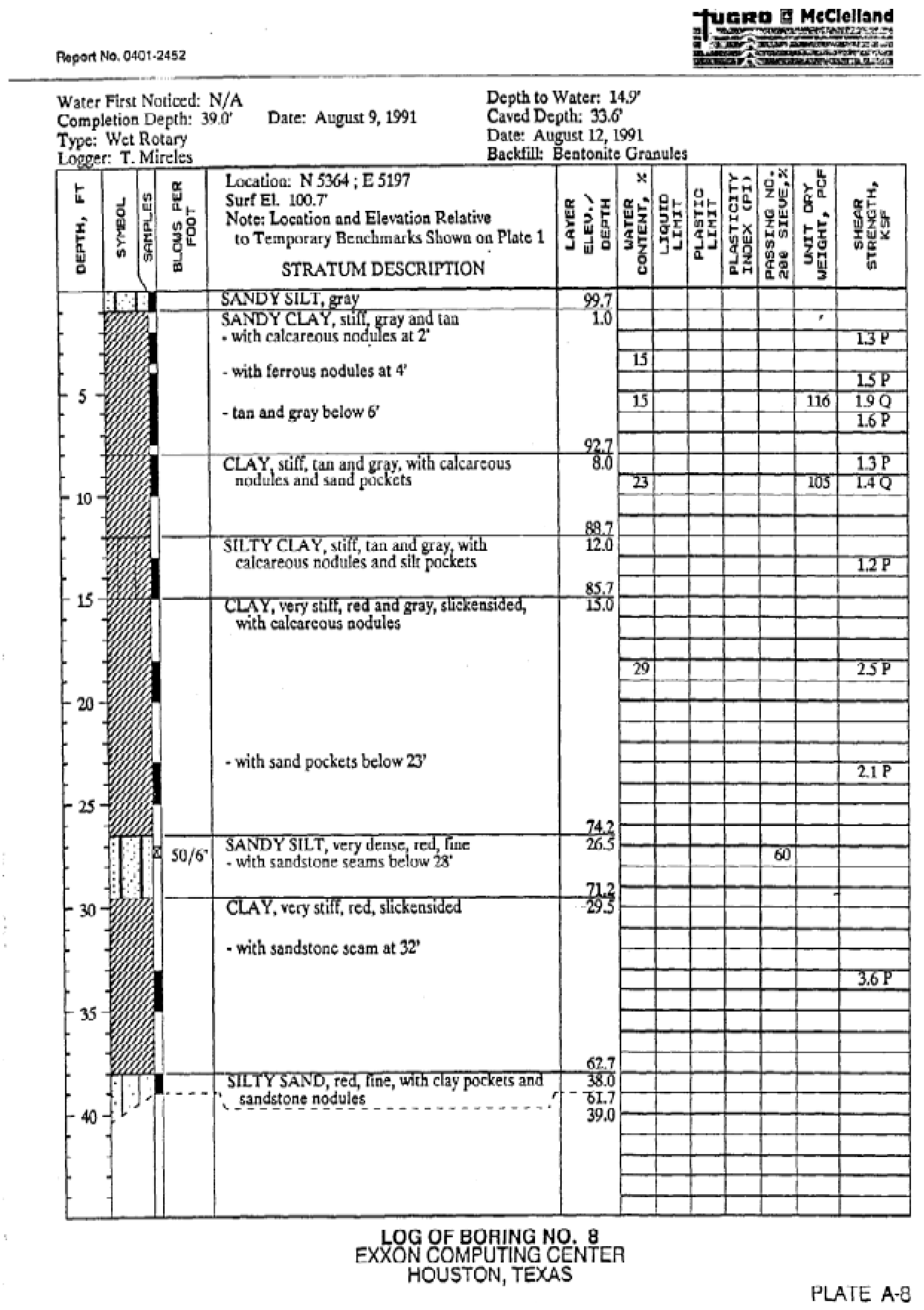
Water First Noticed: N/A
Completion Depth: 30.0' Date: August 10, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 4.8'
Caved Depth: 9.8'
Date: August 12, 1991
Backfill: Bentonite Granules

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT	Location: N 5539 ; E 5592 Surf El. 100.6' Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1 STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
				FILL: SANDY CLAY, very stiff, gray and tan, with calcareous nodules	99.6 1.0							2.7+ P
				SANDY SILT, gray	98.6 2.0							2.7+ P
				SANDY CLAY, very stiff, gray and tan, with sand pockets - stiff, 4' to 8'								
5				- with vertical sand seams at 6'		16						1.3 P
				- tan and gray, with calcareous nodules below 6'								1.8 P
				- very stiff below 8'								2.4 P
						17					108	3.3 Q
10												
												2.1 P
				- with silt pockets below 14'								
15				CLAY, very stiff, red and gray, slickensided, with calcareous nodules and siltstone nodules	85.1 15.5							
						22					104	1.5* O
												2.1 P
20												
				- with silt pockets below 23'								3.6 P
25												
				CLAYEY SILT, medium dense, red, with clay pockets	74.1 26.5							
			18									
30					70.6 30.0							
				* Failed on slickensided plane								
35												
40												

LOG OF BORING NO. 7
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-7



FUGRO McClelland

Report No. 0401-2452

Water First Noticed: N/A
Completion Depth: 39.0'   Date: August 9, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 14.9'
Caved Depth: 33.6'
Date: August 12, 1991
Backfill: Bentonite Granules

