DESIGN OF A MULTISTOREYED BUILDING AND ITS FOUNDATION (Isolated footing)

Enrollment number - 101618

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Submitted in partial fulfillment of the Degree of

Bachelor of Technology

Department of ***Civil Engineering***

Jaypee University of Information Technology,

Wakhnaghat

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Declaration

I hereby declare that the work entitled "**Design of a multistoreyed building and its foundation (Isolated footing)"** submitted to "**Jaypee University of Information Technology**" is a record of an original work done by me under the guidance of **Dr.S.K.Jain** and **Mr. Lav Singh** and this project work has not performed the basis for the award of any other degree or any other project of any kind.

Rupinder Kumar

Roll no. 101618

CERTIFICATE

This is to certify that the work titled "**Design of a multistoreyed building and its foundation**" submitted by "**Rupinder Kumar**" in partial fulfillment for the award of degree of **B. Tech**. 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.

Signature of Supervisor ……………………..
Name of Supervisor ……………………..
Designation ……………………..
Date ……………………..

Signature of Supervisor ……………………..
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Acknowledgement

I take this opportunity to express my profound gratitude and deep regards to my guide **Dr.S. K. Jain and Mr. Lav Singh** for their exemplary guidance, monitoring and constant encouragement throughout the course of this thesis. The blessing, help and guidance given by them, time to time shall carry me a long way in the journey of life on which I am about to embark.

I also take this opportunity to express a deep sense of gratitude to the Head of department (HOD) of Civil engineering **Dr. Ashok Kumar Gupta** for his cordial support, valuable information, guidance and opportunities that he provided throughout my degree which helped me in completing this task through various stages as well as realising my true potential through the course of time.

Signature of the student ……………………..

Name of Student ……………………..

Date ……………………..

Literature Review:

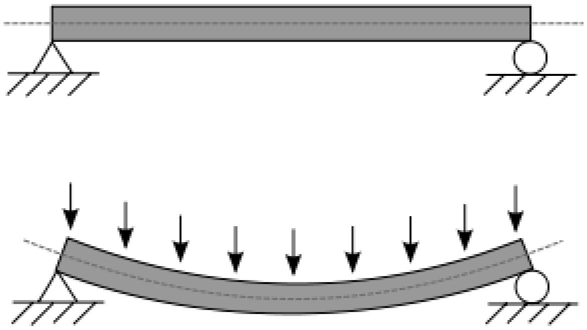
Part A : Superstructure

•Structural Elements:

1.Beam

A beam is a structural element that is capable of withstanding load primarily by resisting bending. The bending force induced into the material of the beam as a result of the external loads, own weight, span and external reactions to these loads is called a bending moment.

Beams generally carry vertical gravitational forces but can also be used to carry horizontal loads (i.e., loads due to an earthquake or wind). The loads carried by a beam are transferred to columns, walls, or girders, which then transfer the force to adjacent structural compression members. In light frame construction the joists rest on the beam.



Types of Beams-

1. simply supported beam
2. fixed beam
3. over hanging beam
4. continuous beam
5. cantilever beam

General Shapes:

Most beams in reinforced concrete buildings have rectangular cross sections, but a more efficient cross section for a beam is an I or H section which is typically seen in steel construction. Because of the parallel axis theorem and the fact that most of the material is away from the neutral axis, the second moment of area of the beam increases, which in turn increases the stiffness.

2.Column:

Column is a structural element that transmits, through compression, the weight of the structure above to other structural elements below. In other words, a column is a compression member. The term column applies especially to a large round support with a capital and base and made of stone, or appearing to be so. A small wooden or metal support is typically called a post, and supports with a rectangular or other non-round section are usually called piers. For the purpose of wind or earthquake engineering, columns may be designed to resist lateral forces. Other compression members are often termed "columns" because of the similar stress conditions. Columns are frequently used to support beams or arches on which the upper parts of walls or ceilings rest.

3. ***Slab :***

A slab is a common structural element of modern buildings. Horizontal slabs of steel reinforced concrete, typically between 100 and 500 millimeters thick, are most often used to construct floors and ceilings, while thinner slabs are also used for exterior paving.

In many domestic and industrial buildings a thick concrete slab, supported on foundations or directly on the subsoil, is used to construct the ground floor of a building. These can either be "ground-bearing" or "suspended" slabs. In high rise buildings and skyscrapers, thinner, pre-cast concrete slabs are slung between the steel frames to form the floors and ceilings on each level.

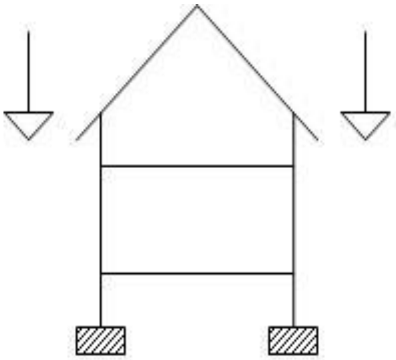
Reinforcement design :

A ***one way slab*** needs moment resisting reinforcement only in its short-direction because the moment along long axes is so small that it can be neglected. When the ratio of the length of long direction to short direction of a slab is greater than 2 it can be considered as a one way slab.
A ***two way slab*** needs moment resisting reinforcement in both directions. If the ratio of the lengths of long and short side is less than two then movement in both direction should be considered in design.

- ## ***LOADS :***

1. ***Dead Loads*** –

Dead loads are static forces that are relatively constant for an extended time. They can be in tension or compression. The term can refer to a laboratory test method or to the normal usage of a material or structure.



The dead load includes loads that are relatively constant over time, including the weight of the structure itself, and immovable fixtures such as walls, plasterboard or carpet. Roof is also a dead load. Dead loads are also known as Permanent loads.

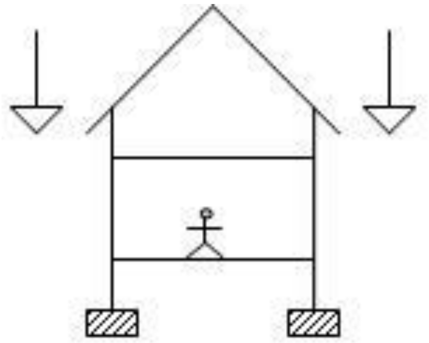
The designer can also be relatively sure of the magnitude of dead loads as they are closely linked to density and quantity of the construction materials. These have a low variance and the designer is normally responsible for specifying these components.

2.__Live Loads__ :

Live loads are usually unstable or moving loads. These dynamic loads may involve considerations such as impact, momentum, vibration, slosh dynamics of fluids, etc. An impact load is one whose time of application on a material is less than one-third of the natural period of vibration of that material.

Live loads, or imposed loads, are temporary, of short duration, or moving. These dynamic loads may involve considerations such as impact momentum vibration slosh dynamics of fluids, fatigue, etc.

Live loads, sometimes also referred to as probabilistic loads include all the forces that are variable within the object's normal operation cycle not including construction or environmental loads.

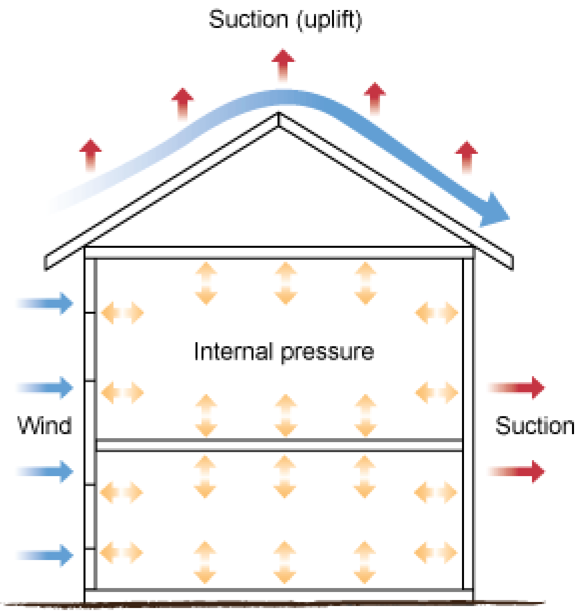


Roof and Floor and materials, and

1. during the life of the structure by movable objects such as planters and by people.
2. Bridge live loads are produced by vehicles traveling over the deck of the bridge.

3.*Wind Loads* :

The force on a structure arising from the impact of wind on it. The force on a structure arising from the impact of wind on it.



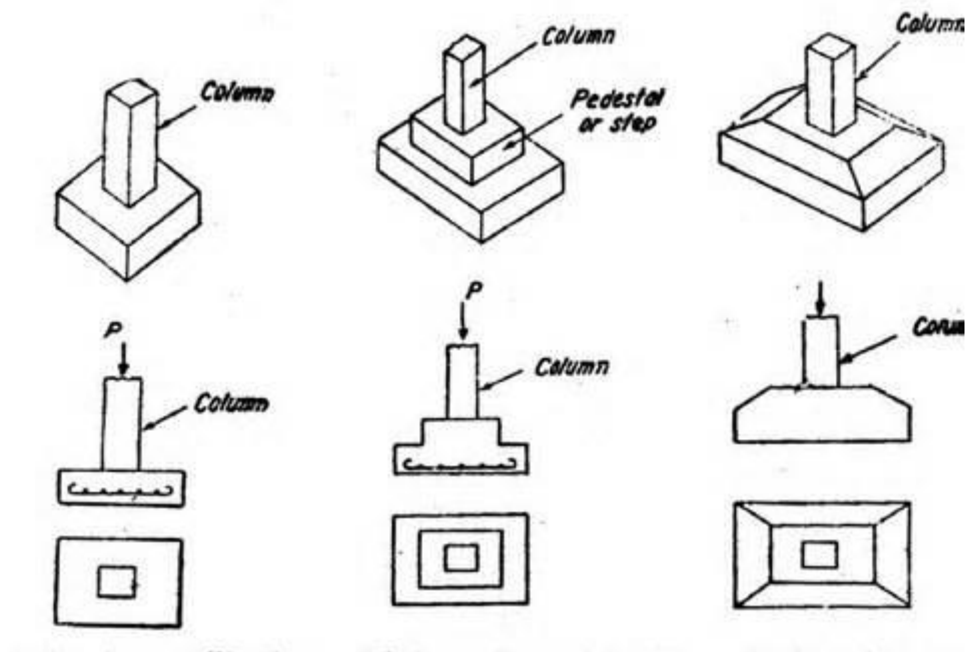
Part B : Sub structure

Shallow foundations :

Shallow foundations are a type of foundation that transfers building load to the very near the surface, rather than to a subsurface layer. Shallow foundations typically have a depth to width ratio of less than 1.

Footings:

Footings (often called "spread footings" because they spread the load) are structural elements which transfer structure loads to the ground by direct areal contact. Footings can be isolated footings for point or column loads, or strip footings for wall or other long (line) loads. Footings are normally constructed from reinforced concrete cast directly onto the soil, and are typically embedded into the ground to penetrate through the zone of frost movement and/or to obtain additional bearing capacity.



(a) Simple spread footing (b) Stepped spread footing (c) Sloped footing

Geotechnical investigation :

Geotechnical engineers perform geotechnical investigations to obtain information on the physical properties of soil and rock underlying (and sometimes adjacent to) a site to design earthworks and foundations for proposed structures, and for repair of distress to earthworks and structures caused by subsurface conditions. A geotechnical investigation will include surface exploration and subsurface exploration of a site. Sometimes, geophysical methods are used to obtain data about sites. Subsurface exploration usually involves in-situ testing (two common examples of in-situ tests are the **standard penetration test** and **cone penetration test**). In addition site investigation will often include subsurface sampling and laboratory testing of the soil samples retrieved. The digging of test pits and trenching (particularly for locating faults and slide planes) may also be used to learn about soil conditions at depth. Large diameter borings are rarely used due to safety concerns and expense, but are sometimes used to allow a geologist or engineer to be lowered into the borehole for direct visual and manual examination of the soil and rock stratigraphy.

A variety of soil samplers exist to meet the needs of different engineering projects. The standard penetration test (SPT), which uses a **thick-walled split spoon sampler**, is the most common way to collect disturbed samples. Piston samplers, employing a thin-walled tube, are most commonly used for the collection of less disturbed samples. More advanced methods, such as ground freezing and the Sherbrooke block sampler, are superior, but even more expensive. **Atterberg limits tests**, **water content** measurements, and grain size analysis, for example, may be performed on disturbed samples obtained from thick walled soil samplers. Properties such as shear strength, stiffness hydraulic conductivity, and coefficient of consolidation may be significantly altered by sample disturbance. To measure these properties in the laboratory, high quality sampling is required. Common tests to measure the strength and stiffness include the triaxial shear and unconfined compression test.

Surface exploration can include geologic mapping, geophysical methods, and photogrammetry; or it can be as simple as an engineer walking around to observe the physical conditions at the site. Geologic mapping and interpretation of geomorphology is typically completed in consultation with a geologist or engineering geologist.

Geophysical exploration is also sometimes used. Geophysical techniques used for subsurface exploration include measurement of seismic waves(pressure, shear, and Rayleigh waves), surface-wave methods and/or downhole methods, and electromagnetic surveys (magnetometer, resistivity, and ground-penetrating radar).

Theoritical terms used in the design of idealised soil profile :

Liquid limit- It is the water content at which soil changes from liquid state to plastic state. At this water content, a soil sample changes from possessing no shear strength to having infinitesimal shear strength.

Plastic Limit- It is water content at which a soil changes from plastic to a semisolid state.

__Plasticity Index__* (Ip) – It is the range of moisture content over which a soil exhibits plasticity.

Ip = (Liquid Limit – Plastic limit)

Ip	**Soil description**
0	Non plastic
< 7	Low plastic
7-17	Medium plastic
>17	Highly plastic

__Consistency index__ - It tells us how far a soil is from its liquid state.

$$i_c = (\text{Liquid Limit-Natural water content}) / \text{Plasticity Index}$$
$$= (W_L - W_n)/I_p$$

Description	**Ic**
Very soft	0-0.25
soft	0.25-0.50
Medium stiff	0.50-0.75
stiff	0.75-1.0

Calculation of Bearing Capacity using **Meyerhoff equation** :

$Q_u = C\,N_c\,S_c\,d_c\,i_c + q\,N_q\,S_q\,d_q\,i_q + 0.5\Upsilon\,B\,N_\Upsilon\,S_\Upsilon\,d_\Upsilon\,i_\Upsilon$

where

s - stand for empirical correction factor called the shape factor,

d- depth factor,

i - inclination factor.

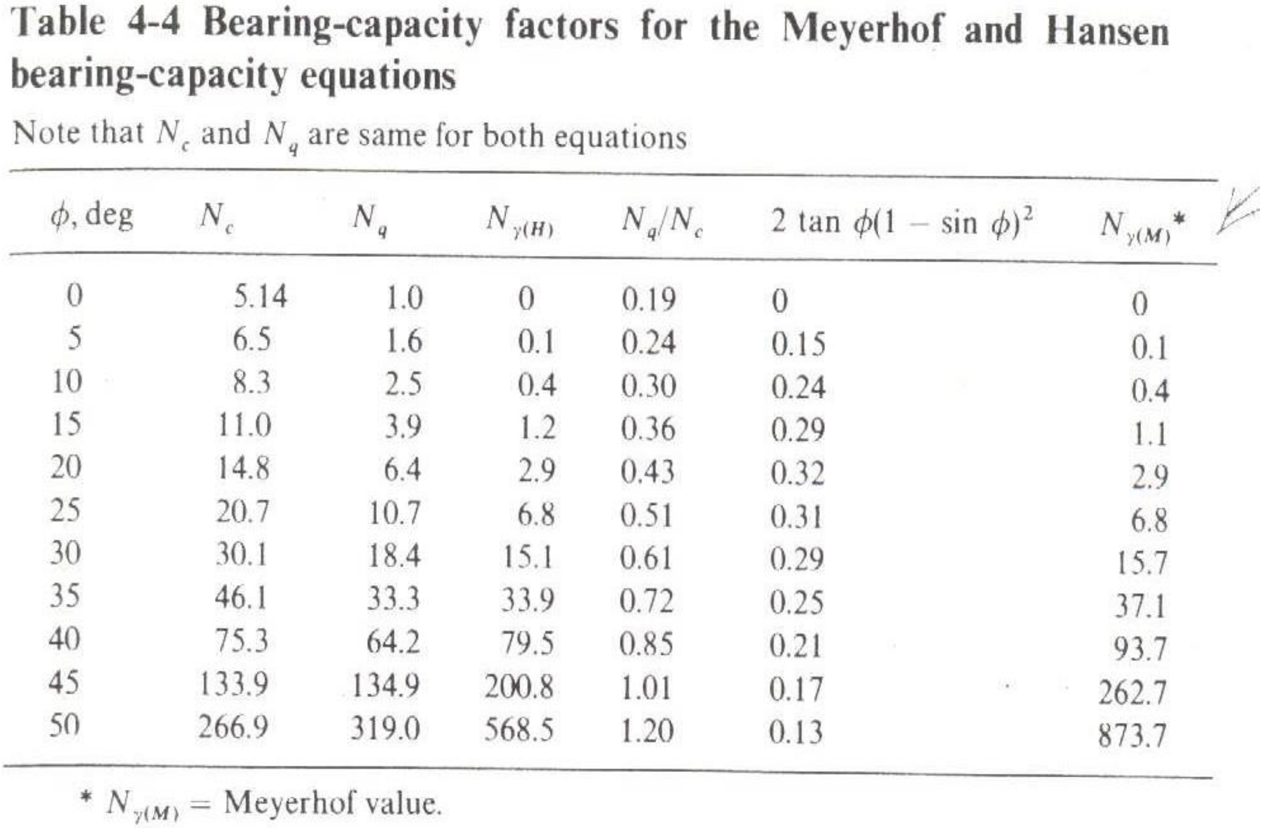


Table 4-4 Bearing-capacity factors for the Meyerhof and Hansen bearing-capacity equations

Note that N_c and N_q are same for both equations

ϕ, deg	N_c	N_q	$N_{\gamma(H)}$	N_q/N_c	$2\tan\phi(1-\sin\phi)^2$	$N_{\gamma(M)}$*
0	5.14	1.0	0	0.19	0	0
5	6.5	1.6	0.1	0.24	0.15	0.1
10	8.3	2.5	0.4	0.30	0.24	0.4
15	11.0	3.9	1.2	0.36	0.29	1.1
20	14.8	6.4	2.9	0.43	0.32	2.9
25	20.7	10.7	6.8	0.51	0.31	6.8
30	30.1	18.4	15.1	0.61	0.29	15.7
35	46.1	33.3	33.9	0.72	0.25	37.1
40	75.3	64.2	79.5	0.85	0.21	93.7
45	133.9	134.9	200.8	1.01	0.17	262.7
50	266.9	319.0	568.5	1.20	0.13	873.7

* $N_{\gamma(M)}$ = Meyerhof value.

Other formulas used in the Design-

$$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$$

Where P_u = axial load on the member,

f_{ck} = characteristic compressive strength of the concrete,

A_c = Area of concrete,

f_y = characteristic strength of the compression reinforcement, and

A_{sc} = area of longitudinal reinforcement for columns.

