INTEGRATING VIRTUAL REALITY WITH STRUCTURAL AIDED DESIGN SYSTEM

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Abstract

The main issues that significantly contribute to problems and delays on construction sites are changing client's view, incomplete design information, and poor site monitoring and control. Although experienced designers and construction managers control or minimize such problems during the design stage, the complexity and amount of the information in construction project make such a task very difficult to accomplish effectively. This paper presents an actual case study model for an integrated system which aims at presenting construction activities in 3D using virtual reality. Firstly, the technology enables construction managers to walk-through the proposed building perhaps at different construction time intervals-giving a vivid appreciation of the whole situation. Secondly, its enables the users to interrogate the building structural elements to present its details progress thus giving total virtual structural view of the project. Thirdly, the design effect of any changes in the building configuration can be modeled, visualized, and cost effect be calculated. Finally the system enables virtual models to be shared and thus facilitates collaborative global design and construction.

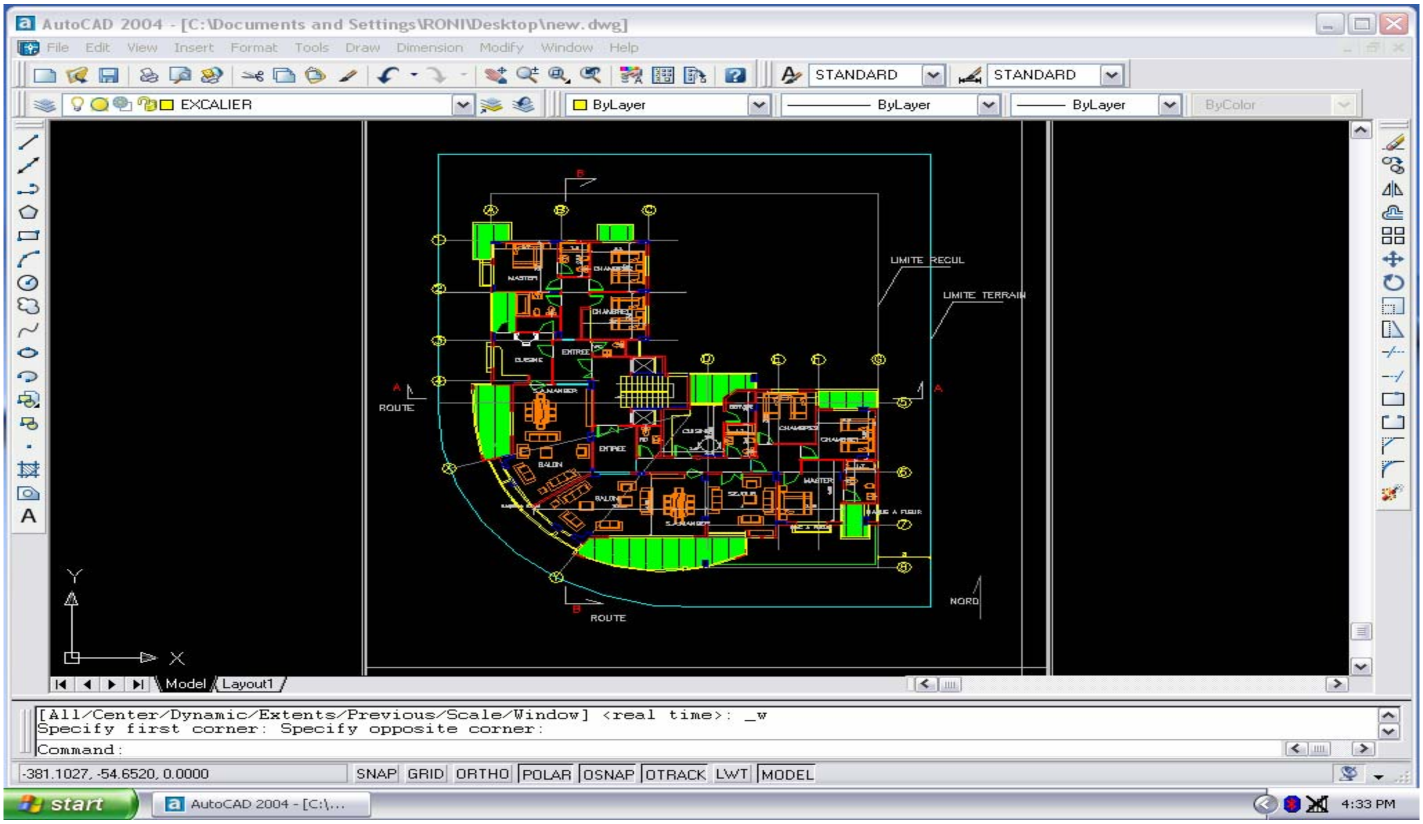
Keywords: *Virtual reality, integrated construction environment, structural project model*

Introduction:

The following project is a design project using ROBOT millennium version 17.0, a structural analysis program with special purpose features for structural design and analysis of building systems. This program enables the user to do a complete design on all structural elements and shows the steel reinforcement of all the main components that constitute the whole building. The basic concept of the program is to create one model consisting of the floor systems and the vertical and lateral framing systems to analyze and design the whole building. The analysis of the building allows modeling of the deck floors and concrete floor systems that can automatically transfer their loads to main girders. This is a unique approach that would give the project engineer the ability to have full control and to completely access the impact of any changes occurring in the field.