Location: N 5364 ; E 5197
Surf El. 100.7'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
				SANDY SILT, gray	99.7							
				SANDY CLAY, stiff, gray and tan	1.0							
				- with calcareous nodules at 2'								1.3 P
						15						
				- with ferrous nodules at 4'								1.5 P
5						15					116	1.9 Q
				- tan and gray below 6'								1.6 P
					92.7							
				CLAY, stiff, tan and gray, with calcareous nodules and sand pockets	8.0							1.3 P
						23					105	1.4 Q
10												
					88.7							
				SILTY CLAY, stiff, tan and gray, with calcareous nodules and silt pockets	12.0							
												1.2 P
					85.7							
15				CLAY, very stiff, red and gray, slickensided, with calcareous nodules	15.0							
						29						2.5 P
20												
				- with sand pockets below 23'								2.1 P
25												
					74.2							
			50/6"	SANDY SILT, very dense, red, fine	26.5							
				- with sandstone seams below 28'						60		
					71.2							
30				CLAY, very stiff, red, slickensided	29.5							
				- with sandstone seam at 32'								
												3.6 P
35												
					62.7							
				SILTY SAND, red, fine, with clay pockets and sandstone nodules	38.0							
					61.7							
40					39.0							

LOG OF BORING NO. 8
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-8

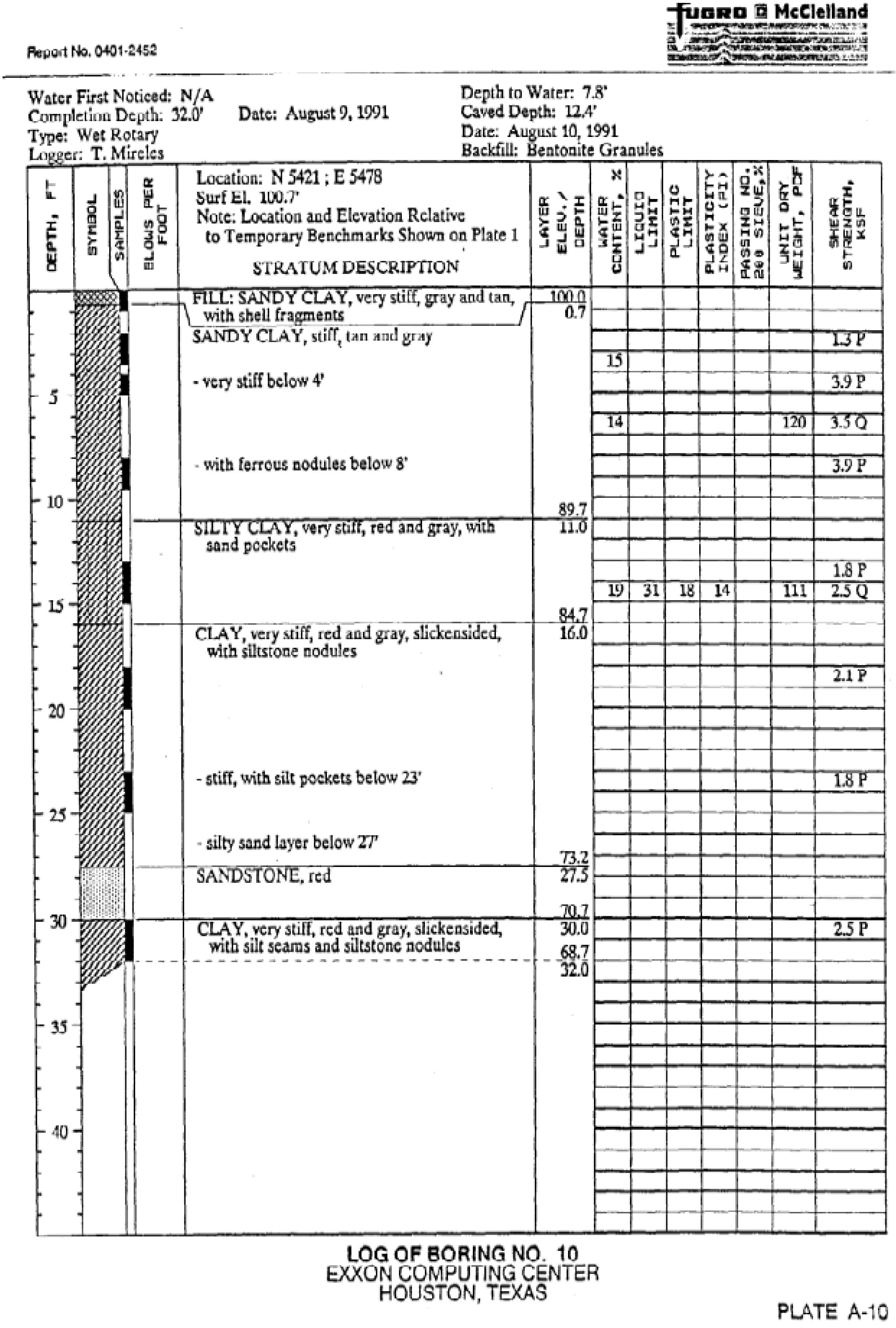
Water First Noticed: N/A
Completion Depth: 39.0' Date: August 1, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 15.9'
Caved Depth: 31.1'
Date: August 12, 1991
Backfill: Bentonite Granules

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT	Location: N 5496 ; E 5654 Surf El. 100.3' Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1 STRATUM DESCRIPTION	LAYER ELEV. / DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
				SANDY SILT, gray	98.8 1.5							
				SANDY CLAY, stiff, tan and gray, with sand pockets								1.2 P
				- very stiff, slickensided, with ferrous nodules below 4'								2.1 P
5						14	41	13	29		119	
				- with vertical sand seams below 6'								
												2.4 Q
						18					109	2.9 Q
10												
					88.3 12.0							
				SILTY CLAY, very stiff, tan and gray, with sand pockets								2.1 P
					85.3 15.0	22					104	2.9 Q
15				CLAY, stiff, red and gray, slickensided - with calcareous nodules to 20'								
												1.6 P
						36	70	23	46		86	
20												
				- with siltstones and silt pockets at 23'								
												2.0 P
25												
					72.8 27.5							
			13	CLAYEY SILT, medium dense, red								
					70.3 30.0							
30				CLAY, very stiff, red and gray, slickensided, with silt pockets								
												2.5 P
35												
				- with calcareous nodules below 38'								3.9 P
					61.3 39.0							
40												