$\tau_v = V_u /bd$

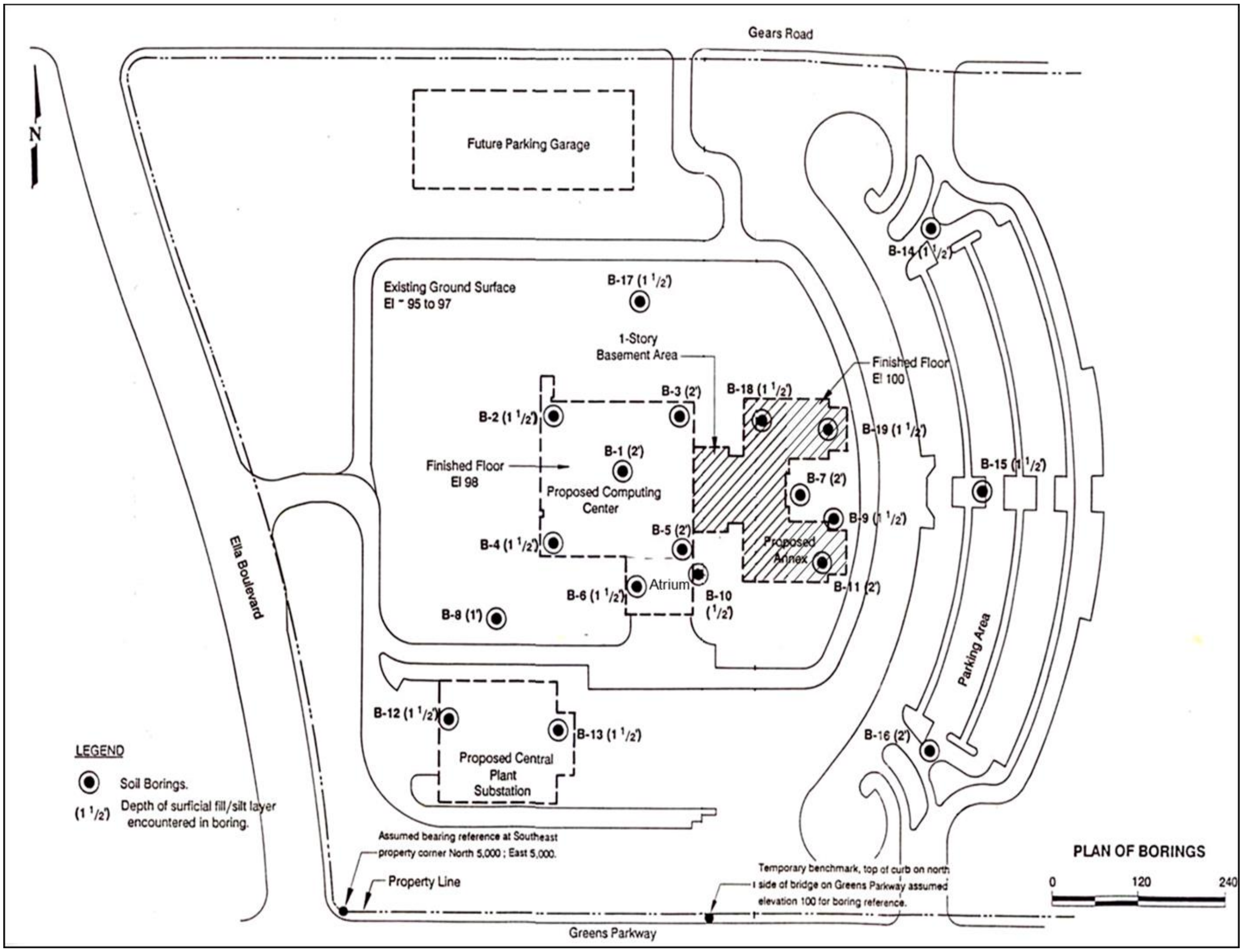
Where τ_v = Nominal shear stress

V_u = Shear force due to design loads

d = effective depth

b = width of the footing

Construction Site :



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 includes:

- Plan of boring
- Boring logs
- Laboratory test data
- In situ test data

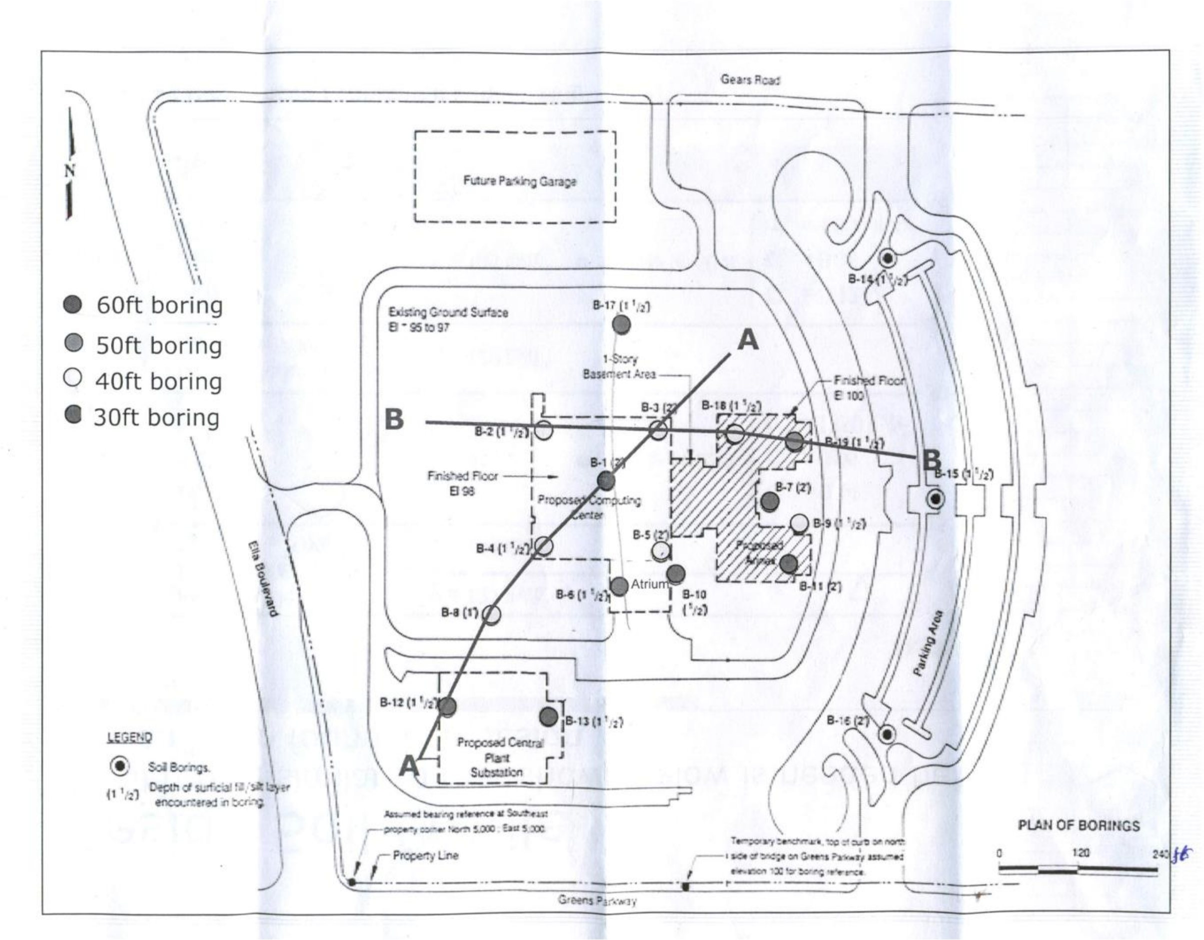
Methods and Methodologies :

For the design of the superstructure, Staad-Pro is used. The design is done according to the Limit state method. The load computations is done automatically by the software.

To find the bearing capacity of soil, various properties of soil are looked into and an idealised soil profile is created. The soil profile is drawn on drawing sheets so as to better look into the soil properties.

Using the soil properties and the load data provided by staad pro is used in the RCC design.

Designing Idealised 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.
2. 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:
1cm = 70.58ft = 21.51m

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

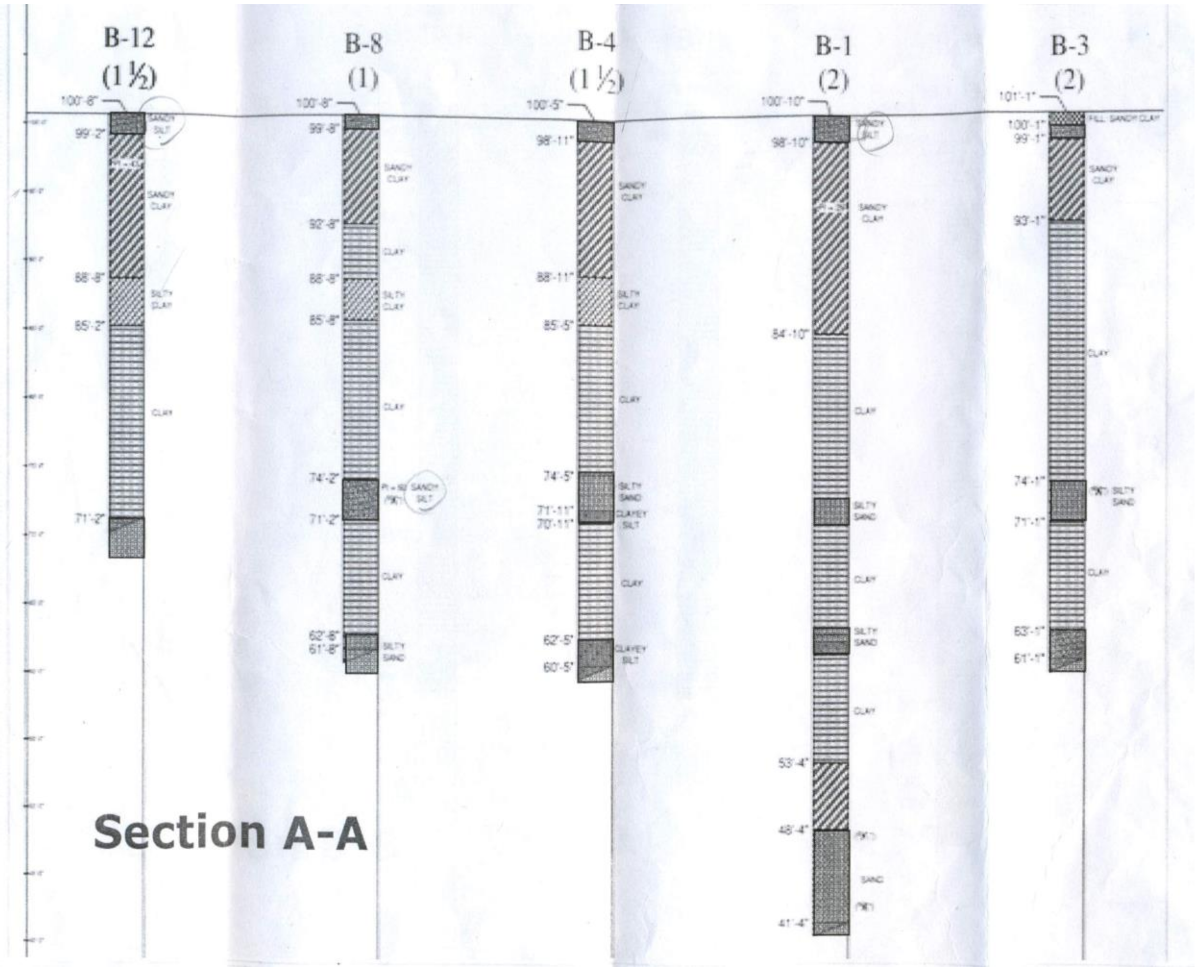
Scale for our drawing sheet

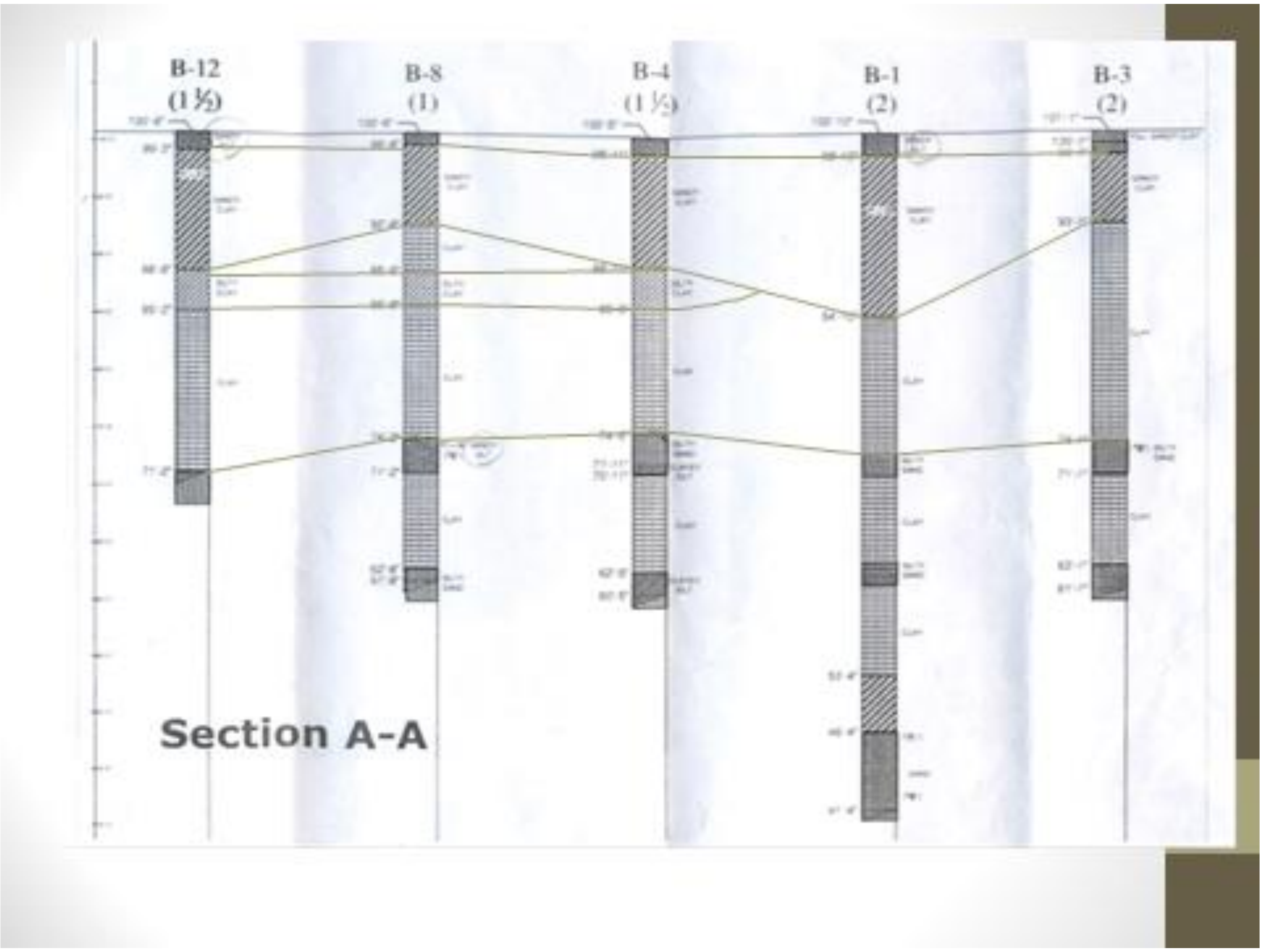
- Vertical scale
  1cm = 2ft
- Horizontal scale
  1cm =10ft

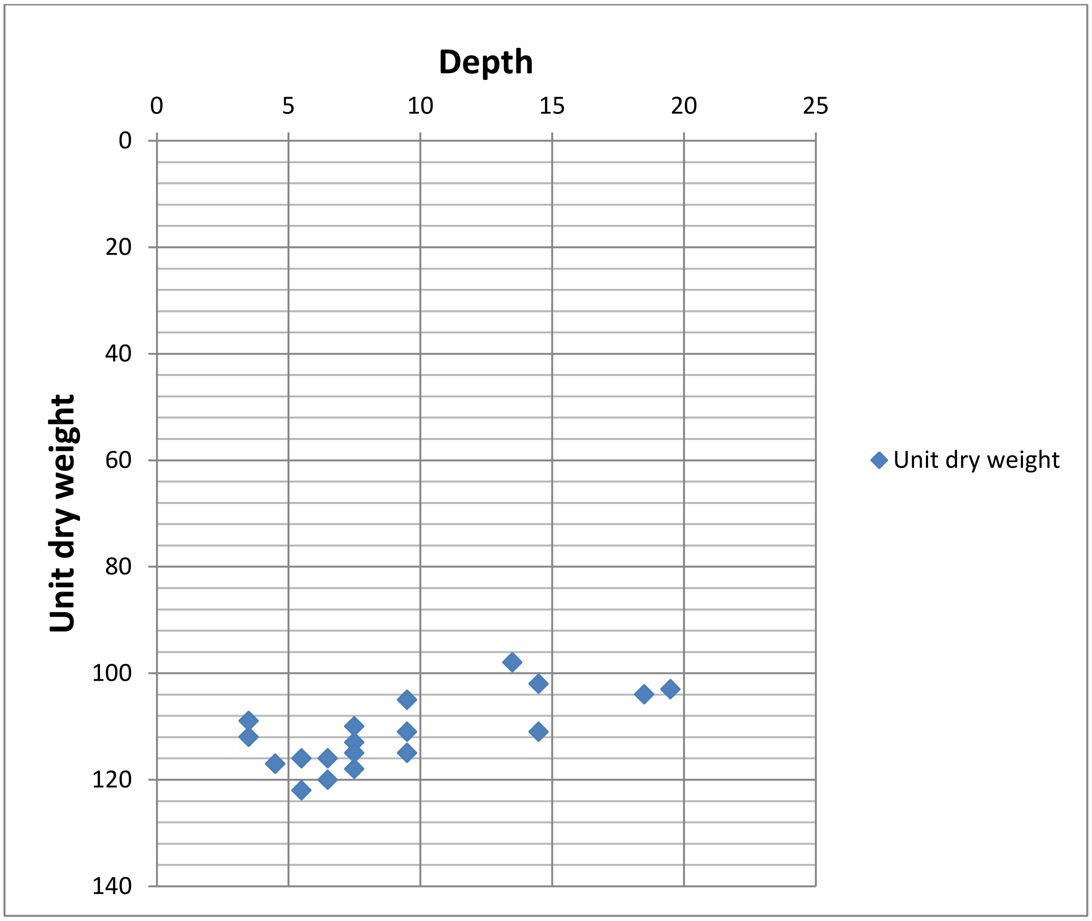
4. Drawing the bore log data on the sheet.
5. After all data has been plotted, some rough indication of the profile will come into picture.
6. Joining all the layers having same soil type and creating lenses too. This was done for all the three sections that we have chosen.
7. When all the three sections 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.
8. 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 :

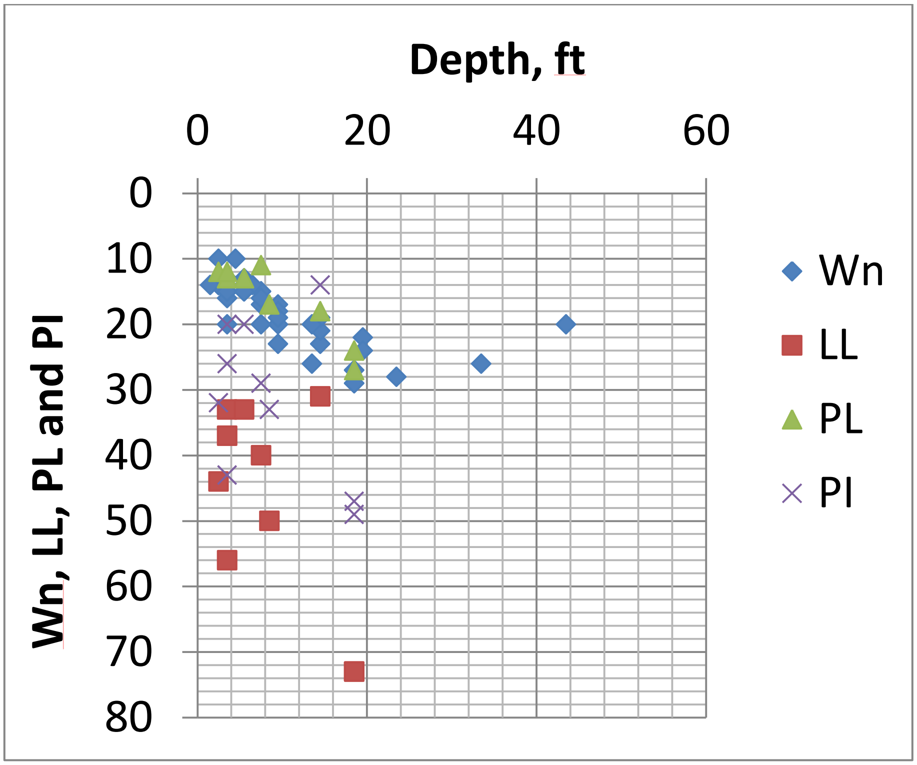
The computations of soil parameters are done by drawing the graph of each parameter against depth. After the graph is drawn, the value of different soil parameters like density, liquid limit, shear strength, etc. for each layer in the idealized soil profile are found by drawing the best fit line.