LOG OF BORING NO. 9
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-9



Report No. 0401-2452

FUGRO McClelland

Water First Noticed: N/A
Completion Depth: 32.0' Date: August 9, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 7.8'
Caved Depth: 12.4'
Date: August 10, 1991
Backfill: Bentonite Granules

Location: N 5421 ; E 5478
Surf El. 100.7'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1

DEPTH, FT	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
	FILL: SANDY CLAY, very stiff, gray and tan, with shell fragments	100.0 0.7							
	SANDY CLAY, stiff, tan and gray								1.3 P
			15						
	- very stiff below 4'								3.9 P
5									
			14					120	3.5 Q
	- with ferrous nodules below 8'								3.9 P
10		89.7 11.0							
	SILTY CLAY, very stiff, red and gray, with sand pockets								
									1.8 P
			19	31	18	14		111	2.5 Q
15		84.7 16.0							
	CLAY, very stiff, red and gray, slickensided, with siltstone nodules								
									2.1 P
20									
	- stiff, with silt pockets below 23'								1.8 P
25									
	- silty sand layer below 27'	73.2 27.5							
	SANDSTONE, red								
30	CLAY, very stiff, red and gray, slickensided, with silt seams and siltstone nodules	70.7 30.0							2.5 P
		68.7 32.0							
35									
40									

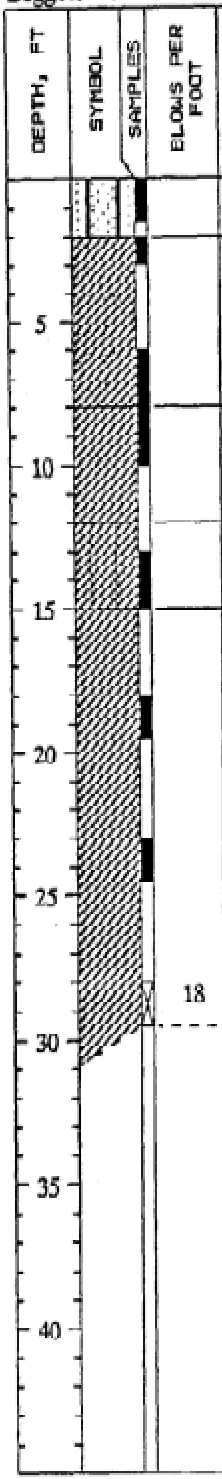
LOG OF BORING NO. 10
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-10

Water First Noticed: N/A
Completion Depth: 29.5' Date: August 10, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 14.3'
Caved Depth: 19.1'
Date: August 12, 1991
Backfill: Bentonite Granules

Location: N 5426 ; E 5633
Surf El. 100.7'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1



BLOWS PER FOOT	STRATUM DESCRIPTION	LAYER ELEV./DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
	SANDY SILT, gray - very stiff sandy clay fill to 0.5'	98.7 2.0							
	SANDY CLAY, stiff, light gray		13						1.2 P
	- with many calcareous nodules to 3'								1.8 Q
	- tan and gray, with ferrous nodules below 4'		17					114	2.1 Q
	- with calcareous nodules below 6'	92.7 8.0							1.3 P
	CLAY, stiff, tan and gray, with ferrous nodules, calcareous nodules, and sand pockets								1.3 P
		88.7 12.0	21					106	1.8 Q
	SILTY CLAY, stiff, tan and gray, with sand pockets and calcareous nodules	85.7 15.0							1.2 P
	CLAY, very stiff, red and gray, slickensided, with siltstone nodules		28						2.7 P
	- with silt pockets below 23'								3.9 P
18	- silt layer, 27.5' to 28' - stiff, with seams below 28'	71.2 29.5							1.5 P