B-12
(1½)
100'-8"
SANDY SILT
99'-2"
SANDY CLAY
88'-8"
SILTY CLAY
85'-2"
CLAY
71'-2"
B-8
(1)
100'-8"
99'-8"
SANDY CLAY
92'-8"
CLAY
88'-8"
SILTY CLAY
85'-8"
CLAY
74'-2"
SANDY SILT
71'-2"
CLAY
62'-8"
61'-8"
SILTY SAND
B-4
(1½)
100'-5"
98'-11"
SANDY CLAY
88'-11"
SILTY CLAY
85'-5"
CLAY
74'-5"
SILTY SAND
71'-11"
70'-11"
CLAYEY SILT
CLAY
62'-5"
60'-5"
CLAYEY SILT
B-1
(2)
100'-10"
SANDY SILT
98'-10"
SANDY CLAY
84'-10"
CLAY
SILTY SAND
CLAY
SILTY SAND
CLAY
53'-4"
48'-4"
SAND
41'-4"
B-3
(2)
101'-1"
FILL: SANDY CLAY
100'-1"
99'-1"
SANDY CLAY
93'-1"
CLAY
74'-1"
SILTY SAND
71'-1"
CLAY
63'-1"
61'-1"
Section A-A

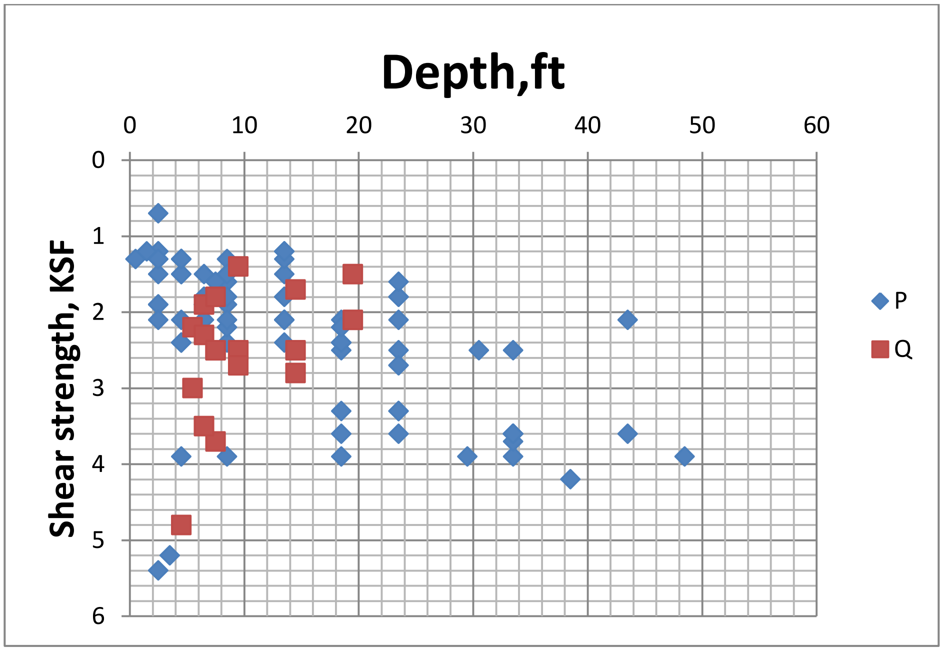

B-12
(1½)
B-8
(1)
B-4
(1½)
B-1
(2)
B-3
(2)
Section A-A



<u>Dry Unit weight vs Depth</u>

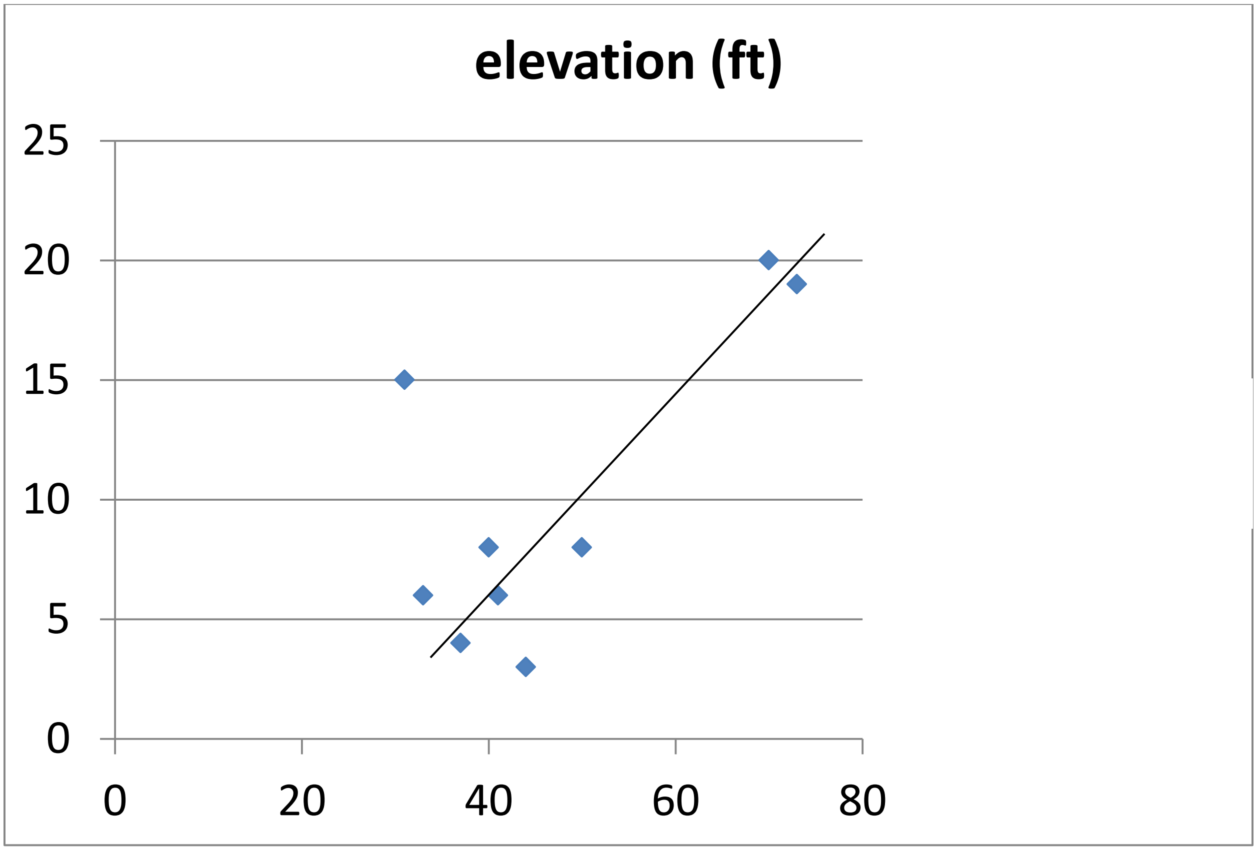


Water content, Liquid Limit, Plastic Limit and Plasticity Index Vs Depth



<u>Depth vs Shear strength</u>

Computation for Cc :

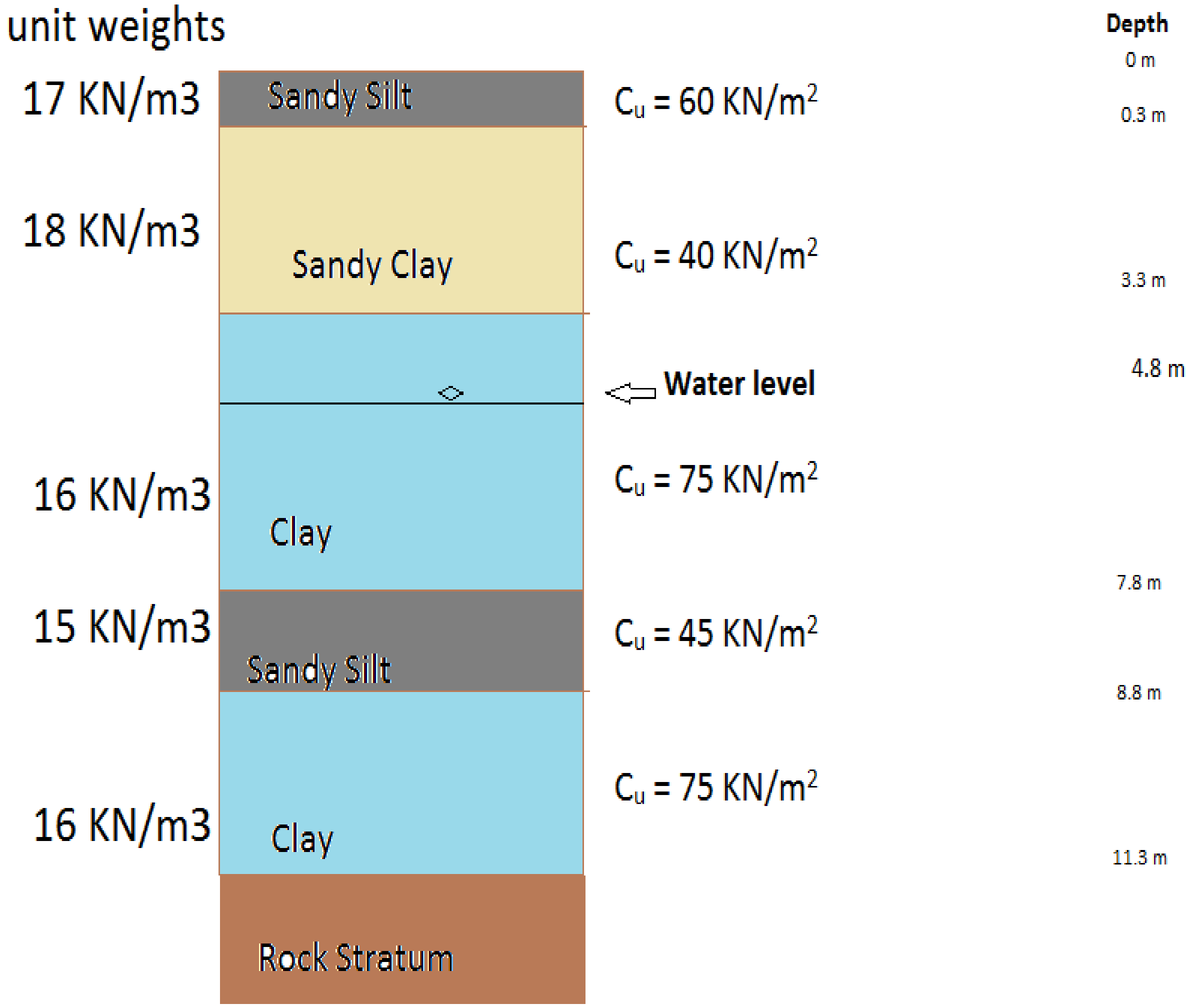


Liquid Limit **(x axis, %)**

Elevation **(y axis, ft)**

The approximate Liquid limit at the desired depth is computed by interpolation after plotting the graph between elevation and water content. Cc can then be calculated by using that water content value using formula Cc = $0.009(w_l - 10)$

Idealised soil profile **:**



Design of superstructure **:**

Dimensions :

- 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 :

Imposed load or Live Load : Imposed load in our case is taken on the basis of occupancy. Our building is a commercial building.

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

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 : 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: 25 x 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.

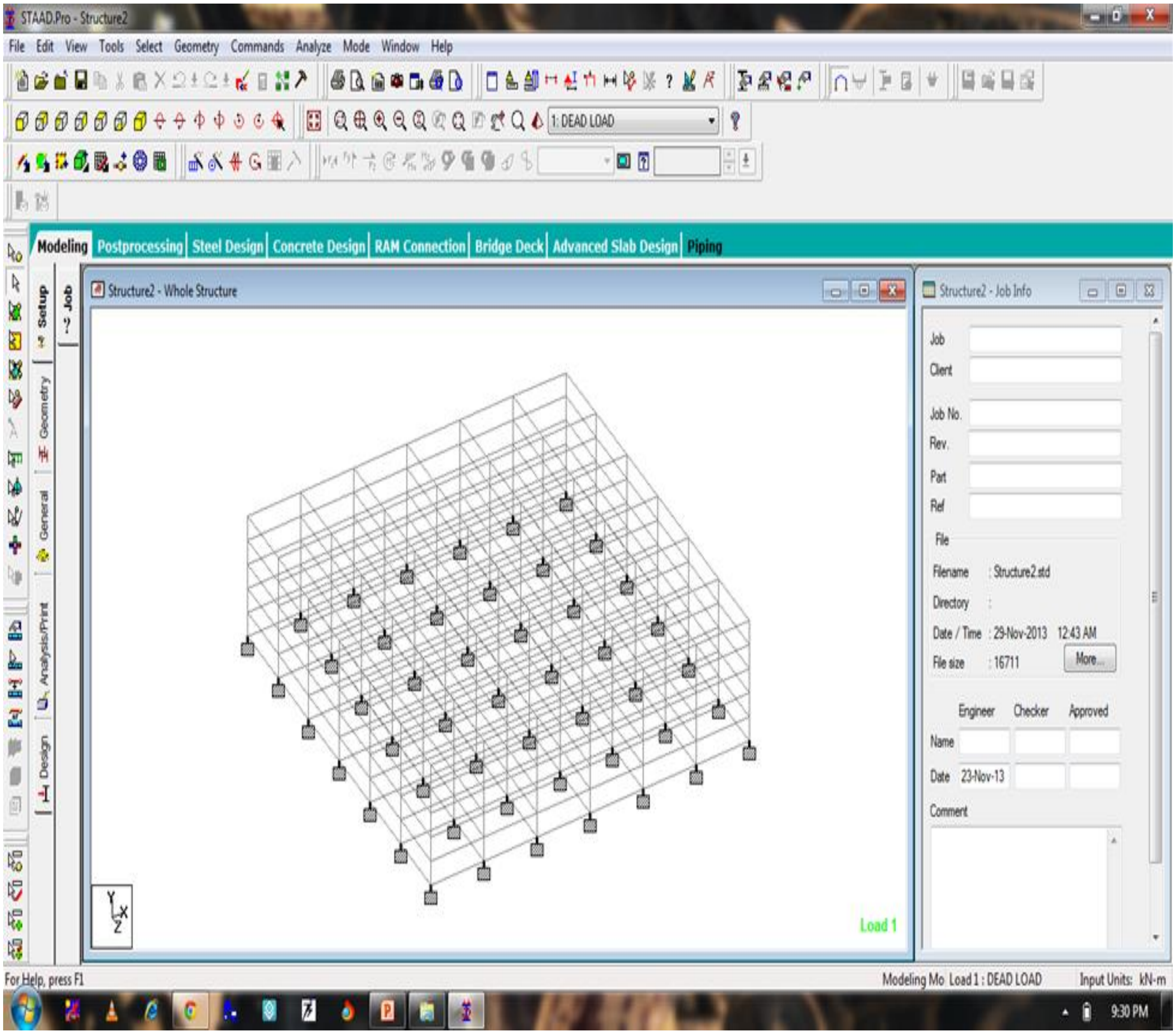
Using above formula and evaluating the values of k2,k2 ,k3 and Vb, the value of design speed can be calculated. The wind pressure is given by

$$P_z=0.6\ V_z^2$$

The plan of boring given to us is from Houston, Texas. 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

Analysing the structure via Staad Pro :

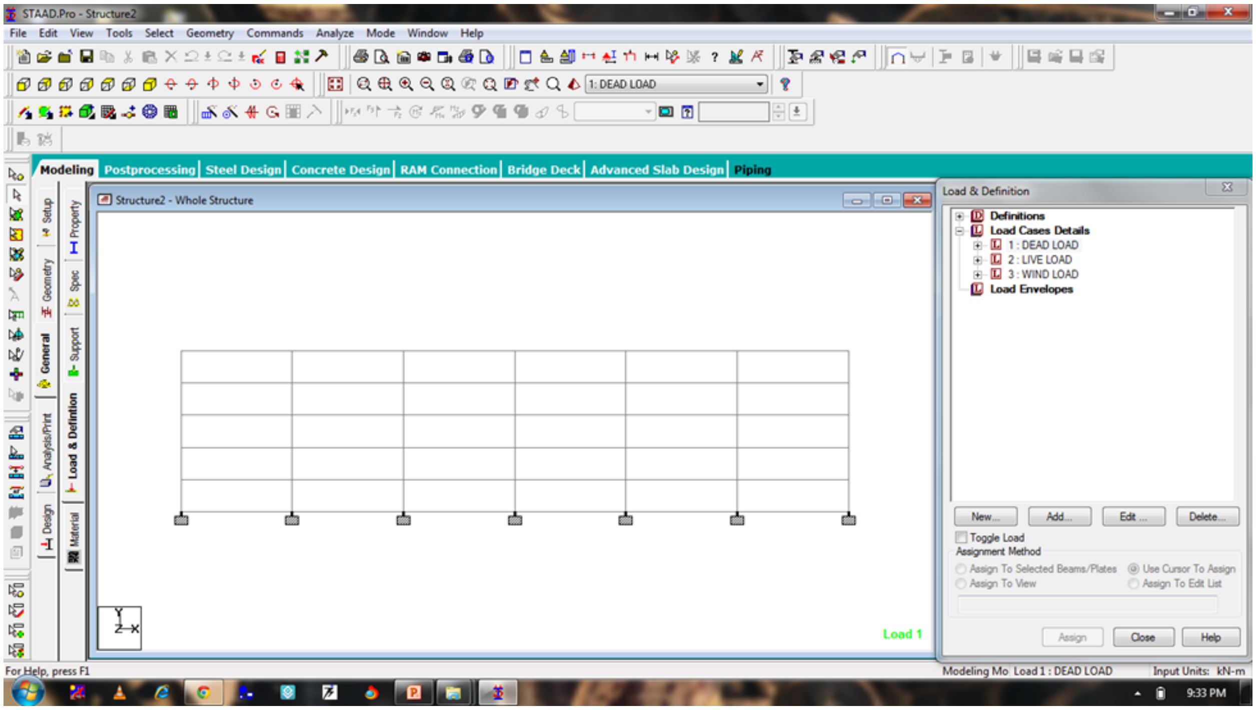


Filename : Structure2.std
Directory :
Date / Time : 29-Nov-2013 12:43 AM
File size : 16711

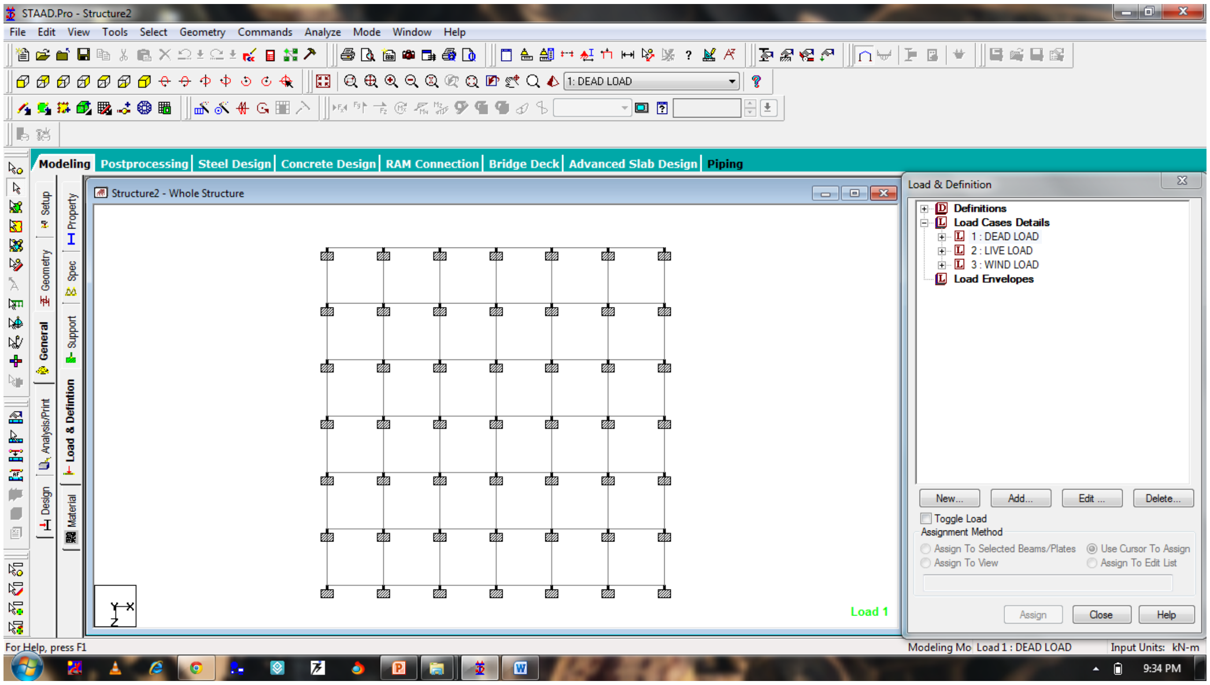
Name
Date 23-Nov-13

For Help, press F1
Modeling Mo Load 1 : DEAD LOAD
Input Units: kN-m

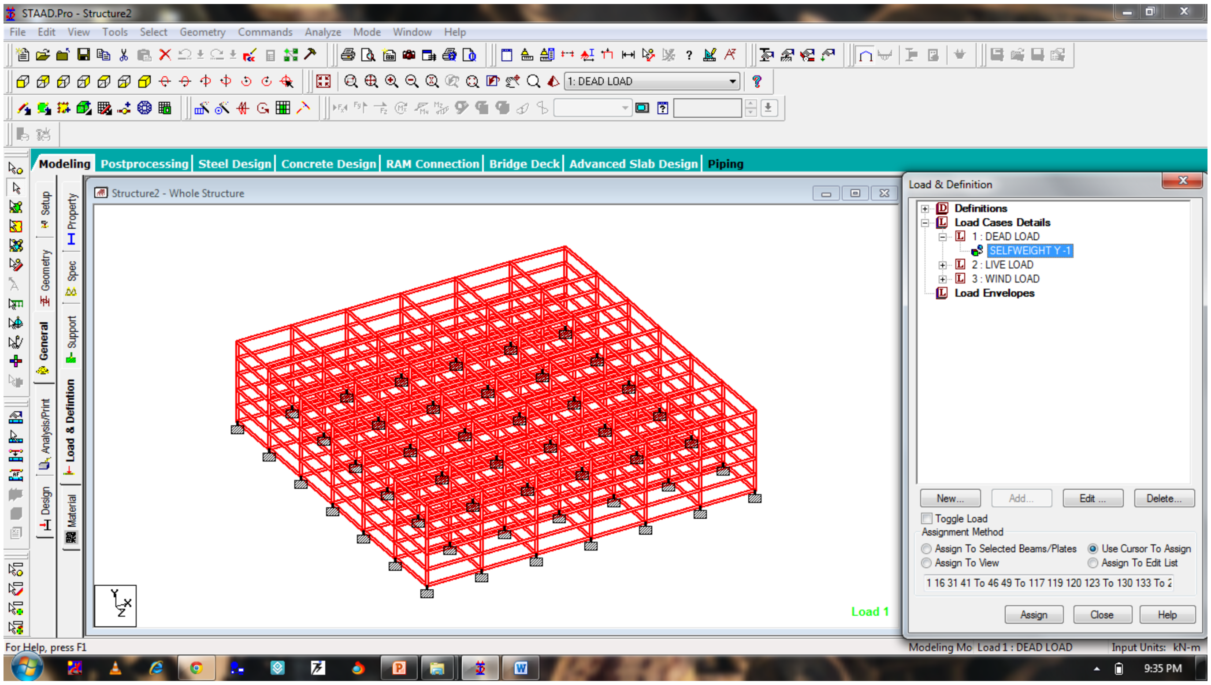
Isometric view



SIDE VIEW



TOP VIEW



Definitions
Load Cases Details
1 : DEAD LOAD
SELFWEIGHT Y -1
2 : LIVE LOAD
3 : WIND LOAD
Load Envelopes

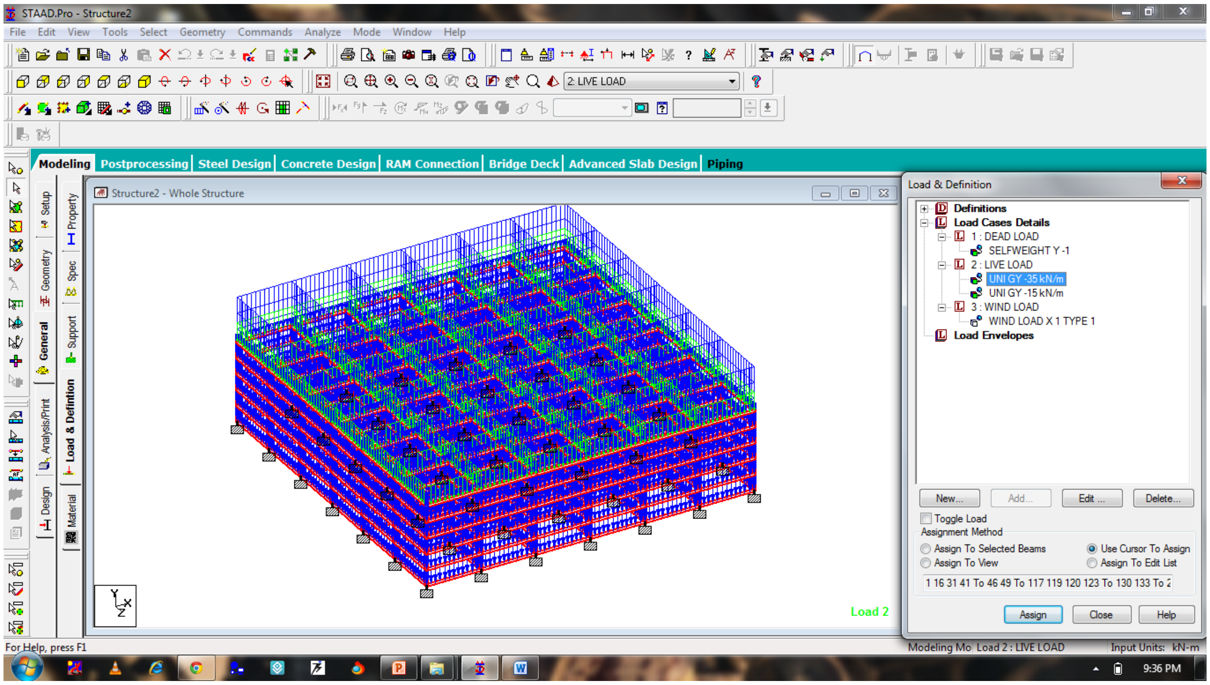
☐ Toggle Load

Assignment Method
○ Assign To Selected Beams/Plates ● Use Cursor To Assign
○ Assign To View ○ Assign To Edit List

1 16 31 41 To 46 49 To 117 119 120 123 To 130 133 To 2

Modeling Mo Load 1 : DEAD LOAD Input Units: kN-m

Dead load or self weight



Definitions
Load Cases Details
1 : DEAD LOAD
SELFWEIGHT Y -1
2 : LIVE LOAD
UNI GY -35 kN/m
UNI GY -15 kN/m
3 : WIND LOAD
WIND LOAD X 1 TYPE 1
Load Envelopes

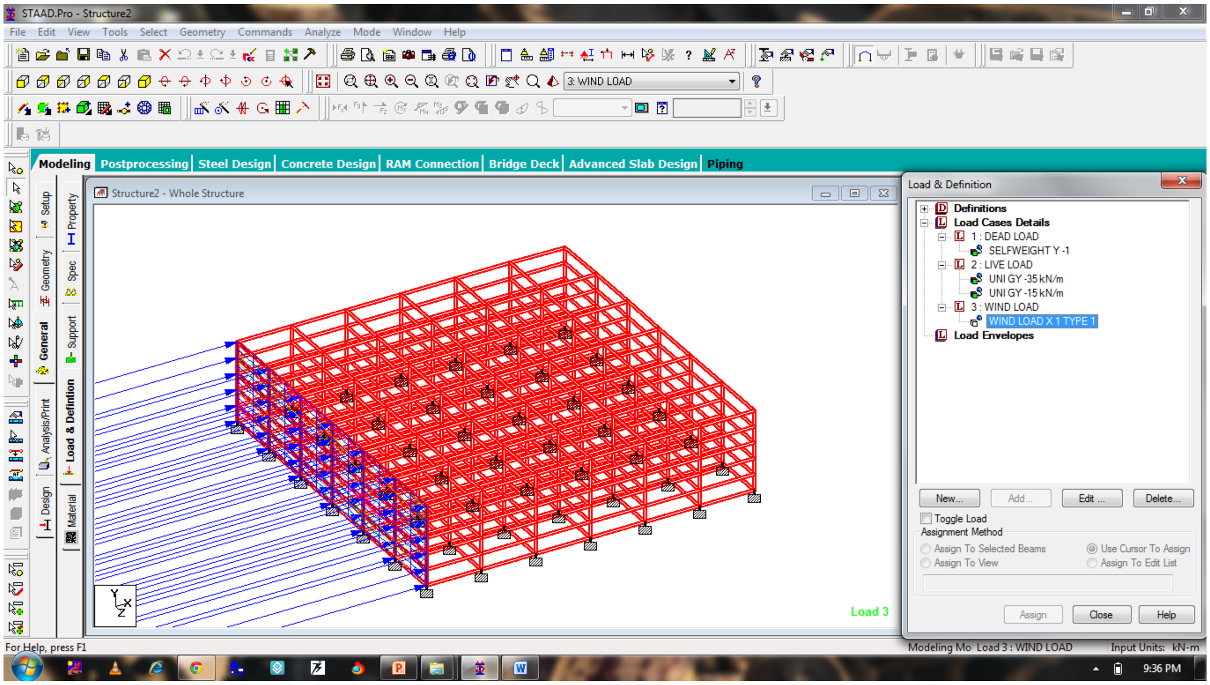
☐ Toggle Load

Assignment Method
○ Assign To Selected Beams ● Use Cursor To Assign
○ Assign To View ○ Assign To Edit List

1 16 31 41 To 46 49 To 117 119 120 123 To 130 133 To 2

Modeling Mo Load 2 : LIVE LOAD Input Units: kN-m

Live load



Definitions
Load Cases Details
- 1 : DEAD LOAD
  - SELFWEIGHT Y -1
- 2 : LIVE LOAD
  - UNI GY -35 kN/m
  - UNI GY -15 kN/m
- 3 : WIND LOAD
  - WIND LOAD X 1 TYPE 1

Load Envelopes

☐ Toggle Load

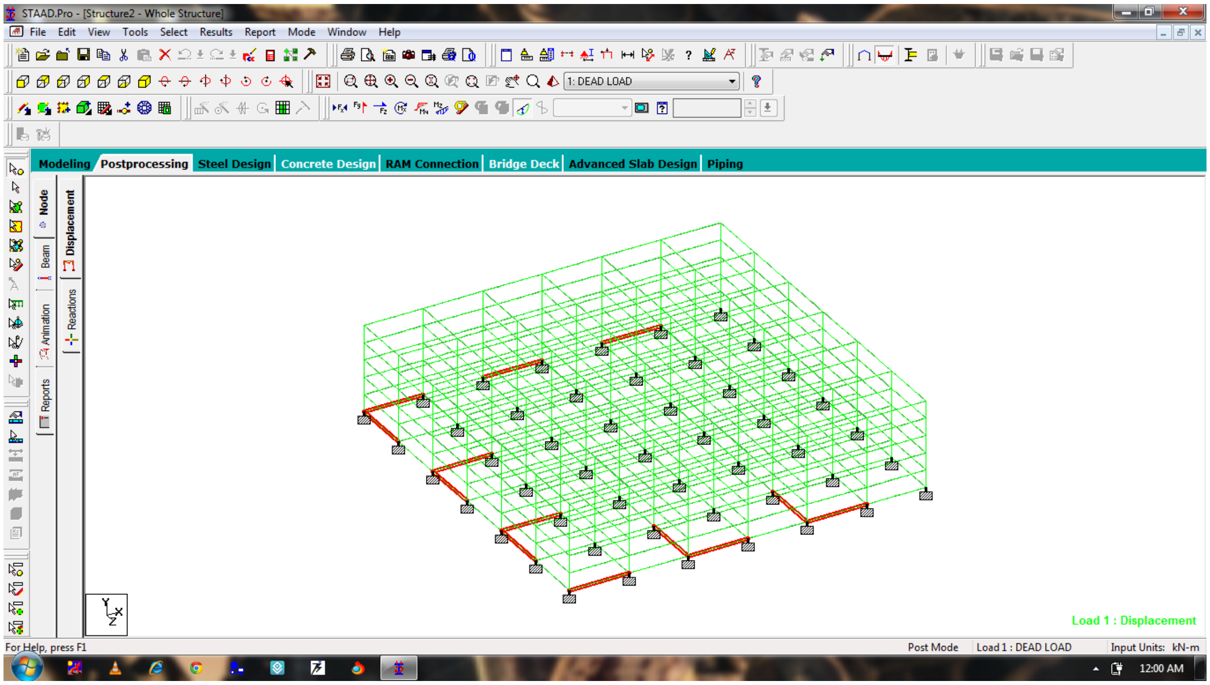
Assignment Method

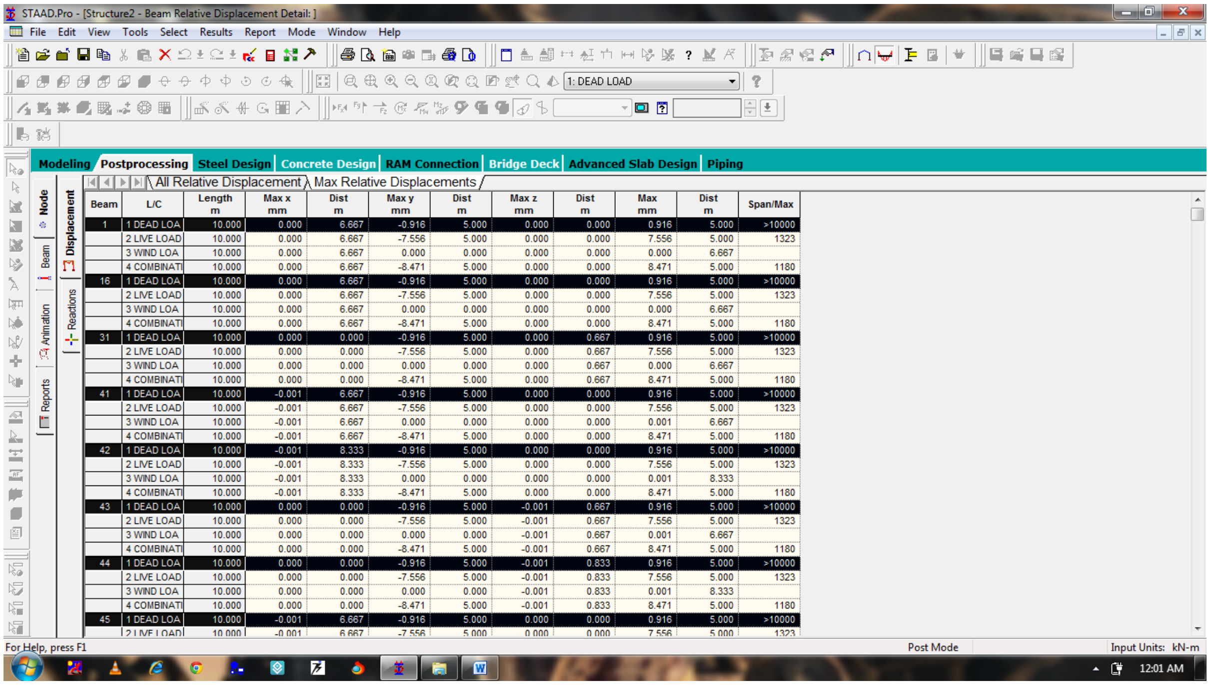
○ Assign To Selected Beams
○ Assign To View
● Use Cursor To Assign
○ Assign To Edit List

Modeling Mo Load 3 : WIND LOAD

Input Units: kN-m

Wind load

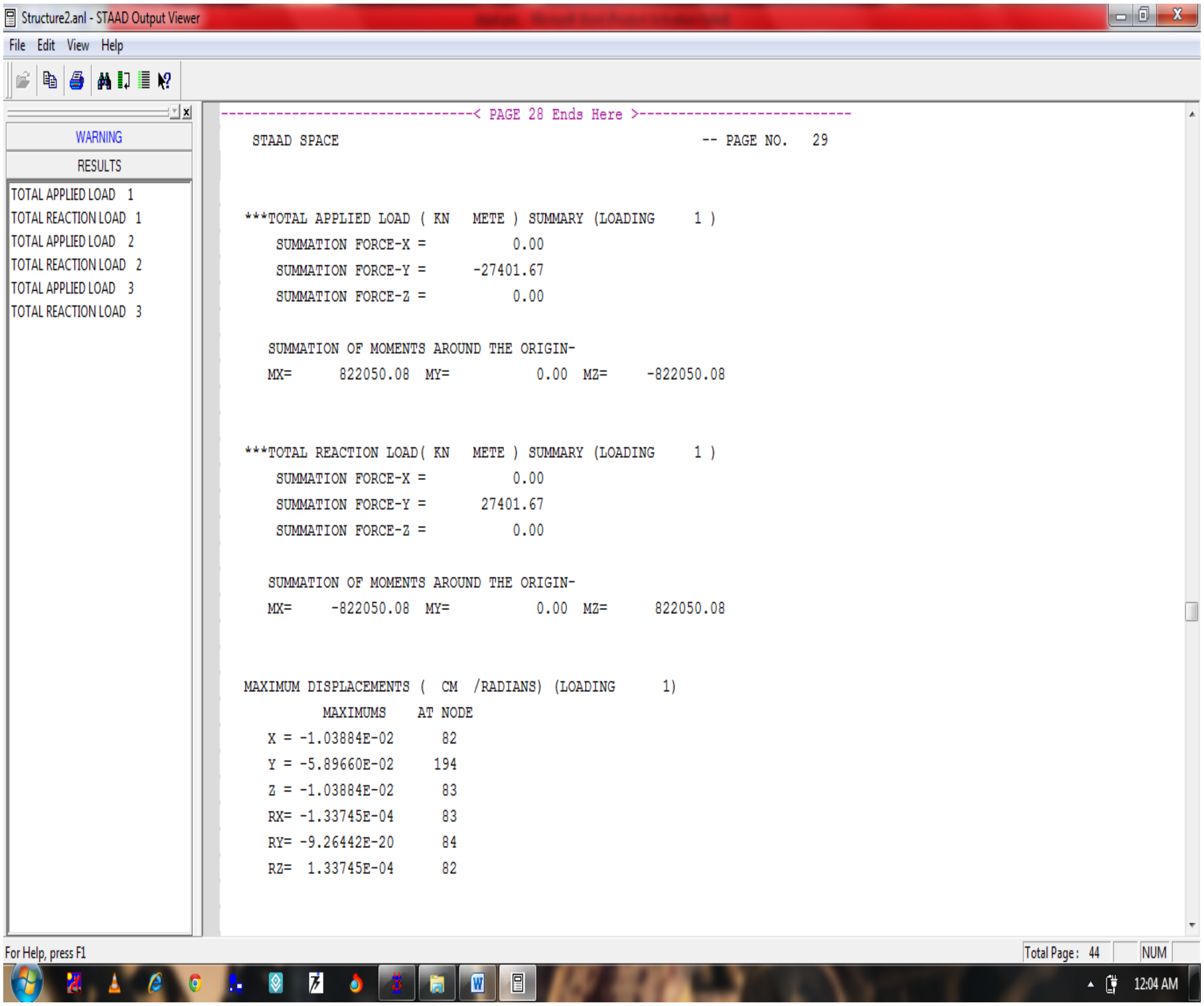




Beam	L/C	Length m	Max x mm	Dist m	Max y mm	Dist m	Max z mm	Dist m	Max mm	Dist m	Span/Max
1	1 DEAD LOA	10.000	0.000	6.667	-0.916	5.000	0.000	0.000	0.916	5.000	>10000
	2 LIVE LOAD	10.000	0.000	6.667	-7.556	5.000	0.000	0.000	7.556	5.000	1323
	3 WIND LOA	10.000	0.000	6.667	0.000	0.000	0.000	0.000	0.000	6.667	
	4 COMBINATI	10.000	0.000	6.667	-8.471	5.000	0.000	0.000	8.471	5.000	1180
16	1 DEAD LOA	10.000	0.000	6.667	-0.916	5.000	0.000	0.000	0.916	5.000	>10000
	2 LIVE LOAD	10.000	0.000	6.667	-7.556	5.000	0.000	0.000	7.556	5.000	1323
	3 WIND LOA	10.000	0.000	6.667	0.000	0.000	0.000	0.000	0.000	6.667	
	4 COMBINATI	10.000	0.000	6.667	-8.471	5.000	0.000	0.000	8.471	5.000	1180
31	1 DEAD LOA	10.000	0.000	0.000	-0.916	5.000	0.000	0.667	0.916	5.000	>10000
	2 LIVE LOAD	10.000	0.000	0.000	-7.556	5.000	0.000	0.667	7.556	5.000	1323
	3 WIND LOA	10.000	0.000	0.000	0.000	0.000	0.000	0.667	0.000	6.667	
	4 COMBINATI	10.000	0.000	0.000	-8.471	5.000	0.000	0.667	8.471	5.000	1180
41	1 DEAD LOA	10.000	-0.001	6.667	-0.916	5.000	0.000	0.000	0.916	5.000	>10000
	2 LIVE LOAD	10.000	-0.001	6.667	-7.556	5.000	0.000	0.000	7.556	5.000	1323
	3 WIND LOA	10.000	-0.001	6.667	0.000	0.000	0.000	0.000	0.001	6.667	
	4 COMBINATI	10.000	-0.001	6.667	-8.471	5.000	0.000	0.000	8.471	5.000	1180
42	1 DEAD LOA	10.000	-0.001	8.333	-0.916	5.000	0.000	0.000	0.916	5.000	>10000
	2 LIVE LOAD	10.000	-0.001	8.333	-7.556	5.000	0.000	0.000	7.556	5.000	1323
	3 WIND LOA	10.000	-0.001	8.333	0.000	0.000	0.000	0.000	0.001	8.333	
	4 COMBINATI	10.000	-0.001	8.333	-8.471	5.000	0.000	0.000	8.471	5.000	1180
43	1 DEAD LOA	10.000	0.000	0.000	-0.916	5.000	-0.001	0.667	0.916	5.000	>10000
	2 LIVE LOAD	10.000	0.000	0.000	-7.556	5.000	-0.001	0.667	7.556	5.000	1323
	3 WIND LOA	10.000	0.000	0.000	0.000	0.000	-0.001	0.667	0.001	6.667	
	4 COMBINATI	10.000	0.000	0.000	-8.471	5.000	-0.001	0.667	8.471	5.000	1180
44	1 DEAD LOA	10.000	0.000	0.000	-0.916	5.000	-0.001	0.833	0.916	5.000	>10000
	2 LIVE LOAD	10.000	0.000	0.000	-7.556	5.000	-0.001	0.833	7.556	5.000	1323
	3 WIND LOA	10.000	0.000	0.000	0.000	0.000	-0.001	0.833	0.001	8.333	
	4 COMBINATI	10.000	0.000	0.000	-8.471	5.000	-0.001	0.833	8.471	5.000	1180
45	1 DEAD LOA	10.000	-0.001	6.667	-0.916	5.000	0.000	0.000	0.916	5.000	>10000
	2 LIVE LOAD	10.000	-0.001	6.667	-7.556	5.000	0.000	0.000	7.556	5.000	1323

Maximum relative displacements corresponding to selected beams as shown

***<u>Analysis for frame via staad pro v8i</u>* :**



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  STAAD SPACE                                            -- PAGE NO.   29


   ***TOTAL APPLIED LOAD ( KN   METE ) SUMMARY (LOADING     1 )
       SUMMATION FORCE-X =           0.00
       SUMMATION FORCE-Y =      -27401.67
       SUMMATION FORCE-Z =           0.00