LOG OF BORING NO. 11
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-11

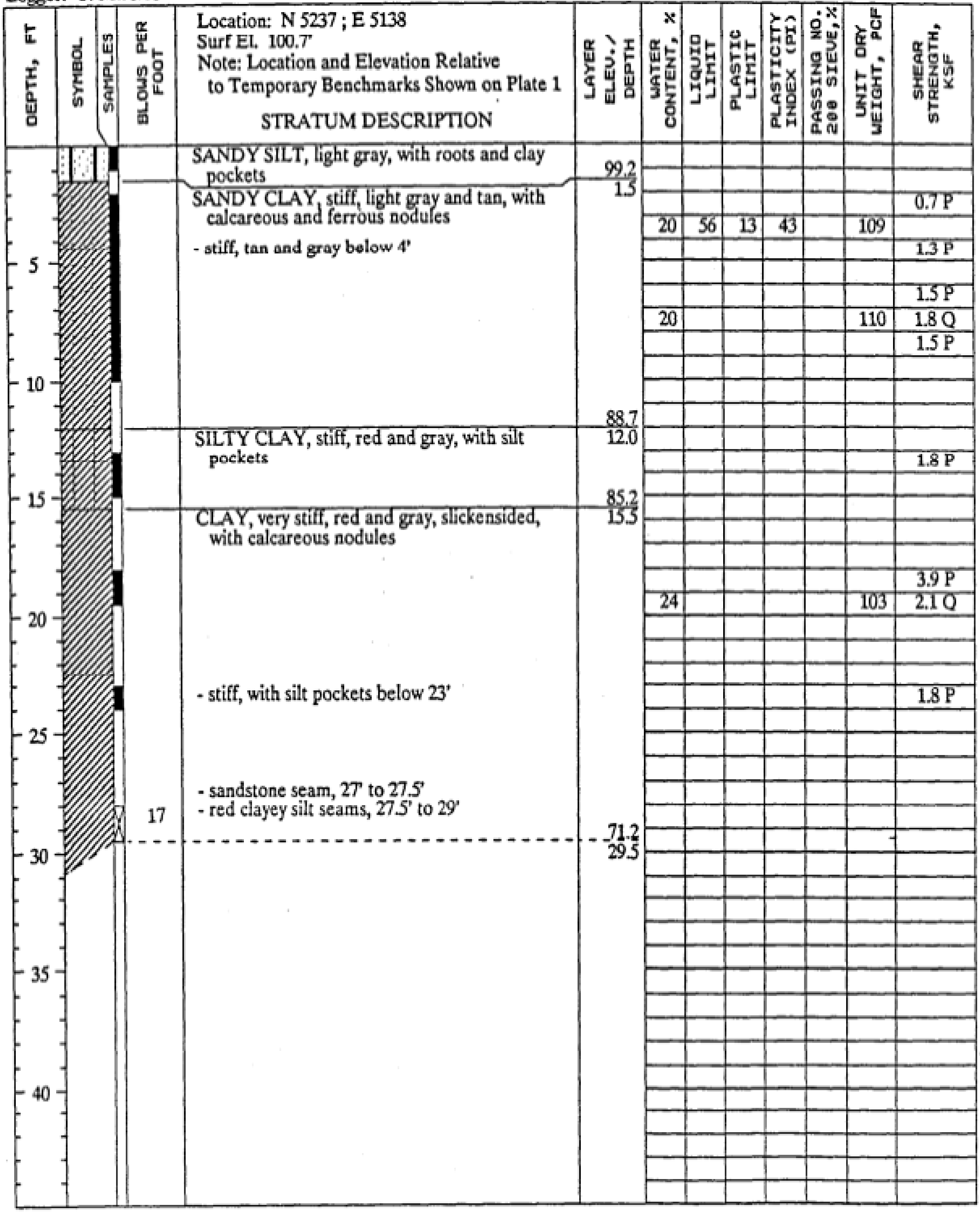
Report No. 0401-2452

Fugro McClelland

Water First Noticed: N/A
Completion Depth: 29.5' Date: August 10, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 10.5'
Caved Depth: 26.2'
Date: August 12, 1991
Backfill: Bentonite Granules

Location: N 5237 ; E 5138
Surf El. 100.7'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1



BLOWS PER FOOT	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
	SANDY SILT, light gray, with roots and clay pockets	99.2 1.5							
	SANDY CLAY, stiff, light gray and tan, with calcareous and ferrous nodules								0.7 P
			20	56	13	43		109	
	- stiff, tan and gray below 4'								1.3 P
									1.5 P
			20					110	1.8 Q
									1.5 P
	SILTY CLAY, stiff, red and gray, with silt pockets	88.7 12.0							
									1.8 P
	CLAY, very stiff, red and gray, slickensided, with calcareous nodules	85.2 15.5							
									3.9 P
			24					103	2.1 Q
	- stiff, with silt pockets below 23'								1.8 P
17	- sandstone seam, 27' to 27.5' - red clayey silt seams, 27.5' to 29'								
		71.2 29.5							

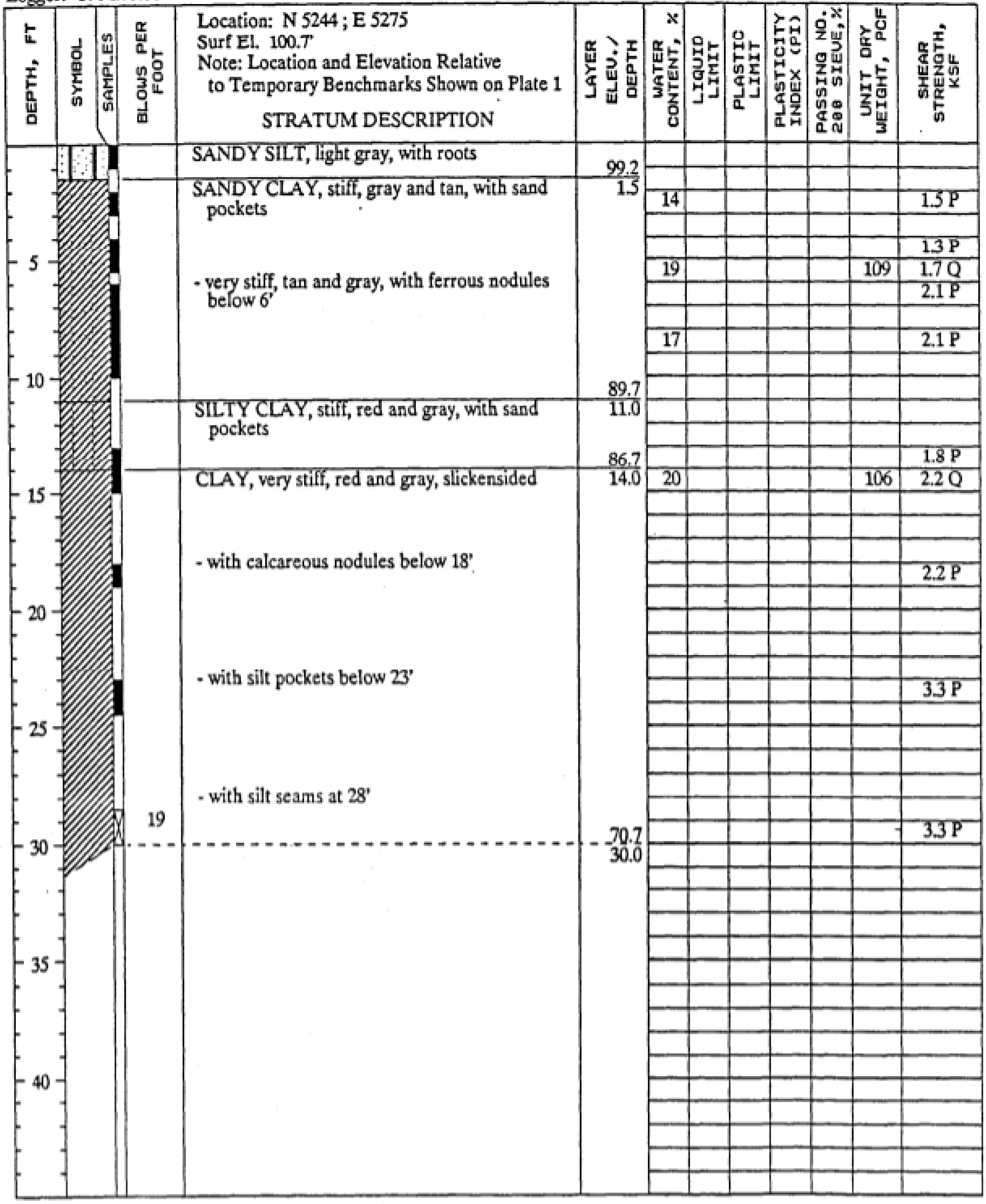
LOG OF BORING NO. 12
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-12