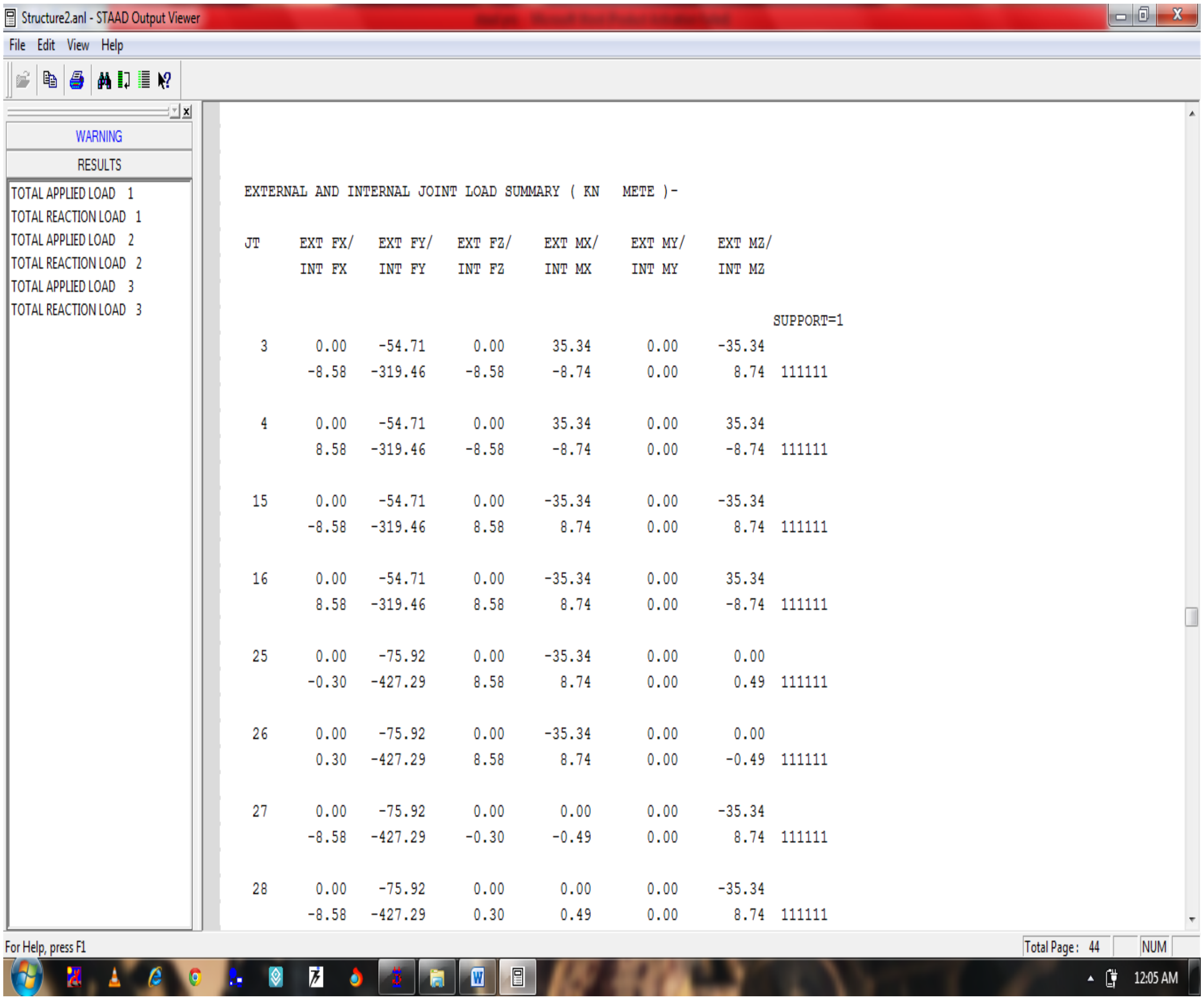
      SUMMATION OF MOMENTS AROUND THE ORIGIN-
      MX=      822050.08  MY=           0.00  MZ=     -822050.08


   ***TOTAL REACTION LOAD( KN   METE ) SUMMARY (LOADING     1 )
       SUMMATION FORCE-X =           0.00
       SUMMATION FORCE-Y =       27401.67
       SUMMATION FORCE-Z =           0.00

      SUMMATION OF MOMENTS AROUND THE ORIGIN-
      MX=     -822050.08  MY=           0.00  MZ=      822050.08


   MAXIMUM DISPLACEMENTS (  CM  /RADIANS) (LOADING      1)
             MAXIMUMS    AT NODE
      X = -1.03884E-02      82
      Y = -5.89660E-02     194
      Z = -1.03884E-02      83
      RX= -1.33745E-04      83
      RY= -9.26442E-20      84
      RZ=  1.33745E-04      82
```

Reaction at supports due to loading **:**



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EXTERNAL AND INTERNAL JOINT LOAD SUMMARY ( KN   METE )-

JT     EXT FX/   EXT FY/   EXT FZ/    EXT MX/    EXT MY/    EXT MZ/
       INT FX    INT FY    INT FZ     INT MX     INT MY     INT MZ

                                                                   SUPPORT=1
  3      0.00    -54.71      0.00      35.34       0.00     -35.34
        -8.58   -319.46     -8.58      -8.74       0.00       8.74  111111

  4      0.00    -54.71      0.00      35.34       0.00      35.34
         8.58   -319.46     -8.58      -8.74       0.00      -8.74  111111

 15      0.00    -54.71      0.00     -35.34       0.00     -35.34
        -8.58   -319.46      8.58       8.74       0.00       8.74  111111

 16      0.00    -54.71      0.00     -35.34       0.00      35.34
         8.58   -319.46      8.58       8.74       0.00      -8.74  111111

 25      0.00    -75.92      0.00     -35.34       0.00       0.00
        -0.30   -427.29      8.58       8.74       0.00       0.49  111111

 26      0.00    -75.92      0.00     -35.34       0.00       0.00
         0.30   -427.29      8.58       8.74       0.00      -0.49  111111

 27      0.00    -75.92      0.00       0.00       0.00     -35.34
        -8.58   -427.29     -0.30      -0.49       0.00       8.74  111111

 28      0.00    -75.92      0.00       0.00       0.00     -35.34
        -8.58   -427.29      0.30       0.49       0.00       8.74  111111
```
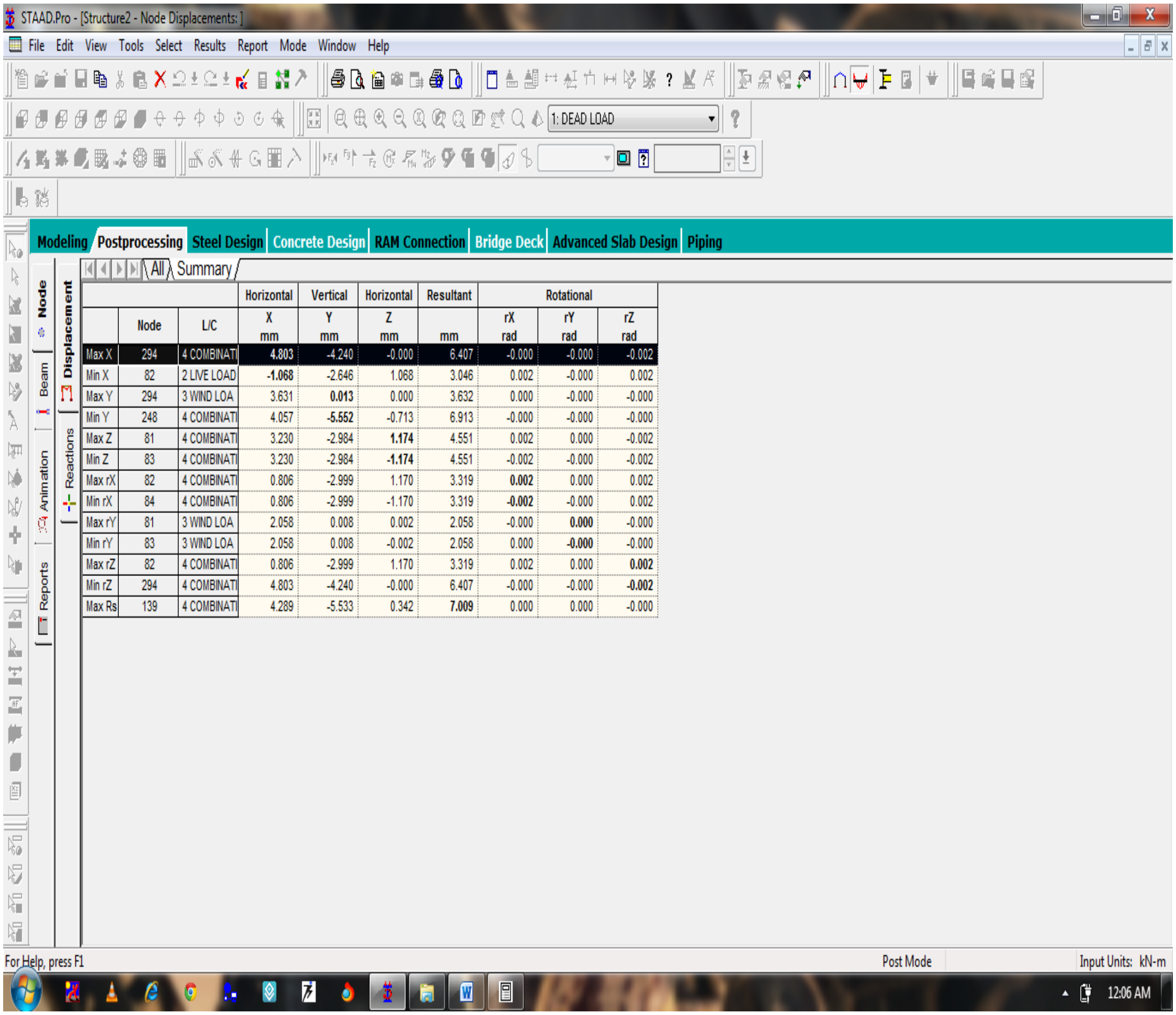
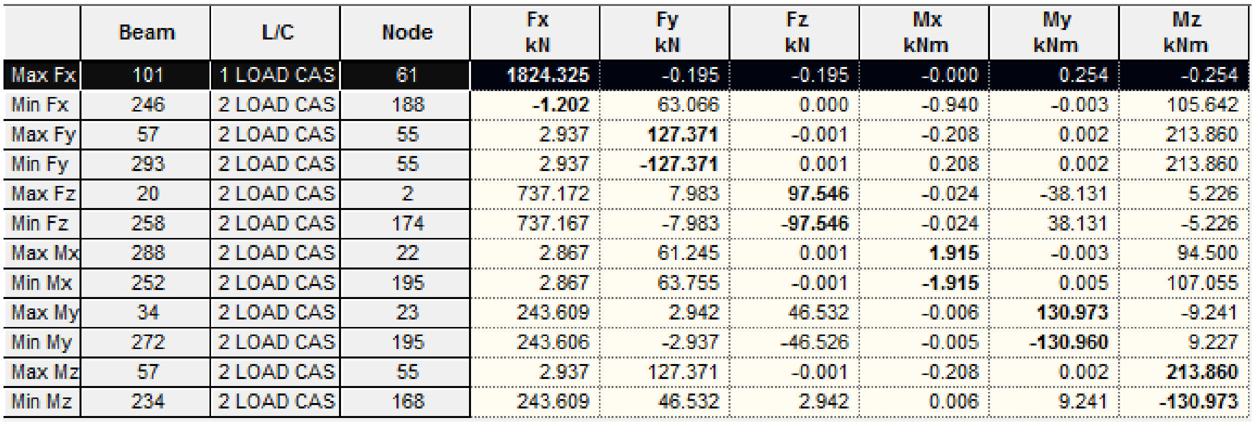
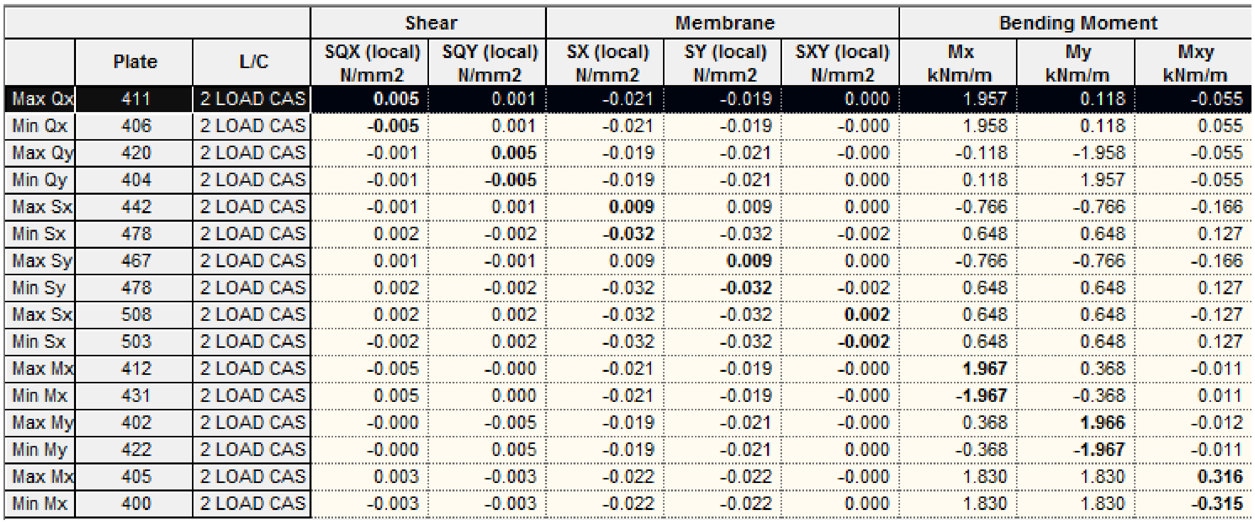



			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	294	4 COMBINATI	4.803	-4.240	-0.000	6.407	-0.000	-0.000	-0.002
Min X	82	2 LIVE LOAD	-1.068	-2.646	1.068	3.046	0.002	-0.000	0.002
Max Y	294	3 WIND LOA	3.631	0.013	0.000	3.632	0.000	-0.000	-0.000
Min Y	248	4 COMBINATI	4.057	-5.552	-0.713	6.913	-0.000	-0.000	-0.000
Max Z	81	4 COMBINATI	3.230	-2.984	1.174	4.551	0.002	0.000	-0.002
Min Z	83	4 COMBINATI	3.230	-2.984	-1.174	4.551	-0.002	-0.000	-0.002
Max rX	82	4 COMBINATI	0.806	-2.999	1.170	3.319	0.002	0.000	0.002
Min rX	84	4 COMBINATI	0.806	-2.999	-1.170	3.319	-0.002	-0.000	0.002
Max rY	81	3 WIND LOA	2.058	0.008	0.002	2.058	-0.000	0.000	-0.000
Min rY	83	3 WIND LOA	2.058	0.008	-0.002	2.058	0.000	-0.000	-0.000
Max rZ	82	4 COMBINATI	0.806	-2.999	1.170	3.319	0.002	0.000	0.002
Min rZ	294	4 COMBINATI	4.803	-4.240	-0.000	6.407	-0.000	-0.000	-0.002
Max Rs	139	4 COMBINATI	4.289	-5.533	0.342	7.009	0.000	0.000	-0.000



	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**

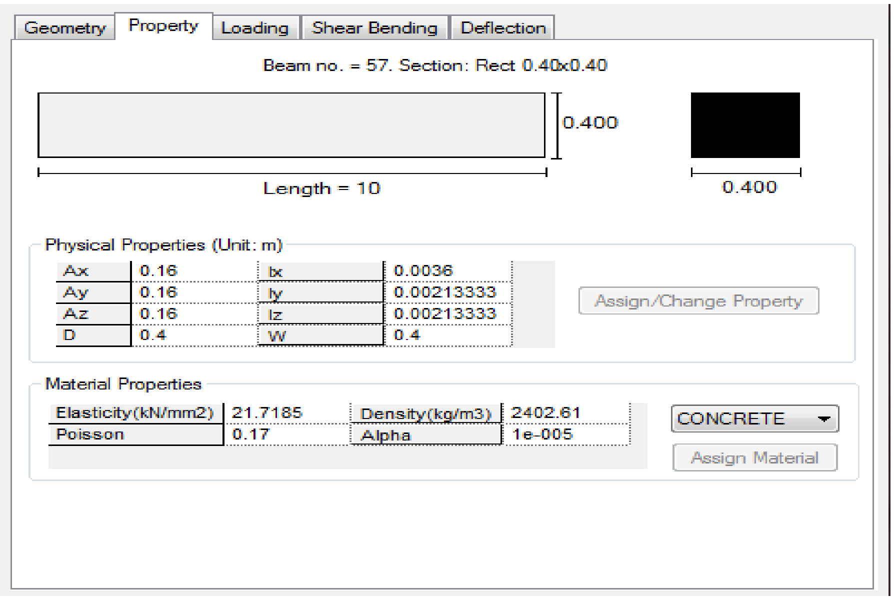
Summaryof beam analysis (Both vertical and horizontal)



			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**

Summary of slab analysis

Design of Beam no. 57



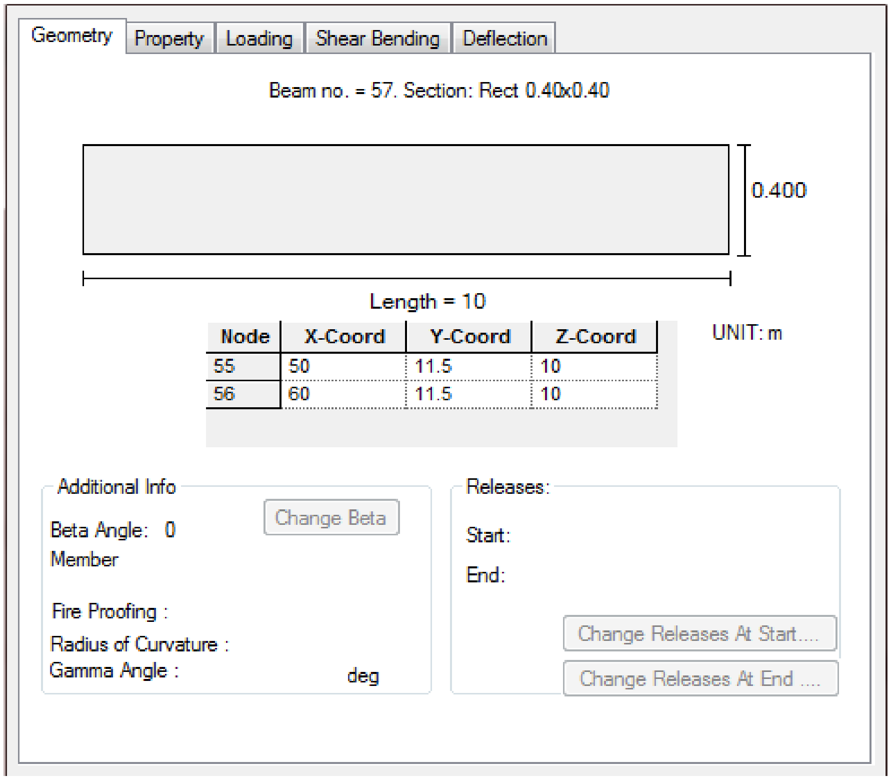
Beam no. = 57. Section: Rect 0.40x0.40

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

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 :

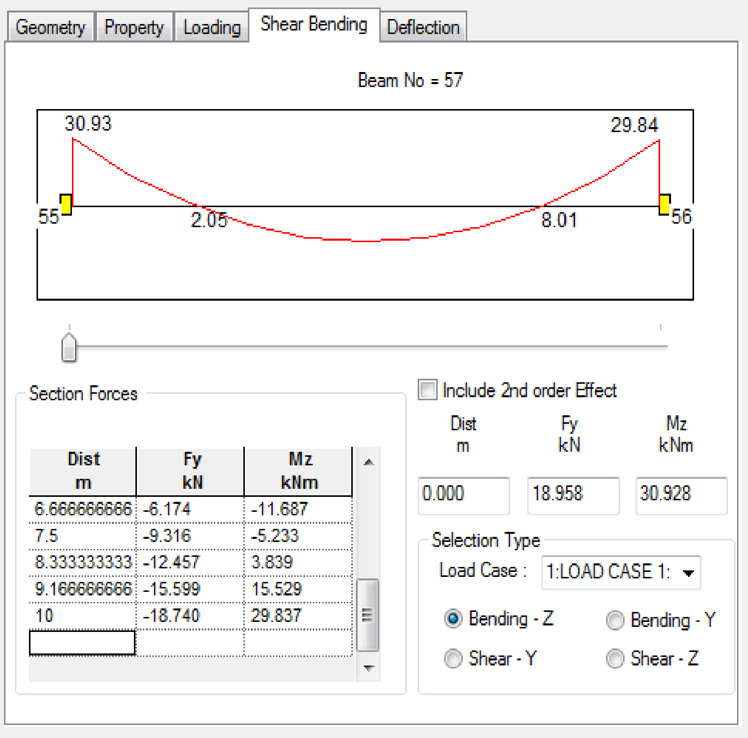
Radius of Curvature :

Gamma Angle : deg

Releases:

Start:

End:



Beam No = 57

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

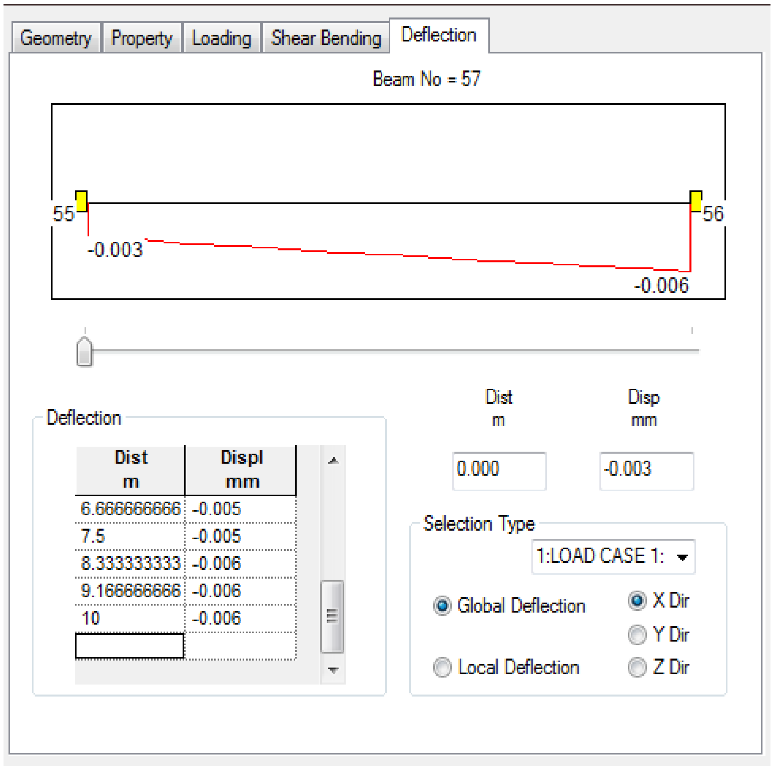
☐ Include 2nd order Effect

Dist m	Fy kN	Mz kNm
0.000	18.958	30.928

Selection Type

Load Case : 1:LOAD CASE 1:

● Bending - Z



Beam No = 57

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

Bending and deflection :

Design of Slab no. 412 :

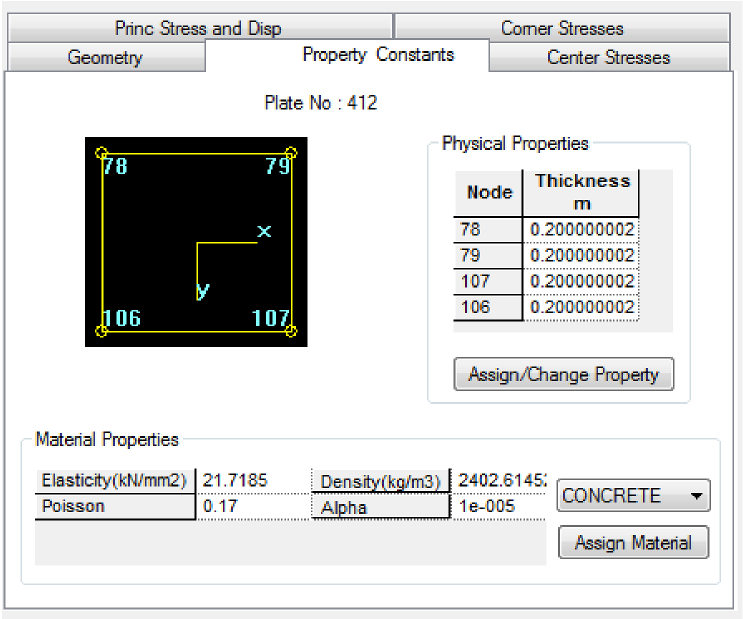


Plate No : 412

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

CONCRETE

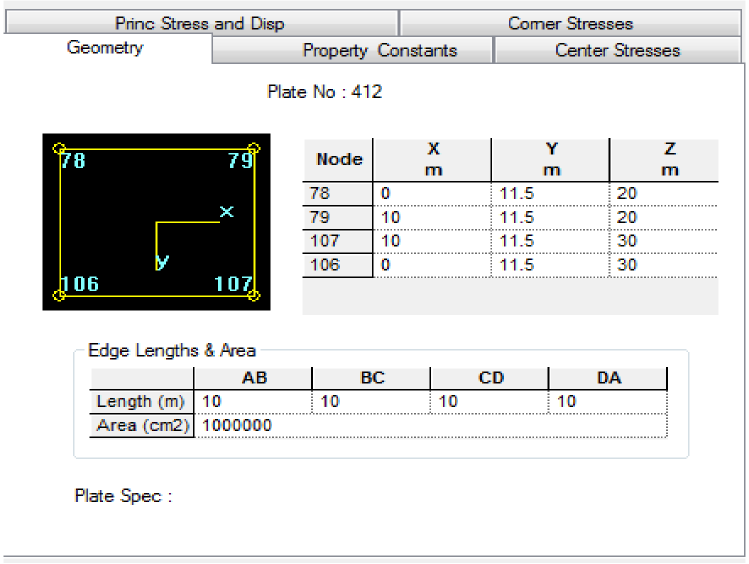


Plate No : 412

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 :

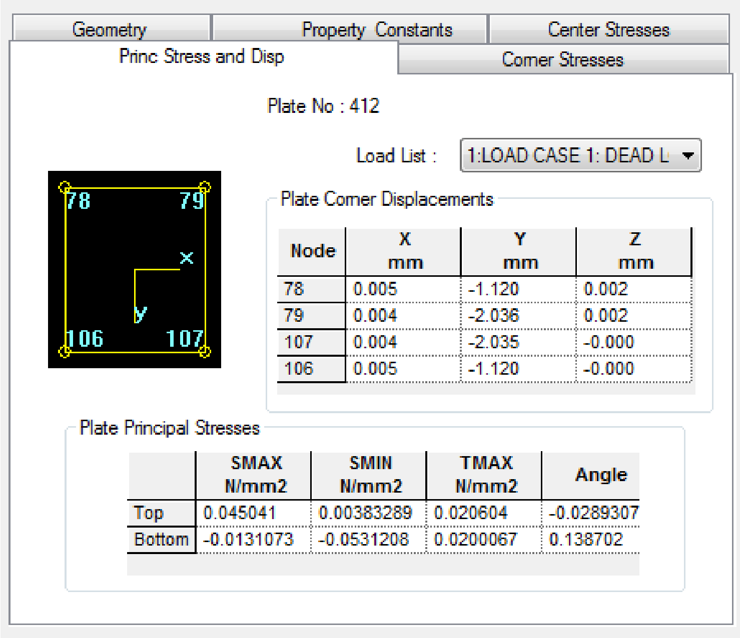


Plate No : 412

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

A. Calculation of Bearing Capacity using Meyerhof equation:

$Q_u = c\ N_c\ S_c\ d_c\ i_c + q\ N_q\ S_q\ d_q\ i_q + 0.5\Upsilon\ B\ N_\Upsilon\ S_\Upsilon\ d_\Upsilon\ i_\Upsilon$

Here, $\varnothing = 0$ (as clay deposits)

Corresponding to angle of internal friction,

$N_c = 5.14$, $N_q = 1$, $N_\Upsilon = 0$ (Table 15.2 Ranjan and Rao)

Finding Cohesion (weighed) :

$$(C_u)_{weighed} = \frac{(60 \times 3) + (40 \times 3) + (75 \times 4.5)}{7.8}$$

$$\boxed{(C_u)_{weighed} = 60.96\ KN/\ m^2}$$

$q = (17 \times 0.3) + (18 \times 1.5) = 32.1\ KN/\ m^2$

$s_c = 1 + 0.2\ B/L\ \tan^2 (45 + \varnothing/2)$ (From Table 15.3 Ranjan And Rao)

As it is a square footing, $s_c = 1.2$

Similarly, values of other factors are-

$d_c = 1.2$, $S_q = 1$, $d_q = 1$, $i_q = 1$

$i_c = (1 – \alpha/90)^2 = 1$ as $\alpha = 0$

Putting all these values in Meyerhof equation, we get

$q_u = ((60.96)(5.14)(1.2)(1.2)(1)) + (32.1 \times 1 \times 1 \times 1)$

$q_u = 483.3$ KN/m^2

After applying a factor of safety, $q_u = 483.3/1.5 = 322.2$ KN/m^2

$q_u = 322.2$ KN/m^2

B. ***Choosing the size of footing*** :

We take the column with maximum load which is 4284.52 KN which can be approximately taken as 4300 KN   (obtained from Staad Pro)

Allowing for 10% self weight of the soil, total load is = 4300 x 1.1 = 4730 KN

Therefore, 4730/ q_u = 4730/ 322.2 = 14.68

Or $B^2 = 14.68$

Or B = 3.83 m   which can be taken as 4 m

Therefore, providing a footing area of 4 x 4 m

Net upward pressure in soil = 4300/16 = 268.75   < 322.2

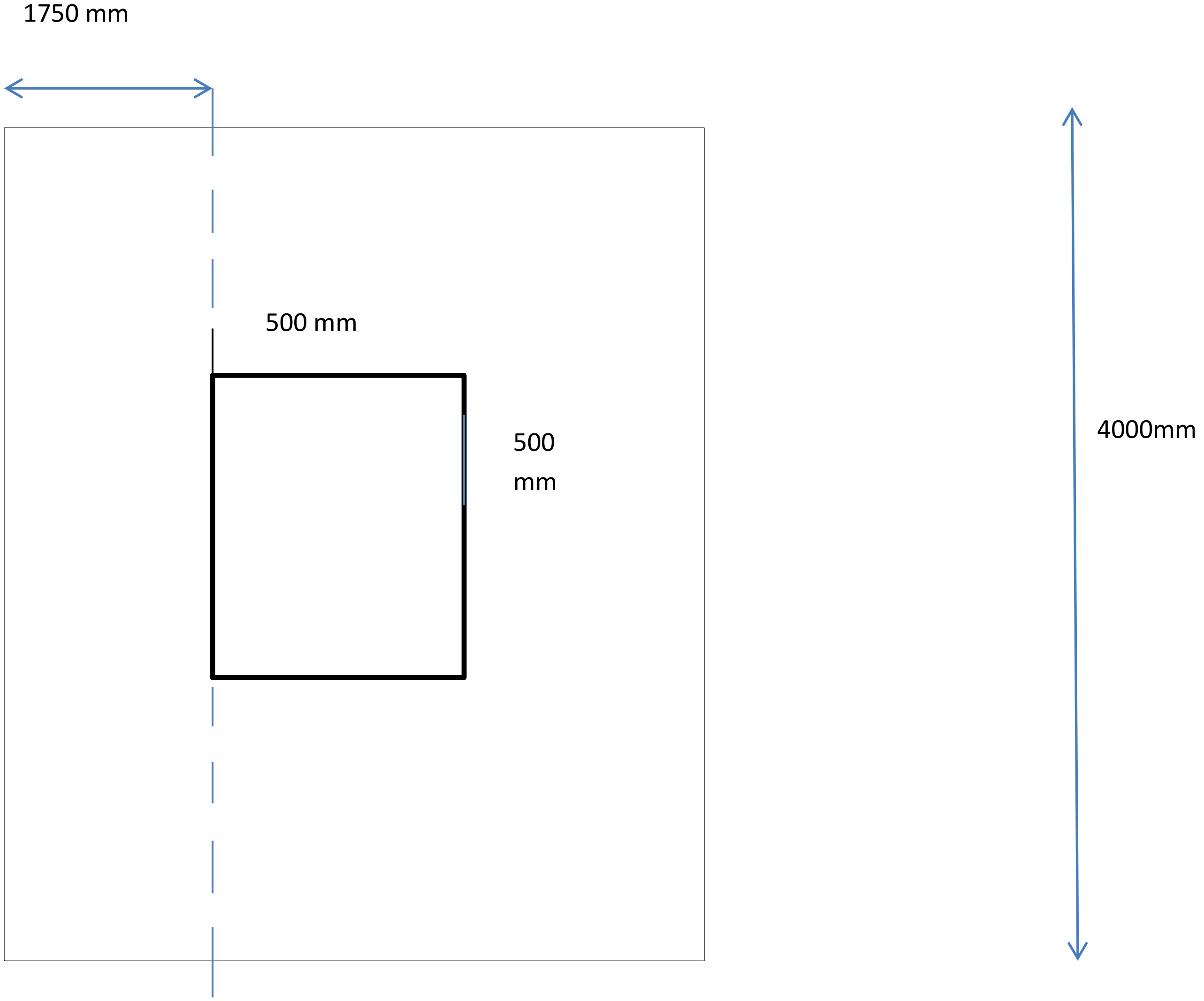
Therefore, ***SAFE***

C(i). ***Depth from Bending moment consideration:***

(4000 – 500)/2 = 1750 mm

Maximum Bending Moment = (268.75 x 10^3) x 4 x 1.75 x (1.75/2)

= 1646093.75 Nm



Critical section for Bending moment

Factored moment, Mu = 1.5 x M

Mu = 1.5 x 1646093.75

Mu = 2469140.625 Nm

Equating $M_{u,limiting}$ to M_u , we get

$0.138\ f_{ck}\ bd^2 = 0.138 \times 20 \times 500 \times d^2 = 2469140.625 \times 10^3$

$d = (1789232.337)^{0.5} = 1337.62$ mm which can be taken as d = 1338 mm

Providing 12mm dia bars at a clear cover of 60 mm

Effective cover to upper layer of bars = 60 + 12 + 6 = 78 mm

Overall depth required = 1338 + 78 = 1416 mm

The depth is increased by 30 % to limit the shear stresses. Therefore,

1.3 x 1416 = 1840.8 mm

Therefore, providing an overall depth of 1850 mm $\longrightarrow$ (1.)

$\boxed{\text{Actual effective depth, d = 1850 – 78 = 1778 mm}}$

(ii.) ***<u>Depth from punching load consideration</u>*** **:**

Punching load = column load – reaction on column area

$= 4300000 - ((268.75 \times 10^3) \times (0.5)^2)$

= 4232812.5 N

Factored punching load = 1.5 x 4232812.5

= 6349218.75 N

Design punching shear stress for M20 concrete = 1.8 N/mm^2

Equating punching shear resistance to the punching load, we get

$4 \times 500 \times D \times 1.8 = 6349218.75$

$D = 1763.67$ mm $\longrightarrow$ (2.)

Therefore, from (1.) and (2.), we have

Providing overall depth = 1770 mm

Actual Effective depth, d = 1770 – 78 = 1692 mm

Now, $M_u / bd^2 = (2469140.625 \times 1000) / ((1692)^2 \times 500) = 1.725$

Therefore, % of steel required, $P_t = 50 (1- (1- 4.6\, M_u/f_{ck}\, bd^2)^{0.5}) / (f_y / f_{ck})$

$P_t = 50 (1- (1- 4.6 \times 1.725/20)^{0.5}) / (415/20)$

$P_t = 0.538$ %

$A_{st} = (0.538 \times 500 \times 1692)/ 100 = 4551.48$ mm^2

No. of bars = $(4551.48) / ((\pi/4) \times 15^2) = 25.76$ (15 mm dia bars)

Therefore, Providing 26 bars of 15 mm dia

D. Check for shear :

(i.) Check for one- way shear :

The critical section for one-way shear is considered at a distance equal to the effective depth from the face of the column. Let the depth of the footing at the edges be reduced to 500 mm

Therefore, Overall depth at the critical section, $D^1 = 1770 - (((1770- 500)/1750) \times 1692)$

$D^1 = 542.09$ mm

Effective depth at the critical section, $d^1 = 542.09 - 78 = 464.09$ mm

Shear force at the critical section $= (268.75 \times 10^3) \times 4 \times 1$

$= 1075000$ N

Factored shear, $V_u = 1.5 \times 1075000 = 1612500$ N

Width of the footing at the top at this critical section, $b^1 = b + 2d$

$= 500 + (2 \times 1692)$

$= 3884$ mm

Nominal shear stress at this section, $\Gamma_v = V_u / b^1 d^1 = ((1612500)/ 3884 \times 1692)$

$\Gamma_v = 0.245$ N/mm^2

Area of steel provided $= (\pi/4) \times 15^2 \times 26 = 4594.58$ mm^2

% of steel provided $= ((4594.58) / (3884 \times 1692)) \times 100 = 0.07$ %

Corresponding $\Gamma_c = 0.28$ N/ mm^2 (IS 456 :2000)

Therefore, $\Gamma_v < \Gamma_c$

<u>SAFE</u>

(ii.) ***Check for two way shear :***

The critical section for two way shear is taken at the periphery surrounding the column at a distance of half the effective depth from the face of the column.

Overall depth of the footing at a distance d/2 = 1692/ 2 = 846 mm from the column face.

= 1770 – (((1770-500)/1750) x 846)

= 1156.05 mm

Effective depth at this section , d^1 = 1156.05 – 78 = 1078.05 mm

Critical perimeter, b^1 = 4(500 +1692) = 8768 mm

Shear force at this critical section, V = $(268.75 \times 10^3)(4^2 - 2.192^2)$

V = 3008692.8 N

Factored shear, V_u = 1.5 x 3008692.8

V_u = 4513039.2

Nominal shear stress, Γ_v = (4513039.2) / (8768 x 1078.05) = 0.47745 N/mm^2

β_c = (Shorter side of column section) / (longer side of column section) = 500/500 = 1

$K_s = 0.5 + \beta_c = 0.5 + 1 = 1.5$

But K_s should not be greater than 1

Therefore, $K_s = 1$

Permissible design shear strength, $\Gamma_c = K_s \times 0.25 (f_{ck})^{0.5}$

$= 1 \times 0.25 \times (20)^{0.5}$

= 1.12 N/mm^2

As $\Gamma_c > \Gamma_v$, therefore ***OK***

Appendix :

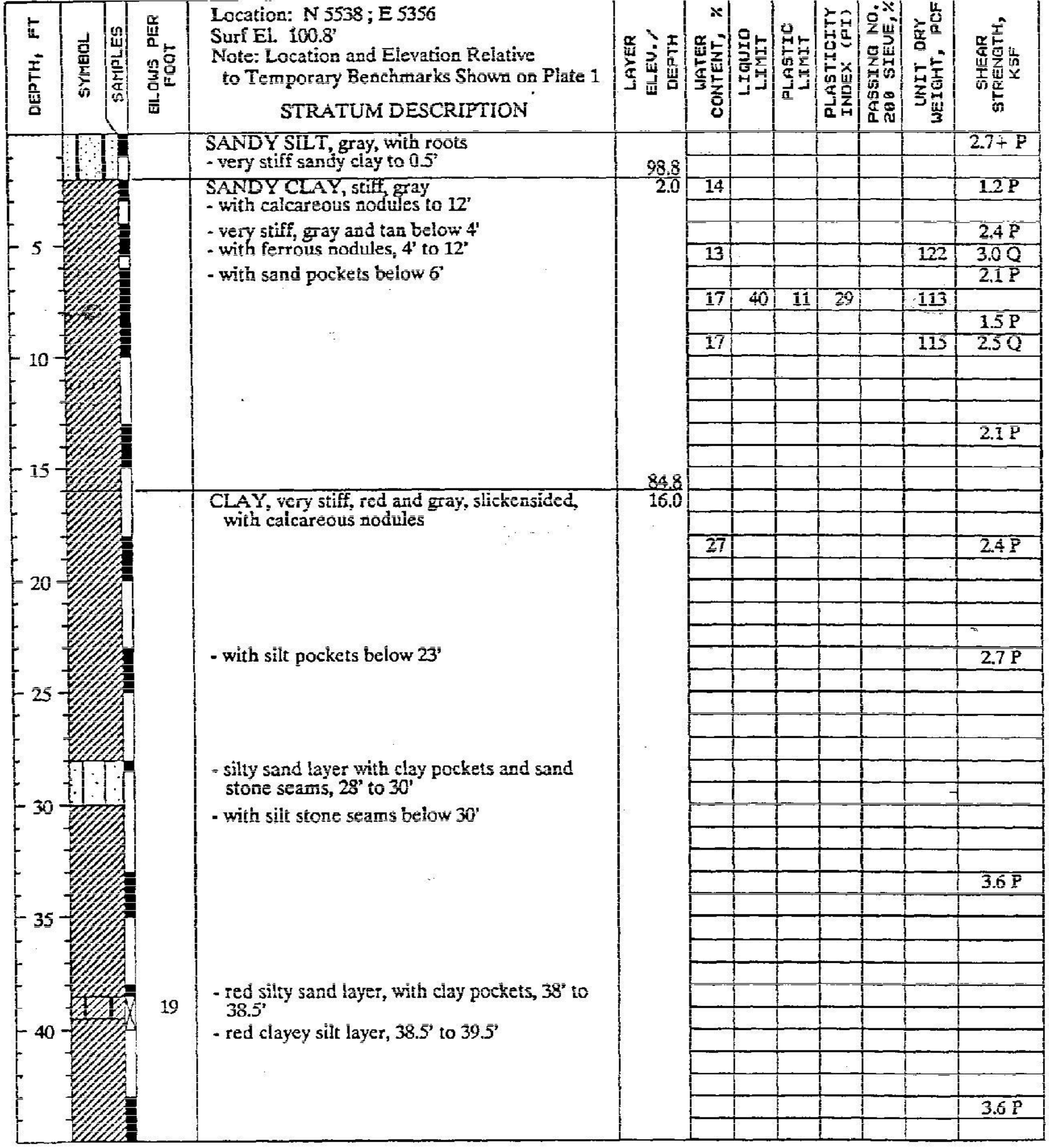
Data available in form of Borehole logs

Report No. 0401-2452

FUGRO McClelland

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

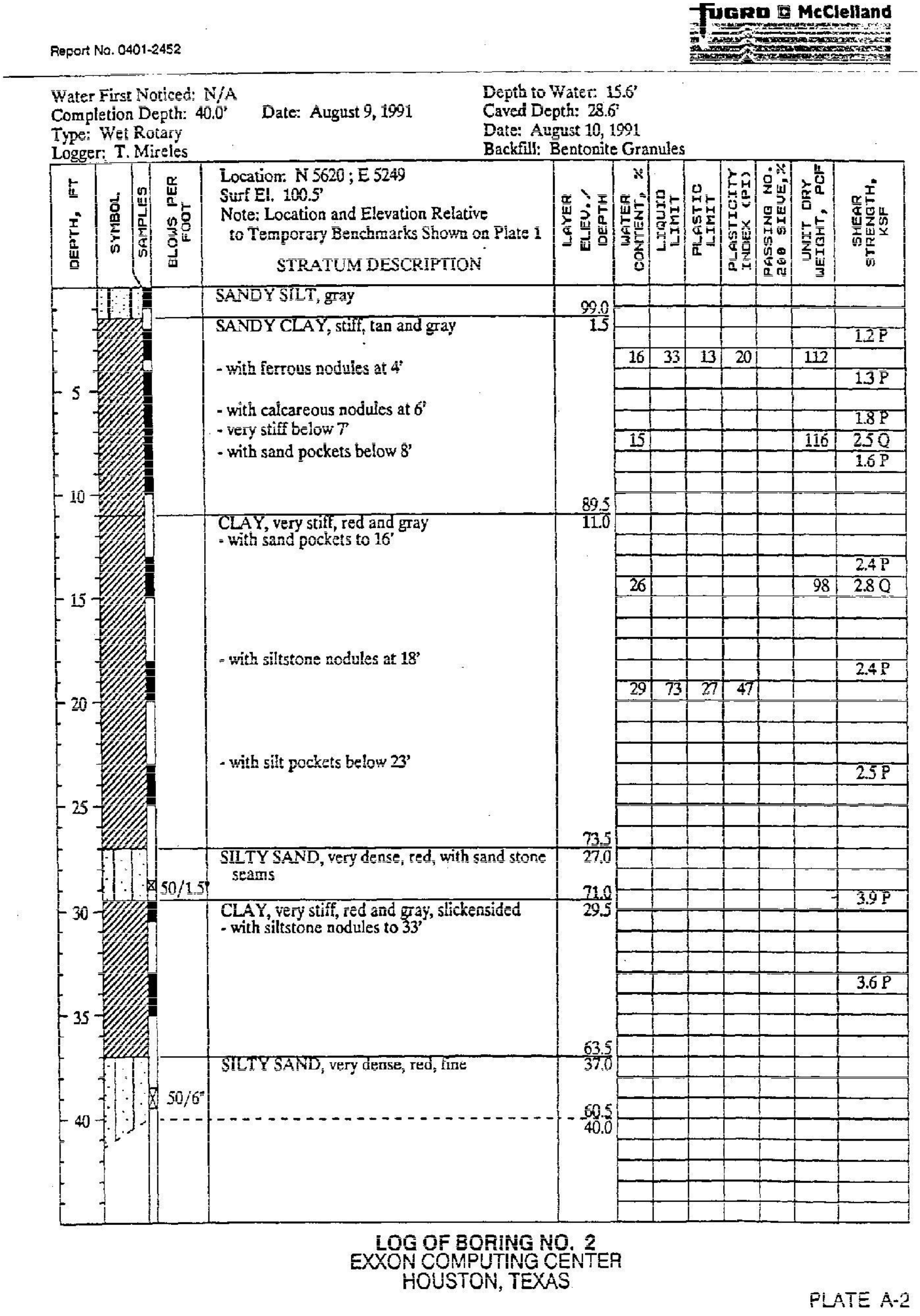


Location: N 5538 ; E 5356
Surf El. 100.8'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1

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



Report No. 0401-2452

FUGRO McClelland

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	
				- with ferrous nodules at 4'								
												1.3 P
5												
				- 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
						26					98	2.8 Q
15												
				- with siltstone nodules at 18'								
												2.4 P
						29	73	27	47			
20												
				- 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							3.9 P
30				CLAY, very stiff, red and gray, slickensided - with siltstone nodules to 33'								
												3.6 P
35												
					63.5 37.0							
		☒	50/6"	SILTY SAND, very dense, red, fine								
40					60.5 40.0							

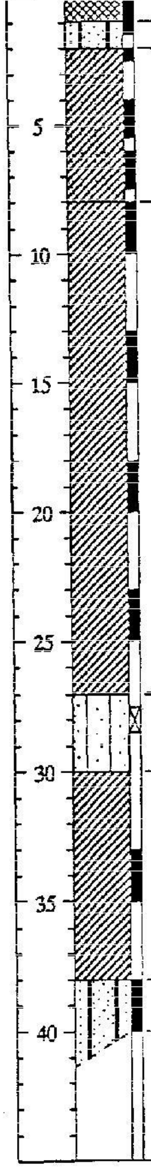
LOG OF BORING NO. 2
EXXON COMPUTING CENTER
HOUSTON, TEXAS

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

Location: N 5626 ; E 5437
Surf El. 101.1'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1

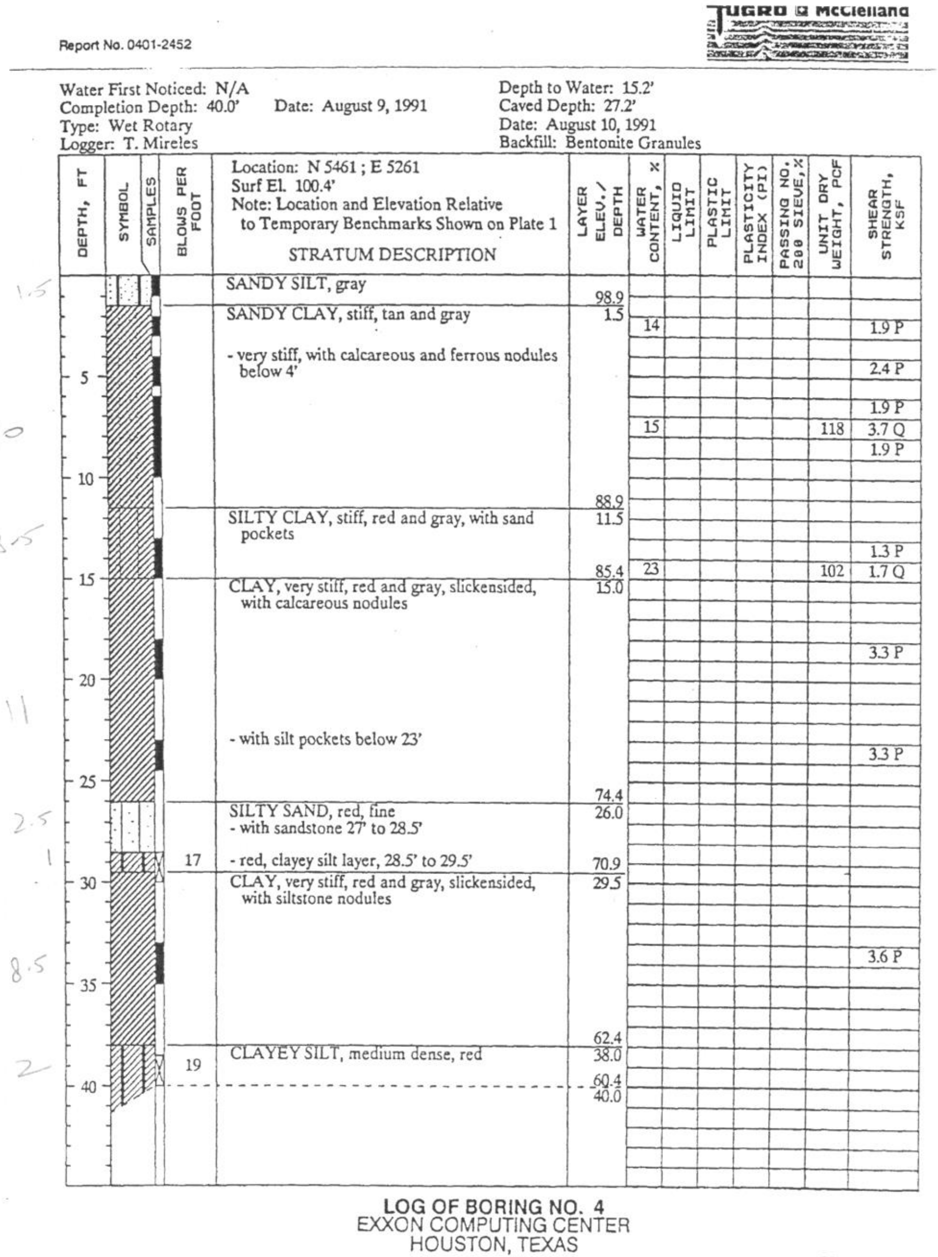


BLOWS PER FOOT	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
	FILL: SANDY CLAY, very stiff, gray and tan, with shell fragments	100.1 1.0							2.7+ P
	SANDY SILT, gray	99.1 2.0	14						1.9 P
	SANDY CLAY, stiff, tan and gray, with sand pockets - with ferrous nodules and calcareous nodules below 4' - very stiff below 5'								1.3 P
			15					117	2.2 Q
									1.8 P
	CLAY, stiff, gray and tan - with sand pockets to 16'	93.1 8.0							2.4 P
			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* Q
	- 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



Report No. 0401-2452

FUGRO McClelland

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

	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
1.5					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
	5												
													1.9 P
10							15					118	3.7 Q
													1.9 P
	10												
					SILTY CLAY, stiff, red and gray, with sand pockets	88.9 11.5							
3.5													1.3 P
						85.4 15.0	23					102	1.7 Q
	15				CLAY, very stiff, red and gray, slickensided, with calcareous nodules								
													3.3 P
	20												
11													
					- with silt pockets below 23'								3.3 P
	25												
2.5					SILTY SAND, red, fine - with sandstone 27' to 28.5'	74.4 26.0							
1				17	- red, clayey silt layer, 28.5' to 29.5'	70.9 29.5							
	30				CLAY, very stiff, red and gray, slickensided, with siltstone nodules								
8.5													3.6 P
	35												
2				19	CLAYEY SILT, medium dense, red	62.4 38.0							
	40					60.4 40.0							

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

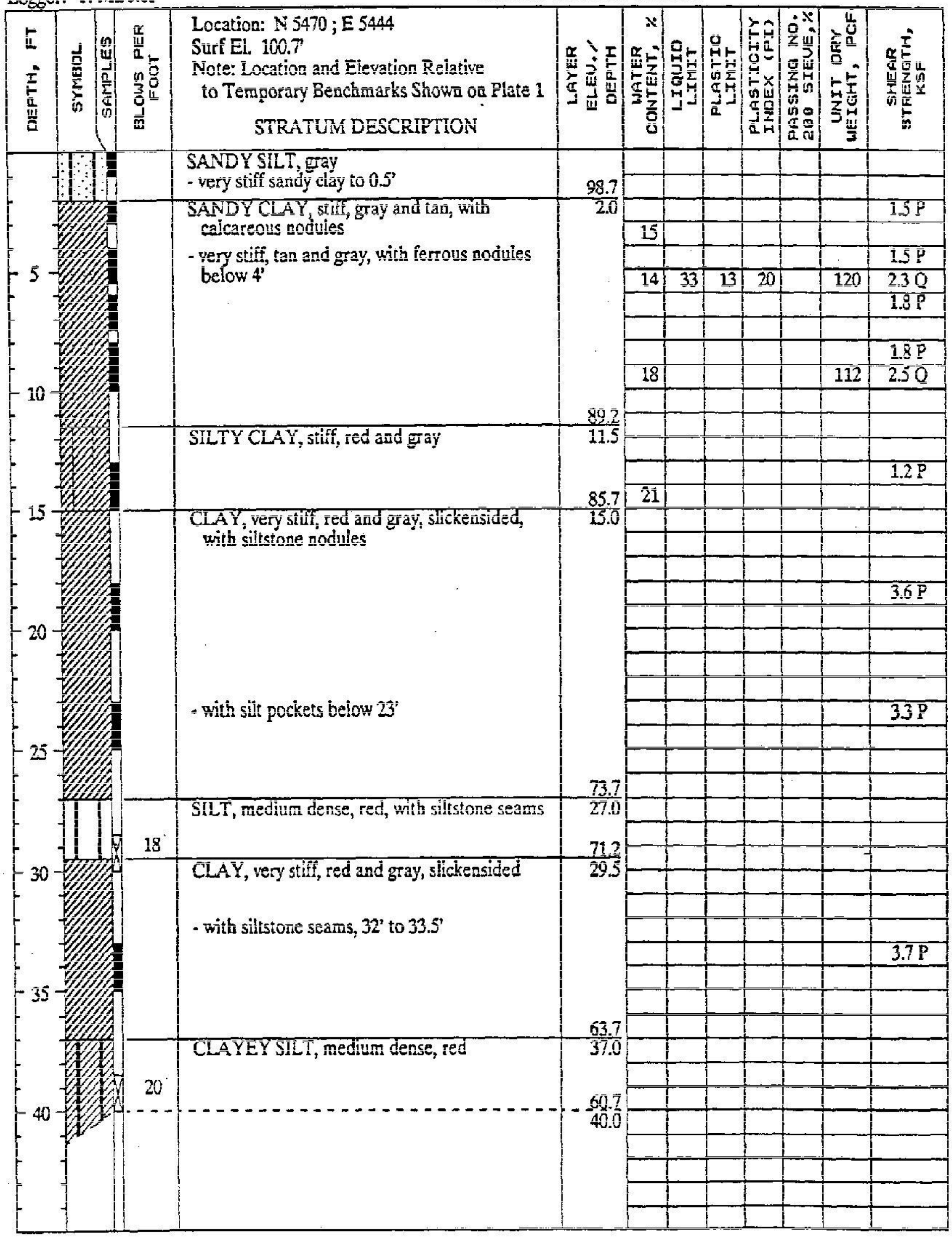
PLATE A-4

Report No. 0401-2452

FUGRO McClelland

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

STRATUM DESCRIPTION	BLOWS PER FOOT	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'		98.7 2.0							
SANDY CLAY, stiff, gray and tan, with calcareous nodules									1.5 P
			15						
- very stiff, tan and gray, with ferrous nodules below 4'									1.5 P
			14	33	13	20		120	2.3 Q
									1.8 P
									1.8 P
			18					112	2.5 Q
SILTY CLAY, stiff, red and gray		89.2 11.5							
									1.2 P
			21						
CLAY, very stiff, red and gray, slickensided, with siltstone nodules		85.7 15.0							
									3.6 P
- with silt pockets below 23'									3.3 P
SILT, medium dense, red, with siltstone seams	18	73.7 27.0							
CLAY, very stiff, red and gray, slickensided - with siltstone seams, 32' to 33.5'		71.2 29.5							3.7 P
CLAYEY SILT, medium dense, red	20	63.7 37.0							
		60.7 40.0							

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

PLATE A-5

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

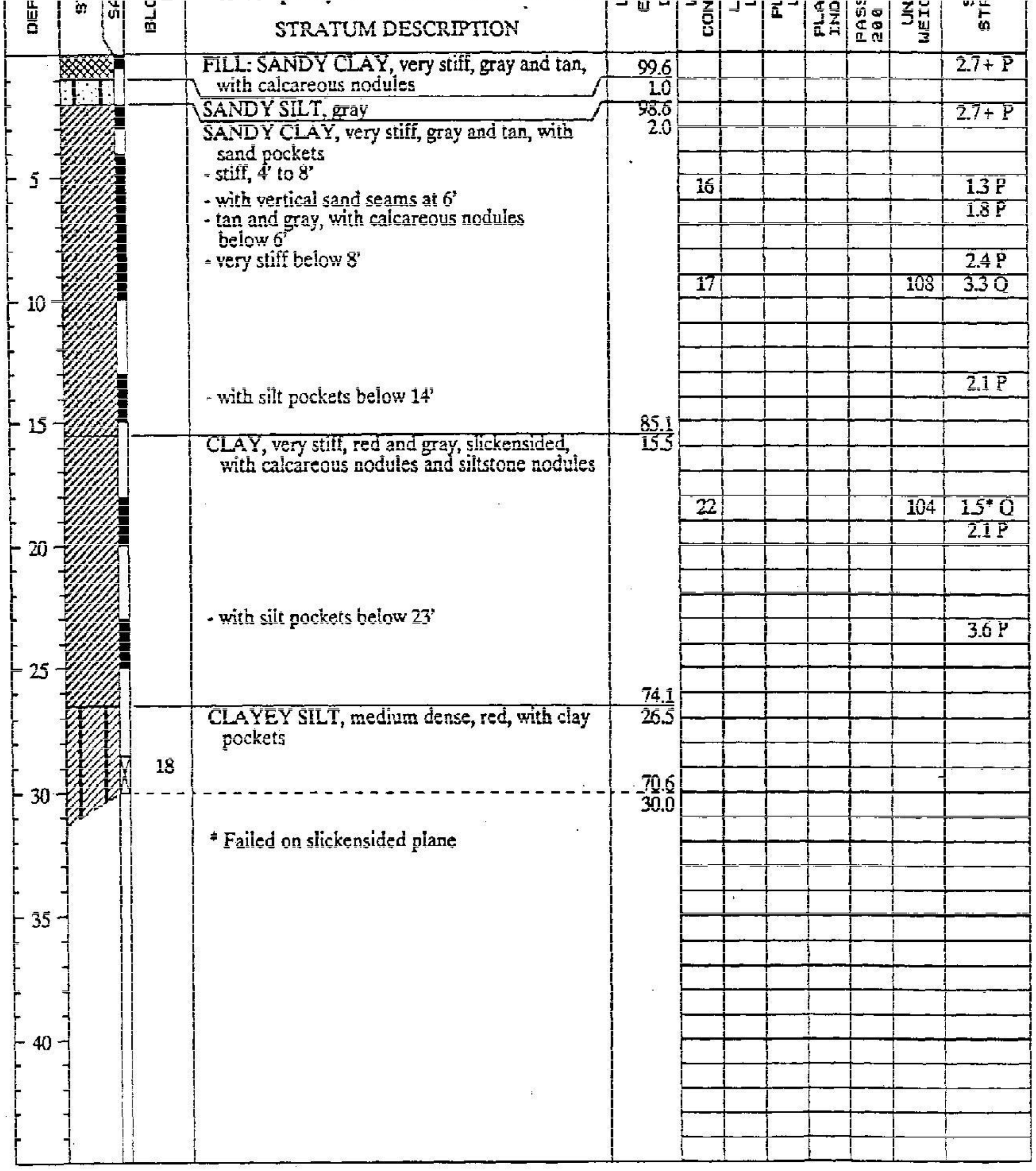
DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT	STRATUM DESCRIPTION	LAYER ELEV./ DEPTH	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	PASSING NO. 200 SIEVE, %	UNIT DRY WEIGHT, PCF	SHEAR STRENGTH, KSF
				SANDY SILT, light gray - very stiff sandy clay to 0.5'	99.2 1.5							
				SANDY CLAY, very stiff, gray, with sand pockets								2.7+ P
5						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
10												
					85.7 15.0							2.2 P
15				CLAY, very stiff, red and gray, slickensided								
				- with calcareous nodules below 18'		33					89	0.88* Q
												2.2 P
20												
				SILTY CLAY, stiff, red and gray	78.2 22.5							
												1.2 P
25												
				CLAYEY SILT, red - with sandstone seams below 27'	74.7 26.0							
												3.3 P
30			20	CLAY, very stiff, red and gray, slickensided	71.2 29.5							
					70.2 30.5							
				* Failed on a slickensided plane								
35												
40												

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

PLATE A-6

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



Location: N 5539 ; E 5592
Surf El. 100.6'
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
				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								
5				- stiff, 4' to 8'		16						1.3 P
				- with vertical sand seams at 6'								1.8 P
				- tan and gray, with calcareous nodules below 6'								
				- very stiff below 8'								2.4 P
						17					108	3.3 Q
10												
				- with silt pockets below 14'								2.1 P
15					85.1 15.5							
				CLAY, very stiff, red and gray, slickensided, with calcareous nodules and siltstone nodules								
						22					104	1.5* Q
												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

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
				CLAY, stiff, tan and gray, with calcareous nodules and sand pockets	92.7 8.0							1.3 P
						23					105	1.4 Q
10												
				SILTY CLAY, stiff, tan and gray, with calcareous nodules and silt pockets	88.7 12.0							
												1.2 P
15				CLAY, very stiff, red and gray, slickensided, with calcareous nodules	85.7 15.0							
						29						2.5 P
20												
				- with sand pockets below 23'								2.1 P
25												
			50/6"	SANDY SILT, very dense, red, fine - with sandstone seams below 28'	74.2 26.5					60		
30				CLAY, very stiff, red, slickensided	71.2 29.5							
				- with sandstone seam at 32'								
												3.6 P
35												
				SILTY SAND, red, fine, with clay pockets and sandstone nodules	62.7 38.0 61.7 39.0							
40												