Water First Noticed: N/A
Completion Depth: 30.0' Date: August 10, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 14.6'
Caved Depth: 23.7'
Date: August 12, 1991
Backfill: Bentonite Granules

Location: N 5244 ; E 5275
Surf El. 100.7'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1



BLOWS PER FOOT	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
	SANDY SILT, light gray, with roots	99.2 1.5							
	SANDY CLAY, stiff, gray and tan, with sand pockets		14						1.5 P
									1.3 P
			19					109	1.7 Q
	- very stiff, tan and gray, with ferrous nodules below 6'								2.1 P
			17						2.1 P
	SILTY CLAY, stiff, red and gray, with sand pockets	89.7 11.0							
									1.8 P
	CLAY, very stiff, red and gray, slickensided	86.7 14.0	20					106	2.2 Q
	- with calcareous nodules below 18'								2.2 P
	- with silt pockets below 23'								3.3 P
19	- with silt seams at 28'								3.3 P
		70.7 30.0							

LOG OF BORING NO. 13
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-13

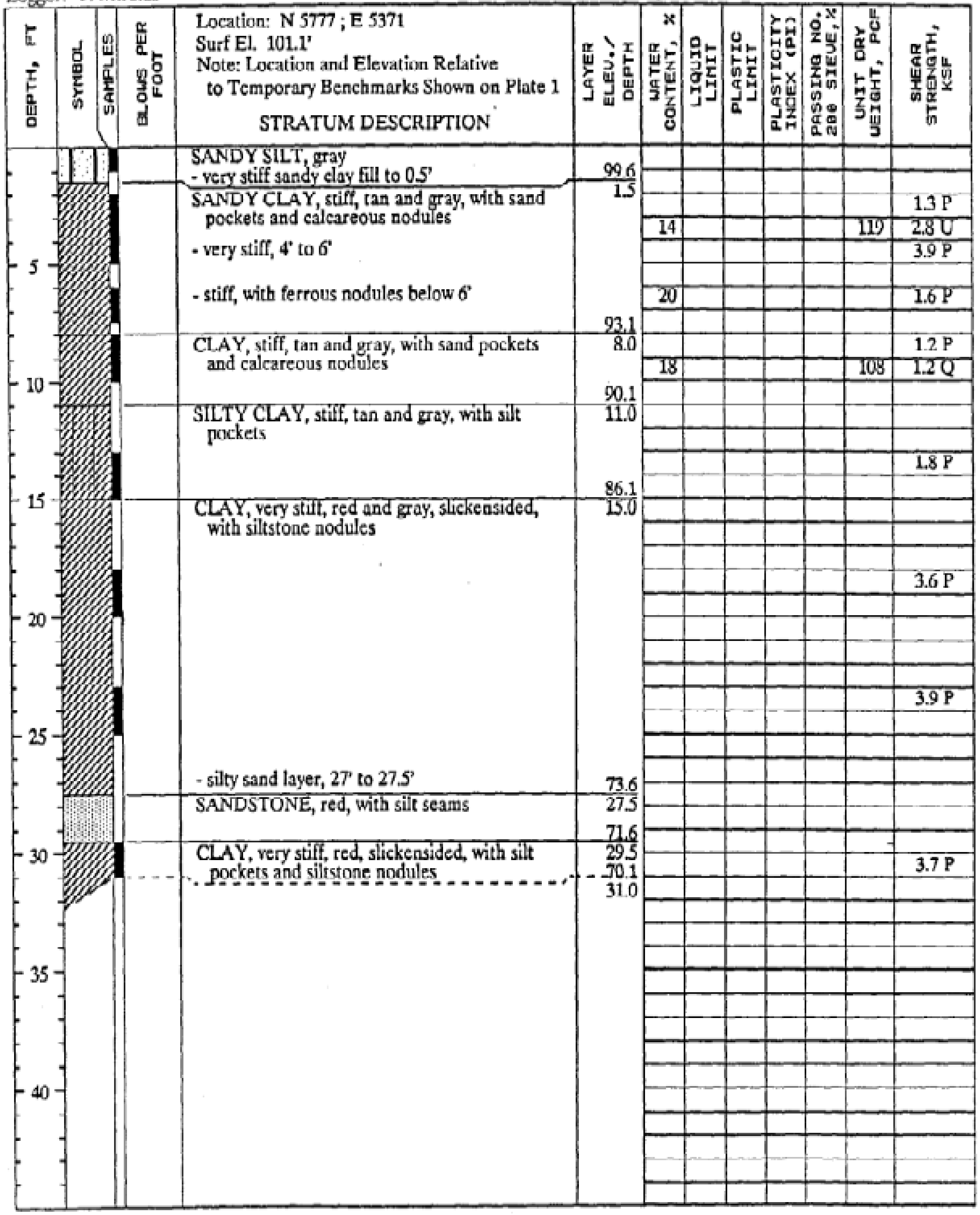
Report No. 0401-2452

FUGRO McClelland

Water First Noticed: N/A
Completion Depth: 31.0'
Date: August 9, 1991
Type: Wet Rotary
Logger: T. Mireles

Depth to Water: 14.9'
Caved Depth: 18.4'
Date: August 10, 1991
Backfill: Bentonite Granules

Location: N 5777 ; E 5371
Surf El. 101.1'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1



STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
SANDY SILT, gray - very stiff sandy clay fill to 0.5'	99.6 1.5							
SANDY CLAY, stiff, tan and gray, with sand pockets and calcareous nodules								1.3 P
		14					119	2.8 U
- very stiff, 4' to 6'								3.9 P
- stiff, with ferrous nodules below 6'		20						1.6 P
CLAY, stiff, tan and gray, with sand pockets and calcareous nodules	93.1 8.0							1.2 P
		18					108	1.2 Q
SILTY CLAY, stiff, tan and gray, with silt pockets	90.1 11.0							
								1.8 P
CLAY, very stiff, red and gray, slickensided, with siltstone nodules	86.1 15.0							
								3.6 P
								3.9 P
- silty sand layer, 27' to 27.5'								
SANDSTONE, red, with silt seams	73.6 27.5							
CLAY, very stiff, red, slickensided, with silt pockets and siltstone nodules	71.6 29.5							3.7 P
	70.1 31.0							

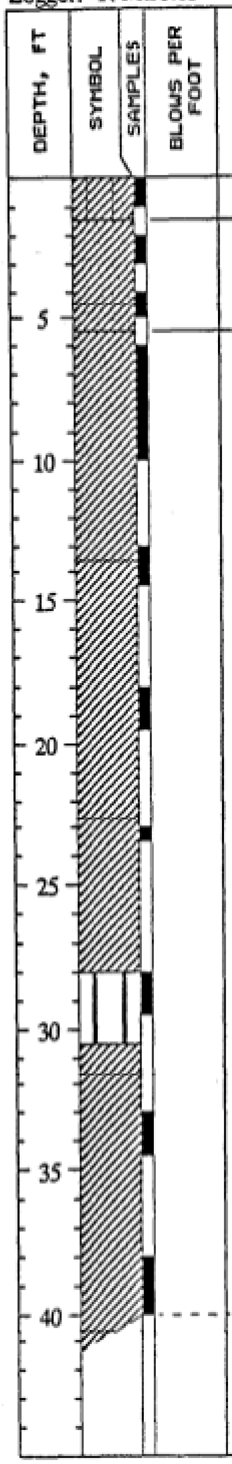
LOG OF BORING NO. 17
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-17

Water First Noticed: --
Completion Depth: 40.0' Date: November 3, 1991
Type: Dry Auger to 6'; Wet Rotary below 6'
Logger: T. Mireles

Depth to Water: --
Caved Depth: --
Date: --
Backfill: --

Location: N 5630 ; E 5567
Surf El. 100.6'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1



STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
SILTY CLAY, stiff, gray, with roots								1.3 P
	99.1 1.5							
SANDY CLAY, very stiff, light gray and tan, with sand pockets and vertical sand seams		10	44	12	32			5.4 P
								5.2 P
		10					117	4.8 Q
	95.1 5.5							
CLAY, stiff, tan and light gray - with vertical sand seams to 8' - with ferrous nodules to 10' - with sand pockets to 16'								1.9 P
								2.2 P
		19					111	2.7 Q
- slickensided below 10'								
- very stiff below 13' - with silt pockets, 13' to 16'								2.1 P
- red and gray below 16'								
- with calcareous nodules at 18'		27	73	24	49			2.4 P
								2.7 P
- with silt seams at 27'								
- red silt, with clay pockets, 28' to 30.5'						87		
- with silt seams, 30.5' to 34'								
								3.6 P
- with silt pockets and seams below 38'								
		22						
	60.6 40.0							

LOG OF BORING NO. 18
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-18

Water First Noticed: --
Completion Depth: 50.0' Date: November 3, 1991
Type: Dry Auger to 10'; Wet Rotary below 10'
Logger: T. Mireles

Depth to Water: --
Caved Depth: --
Date: --
Backfill: Bentonite Granules

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT	Location: N 5634 ; E 5712 Surf El. 100.4' Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1 STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE,%	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
				SILTY CLAY, stiff, gray								
					98.9 1.5	14						1.2 P
				SAND CLAY, very stiff, gray and tan, with sand pockets and ferrous nodules								2.1 P
				- stiff to 2'		13	37	12	26			
				- with calcareous nodules below 4'								2.1 P
5					94.4 6.0	15						
				CLAY, stiff, tan and light gray								1.8 P
				- with sand pockets and ferrous nodules to 16'		16					115	2.5 Q
				- with silt pockets, 8' to 16'			50	17	33			2.1 P
				- very stiff, 8' to 23'								
10												
						20						2.1 P
15				- slickensided below 16'								
				- with calcareous nodules below 18'								2.2 P
20												
				- stiff, 23' to 28'		28						1.6 P
				- with silt pockets, 23' to 30.5'								
25												
				- firm, with silty sand seams, 28' to 30.5'								
			20									
30				- very stiff, red and gray below 30.5'								
						26						2.5 P
35												
				- with silty sand seams at 38.5								4.2 P
				- with sand stone seam at 39'								
40					59.4 41.0							
				SANDY CLAY, very stiff, gray and red, with sand pockets								
						20						2.1 P

LOG OF BORING NO. 19
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-19a

Water First Noticed: --
Completion Depth: 50.0'   Date: November 3, 1991
Type: Dry Auger to 10'; Wet Rotary below 10'
Logger: T. Mircles

Depth to Water: --
Caved Depth: --
Date: --
Backfill: Bentonite Granules

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT	Location: N 5634 ; E 5712 Surf El. 100.4' Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1 STRATUM DESCRIPTION	LAYER ELEV. / DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
	▨				52.4 48.0							
50	⁙	☒	27	SILTY SAND, medium dense, light gray and tan, fine, with sandy clay pockets	50.4 50.0					37		
55												
60												
65												
70												
75												
80												
85												