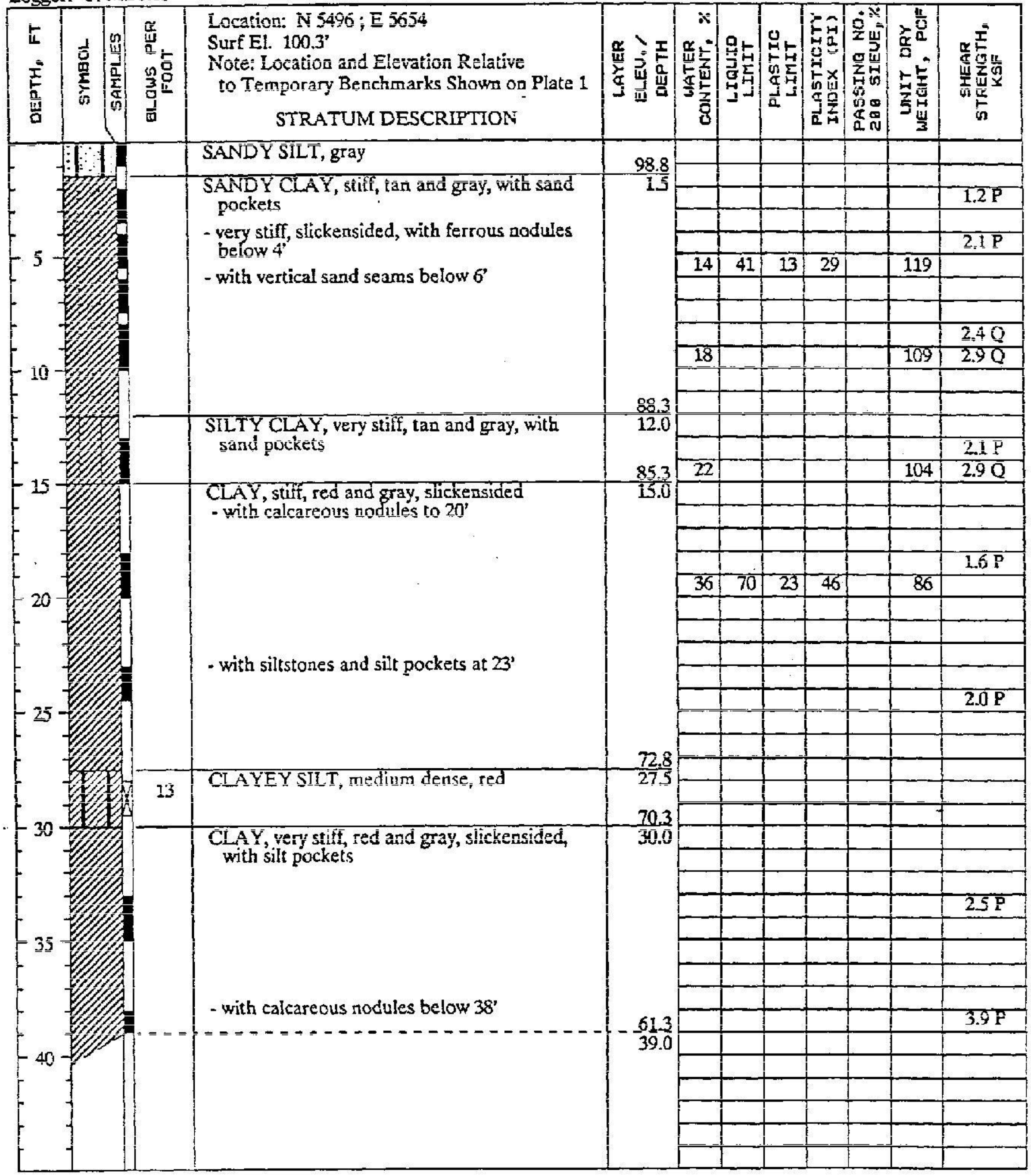
LOG OF BORING NO. 8
EXXON COMPUTING CENTER
HOUSTON, TEXAS

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

Location: N 5496 ; E 5654
Surf El. 100.3'
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								
		98.8 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
	- with vertical sand seams below 6'		14	41	13	29		119	
									2.4 Q
			18					109	2.9 Q
		88.3 12.0							
	SILTY CLAY, very stiff, tan and gray, with sand pockets								2.1 P
			22					104	2.9 Q
		85.3 15.0							
	CLAY, stiff, red and gray, slickensided - with calcareous nodules to 20'								1.6 P
			36	70	23	46		86	
	- with siltstones and silt pockets at 23'								2.0 P
		72.8 27.5							
13	CLAYEY SILT, medium dense, red								
		70.3 30.0							
	CLAY, very stiff, red and gray, slickensided, with silt pockets								2.5 P
	- with calcareous nodules below 38'								3.9 P
		61.3 39.0							

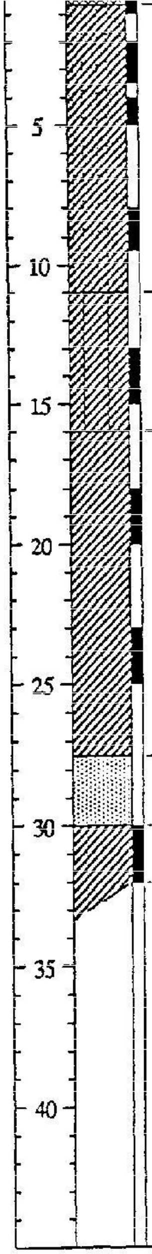
LOG OF BORING NO. 9
EXXON COMPUTING CENTER
HOUSTON, TEXAS

PLATE A-9

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



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
	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
			14					120	3.5 Q
	- with ferrous nodules below 8'								3.9 P
	SILTY CLAY, very stiff, red and gray, with sand pockets	89.7 11.0							
									1.8 P
			19	31	18	14		111	2.5 Q
	CLAY, very stiff, red and gray, slickensided, with siltstone nodules	84.7 16.0							
									2.1 P
	- stiff, with silt pockets below 23'								1.8 P
	- silty sand layer below 27'								
	SANDSTONE, red	73.2 27.5							
	CLAY, very stiff, red and gray, slickensided, with silt seams and siltstone nodules	70.7 30.0							2.5 P
		68.7 32.0							

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

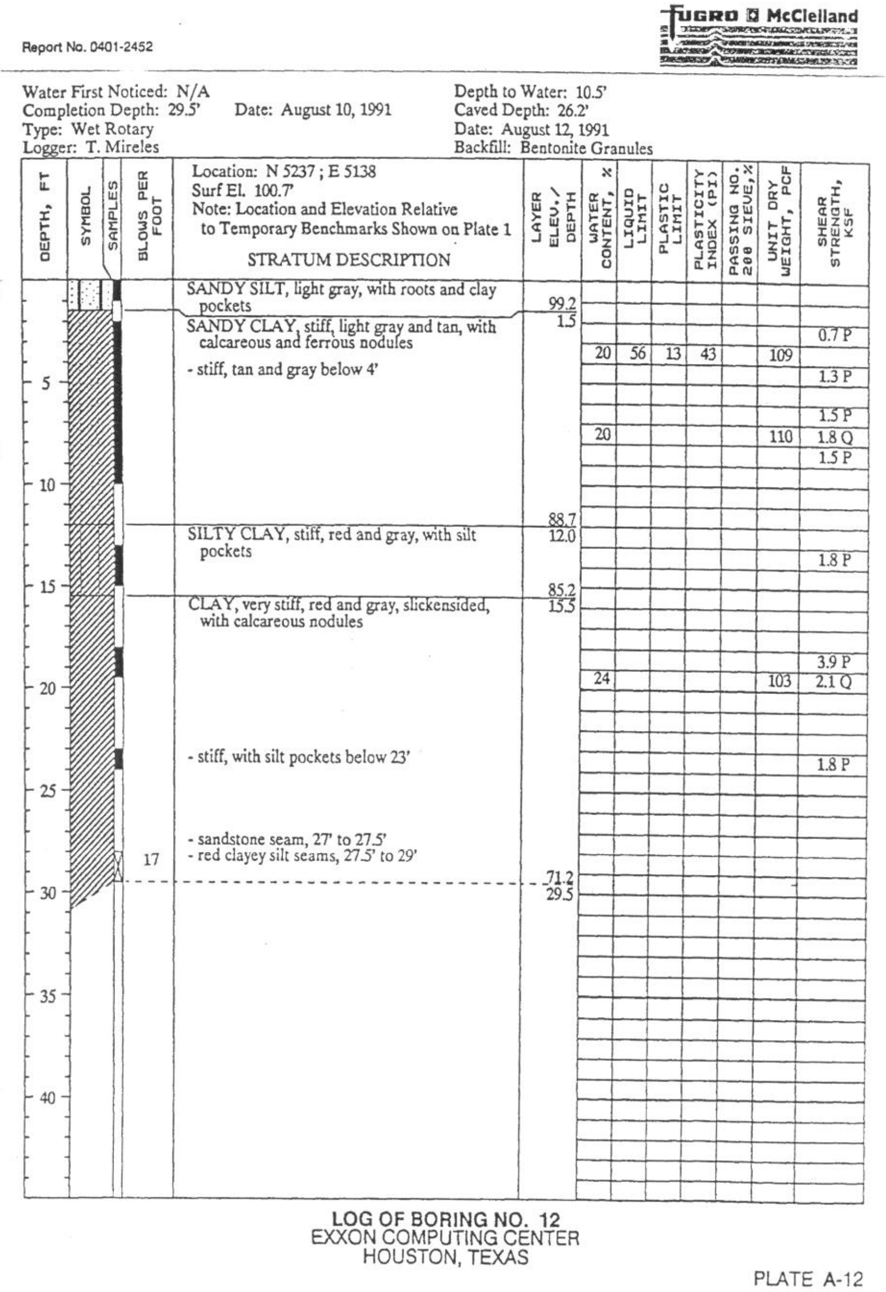
Depth to Water: 14.3'
Caved Depth: 19.1'
Date: August 12, 1991
Backfill: Bentonite Granules

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

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 - very stiff sandy clay fill to 0.5'	98.7 2.0							
				SANDY CLAY, stiff, light gray - with many calcareous nodules to 3'		13						1.2 P
												1.8 Q
				- tan and gray, with ferrous nodules below 4'		17					114	2.1 Q
5												
				- with calcareous nodules below 6'								1.3 P
				CLAY, stiff, tan and gray, with ferrous nodules, calcareous nodules, and sand pockets	92.7 8.0							1.3 P
						21					106	1.8 Q
10												
				SILTY CLAY, stiff, tan and gray, with sand pockets and calcareous nodules	88.7 12.0							1.2 P
15				CLAY, very stiff, red and gray, slickensided, with siltstone nodules	85.7 15.0							
						28						2.7 P
20												
				- with silt pockets below 23'								3.9 P
25												
			18	- silt layer, 27.5' to 28' - stiff, with seams below 28'	71.2 29.5							1.5 P
30												
35												
40												

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

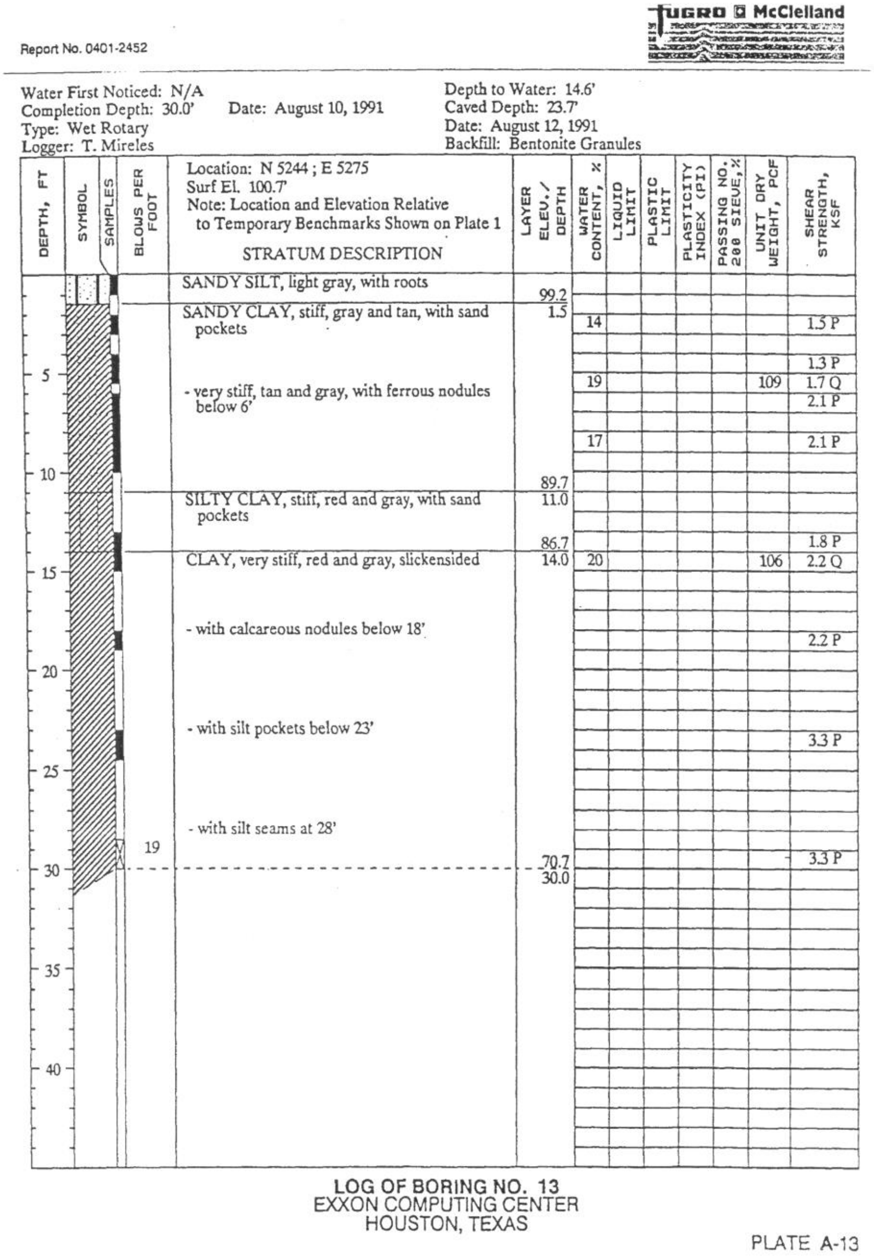
Location: N 5237 ; E 5138
Surf El. 100.7'
Note: Location and Elevation Relative to Temporary Benchmarks Shown on Plate 1

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, 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	
5				- stiff, tan and gray below 4'								1.3 P
												1.5 P
						20					110	1.8 Q
												1.5 P
10												
				SILTY CLAY, stiff, red and gray, with silt pockets	88.7 12.0							
												1.8 P
15				CLAY, very stiff, red and gray, slickensided, with calcareous nodules	85.2 15.5							
												3.9 P
20						24					103	2.1 Q
				- stiff, with silt pockets below 23'								1.8 P
25												
			17	- sandstone seam, 27' to 27.5' - red clayey silt seams, 27.5' to 29'								
30					71.2 29.5							
35												
40												

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

PLATE A-12

1.5
10.5
3.5
14



Report No. 0401-2452

TUGRO McClelland

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

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, light gray, with roots	99.2							
				SANDY CLAY, stiff, gray and tan, with sand pockets	1.5	14						1.5 P
												1.3 P
5						19					109	1.7 Q
				- very stiff, tan and gray, with ferrous nodules below 6'								2.1 P
						17						2.1 P
10					89.7							
				SILTY CLAY, stiff, red and gray, with sand pockets	11.0							
					86.7							1.8 P
				CLAY, very stiff, red and gray, slickensided	14.0	20					106	2.2 Q
15												
				- with calcareous nodules below 18'								2.2 P
20												
				- with silt pockets below 23'								3.3 P
25												
				- with silt seams at 28'								
			19		70.7							3.3 P
30					30.0							
35												
40												

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

PLATE A-13

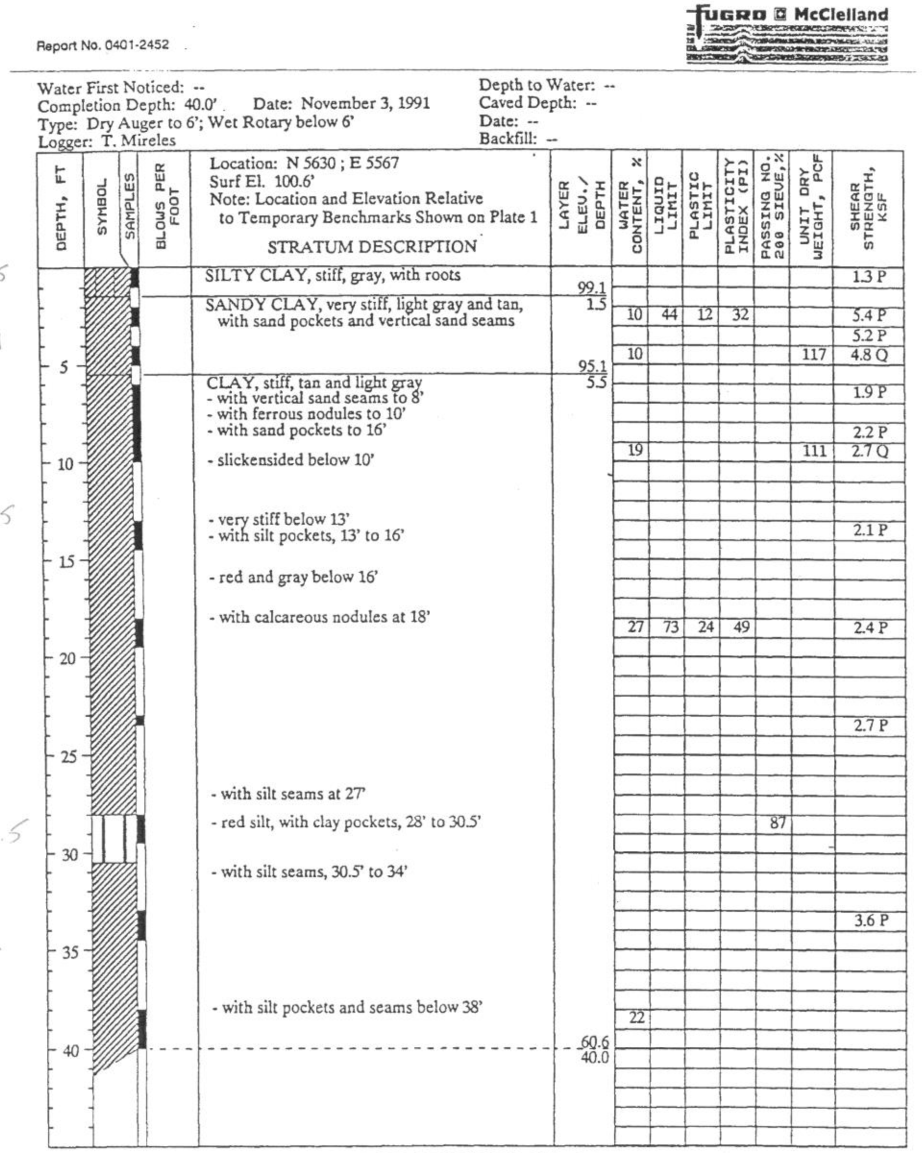
Water First Noticed: N/A
Completion Depth: 31.0' Date: August 9, 1991
Type: Wet Rotary
Logger: T. Mireles

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

DEPTH, FT	SYMBOL	SAMPLES	BLOWS PER FOOT	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							
				SANDY CLAY, stiff, tan and gray, with sand pockets and calcareous nodules	1.5							1.3 P
						14					119	2.8 U
5				- very stiff, 4' to 6'								3.9 P
				- stiff, with ferrous nodules below 6'		20						1.6 P
					93.1							
				CLAY, stiff, tan and gray, with sand pockets and calcareous nodules	8.0							1.2 P
						18					108	1.2 Q
10					90.1							
				SILTY CLAY, stiff, tan and gray, with silt pockets	11.0							
												1.8 P
					86.1							
15				CLAY, very stiff, red and gray, slickensided, with siltstone nodules	15.0							
												3.6 P
20												
												3.9 P
25												
				- silty sand layer, 27' to 27.5'	73.6							
				SANDSTONE, red, with silt seams	27.5							
					71.6							
30				CLAY, very stiff, red, slickensided, with silt pockets and siltstone nodules	29.5							3.7 P
					70.1							
					31.0							
35												
40												

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

PLATE A-17



Report No. 0401-2452

FUGRO McClelland

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

0.75 -1.5
2 4
11.25-22.5
1.25 - 2.5
4.75-9.5

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
				SILTY CLAY, stiff, gray, with roots	99.1 1.5							1.3 P
				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
5				CLAY, stiff, tan and light gray	95.1 5.5							
				- with vertical sand seams to 8'								1.9 P
				- with ferrous nodules to 10'								
				- with sand pockets to 16'								2.2 P
10				- slickensided below 10'		19					111	2.7 Q
				- very stiff below 13' - with silt pockets, 13' to 16'								2.1 P
15				- red and gray below 16'								
				- with calcareous nodules at 18'		27	73	24	49			2.4 P
20												
												2.7 P
25												
				- with silt seams at 27'								
				- red silt, with clay pockets, 28' to 30.5'						87		
30				- with silt seams, 30.5' to 34'								
												3.6 P
35												
				- with silt pockets and seams below 38'		22						
40					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

Location: N 5634 ; E 5712
Surf El. 100.4'
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
	▨				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

References :

- IS 456:2000 (For RCC design)
- IS 6403:1981 (For designing isolated footing)
- ‘Basic and Applied Soil Mechanics’ by Ranjan and Rao
- ‘Design of Reinforced Concrete structures’ by S Ramamrutham
- ‘Foundation design, Principles and practices’ by Donald P. Coduto.