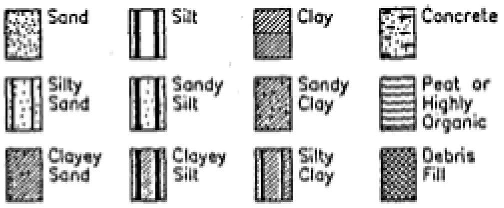
LOG OF BORING NO. 19

EXXON COMPUTING CENTER
HOUSTON, TEXAS

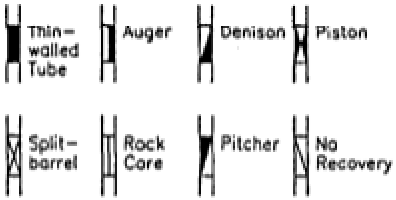
PLATE A-19b

TERMS AND SYMBOLS USED ON BORING LOGS

SOIL TYPES

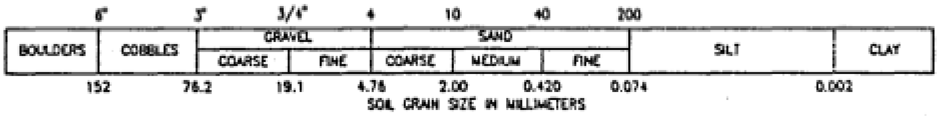


SAMPLER TYPES



SOIL GRAIN SIZE

U.S. STANDARD SIEVE



STRENGTH OF COHESIVE SOILS (1)

Consistency	Undrained Shear Strength Kips Per Sq Ft
Very Soft	less than 0.25
Soft	0.25 to 0.50
Firm	0.50 to 1.00
Stiff	1.00 to 2.00
Very Stiff	2.00 to 4.00
Hard	greater than 4.00

DENSITY OF GRANULAR SOILS (2,3)

Descriptive Term	•Relative Density, %
Very Loose	less than 15
Loose	15 to 35
Medium Dense	35 to 65
Dense	65 to 85
Very Dense	greater than 85

•Estimated from sampler driving record

SPLIT-BARREL SAMPLER DRIVING RECORD

Blows Per Foot	Description
25	25 blows drove sampler 12 inches, after initial 6 inches of seating.
50/7"	50 blows drove sampler 7 inches, after initial 6 inches of seating.
Ref/3"	50 blows drove sampler 3 inches during initial 6-inch seating interval.

Note: To avoid damage to sampling tools, driving is limited to 50 blows during or after seating interval.

SHEAR STRENGTH TEST METHOD

U = Unconfined
Q = Unconsolidated-Undrained Triaxial
P = Pocket Penetrometer
T = Torvane
V = Miniature Vane

SOIL STRUCTURE (1)

Slickensided	Having planes of weakness that appear slick and glossy. The degree of slickensidedness depends upon the spacing of slickensides and the ease of breaking along these planes.
Fissured	Containing shrinkage or relief cracks, often filled with fine sand or silt; usually more or less vertical.
Pocket	Inclusion of material of different texture that is smaller than the diameter of the sample.
Parting	Inclusion less than 1/8 inch thick extending through the sample.
Seam	Inclusion 1/8 inch to 3 inches thick extending through the sample.
Layer	Inclusion greater than 3 inches thick extending through the sample.
Laminated	Soil sample composed of alternating partings or seams of different soil types.
Interlayered	Soil sample composed of alternating layers of different soil types.
Intermixed	Soil sample composed of pockets of different soil types and layered or laminated structure is not evident.
Calcareous	Having appreciable quantities of carbonate. (12 to 49%)
Carbonate	Having more than 50% carbonate content.

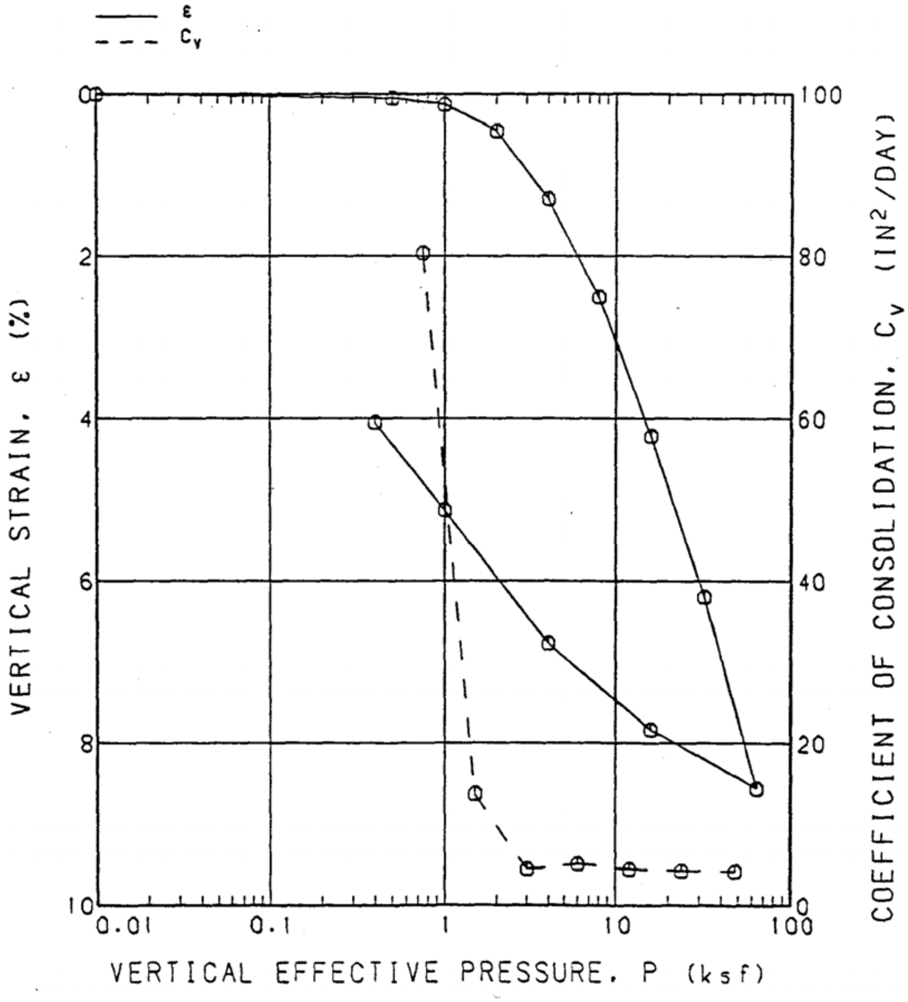
REFERENCES:

(1) ASTM D 2488
(2) ASCE Manual 56 (1976)
(3) ASTM D 2049

Information on each boring log is a compilation of subsurface conditions and soil or rock classifications obtained from the field as well as from laboratory testing of samples. Strata have been interpreted by commonly accepted procedures. The stratum lines on the log may be transitional and approximate in nature. Water level measurements refer only to those observed at the times and places indicated, and may vary with time, geologic condition or construction activity.

PLATE A-20

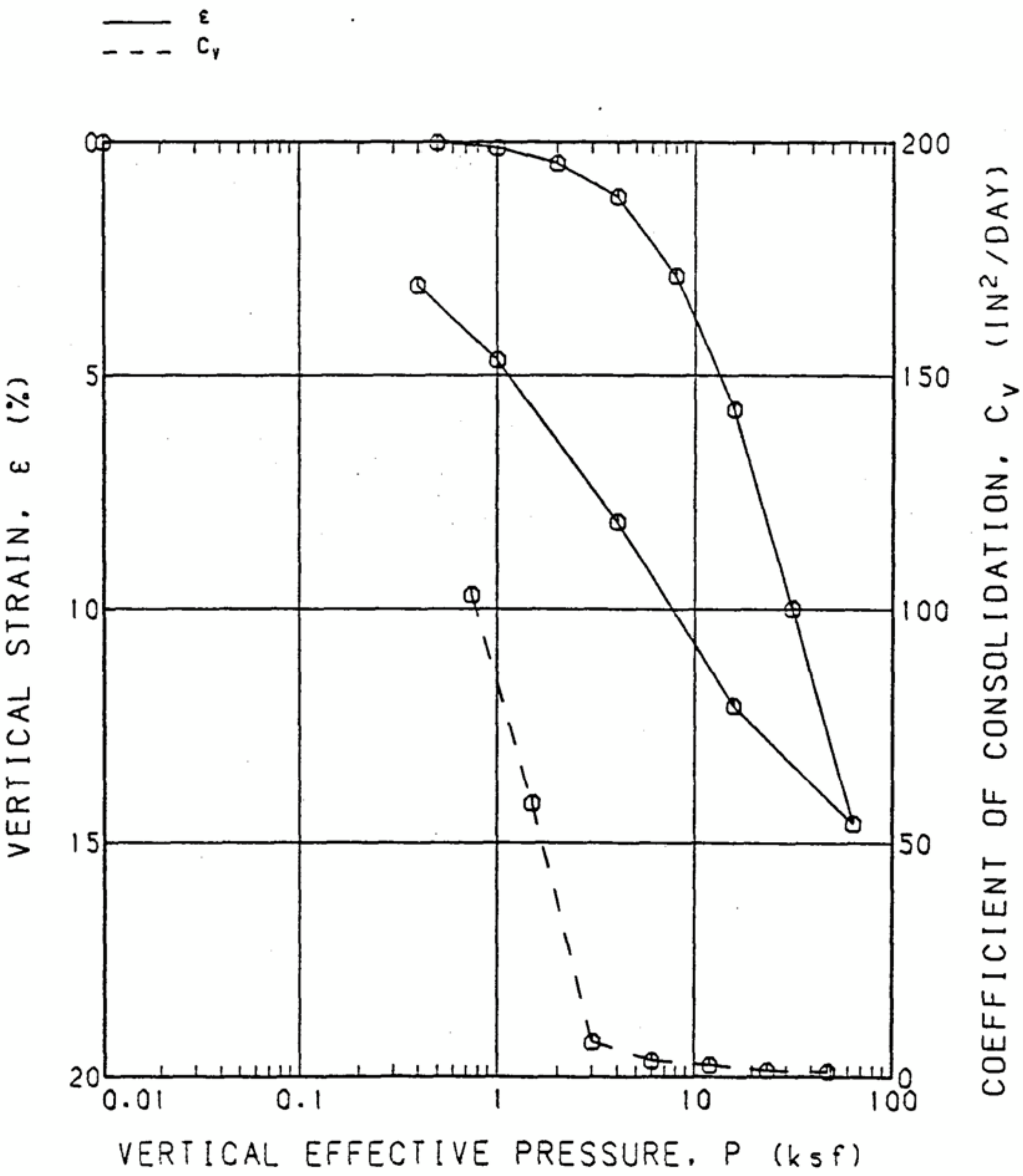
BORING: 1
PENETRATION: 8.0 Ft
MATERIAL: SANDY CLAY, stiff, gray
DRY UNIT WEIGHT: 113.3 pcf
WATER CONTENT: 17 %
LIQUID LIMIT: 40
PLASTIC LIMIT: 11
SPECIFIC GRAVITY: 2.70 (assumed)
INITIAL VOID RATIO: 0.487



CONSOLIDATION TEST RESULTS
JOB NUMBER 0401-2453
BORING 1 DEPTH 8 FT

PLATE A-21

BORING: 9
PENETRATION: 20.0 Ft
MATERIAL: CLAY, stiff, red and gray
DRY UNIT WEIGHT: 85.7 pcf
WATER CONTENT: 36 %
LIQUID LIMIT: 70
PLASTIC LIMIT: 23
SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL VOID RATIO: 1.002



CONSOLIDATION TEST RESULTS
JOB NUMBER 0401-2453
BORING 9 DEPTH 20 FT

PLATE A-22