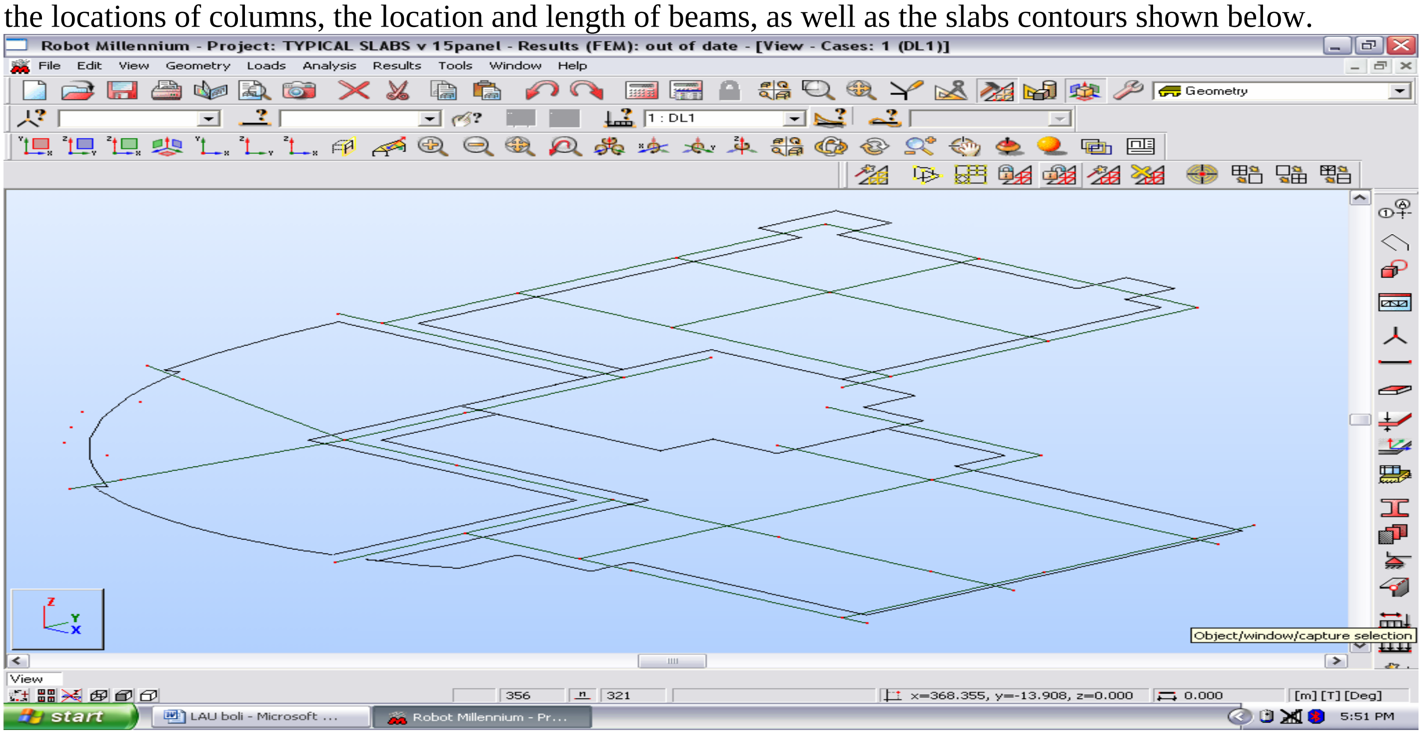
Project General Overview

The building is a residential building which consisting of 12 floors and 2 basements located in Lebanon in a coastal region near the Mediterranean Sea. Because of the very poor soil conditions and high water table a mat foundation of thickness 90cm was used, the columns are mostly rectangular; there are two L-shaped columns per floor, three 30x20cm columns for architectural purposes. The slabs are divided into three parts: Two one way joist slab systems and One two way slab. The beams are rectangular. The retaining walls are all around the peripheral area of the basement floors in addition to internal concrete walls for the staircase and the elevator shaft. Partition walls of variable thicknesses 10, 15, 20 cm defines the area of the different rooms in each apartment.



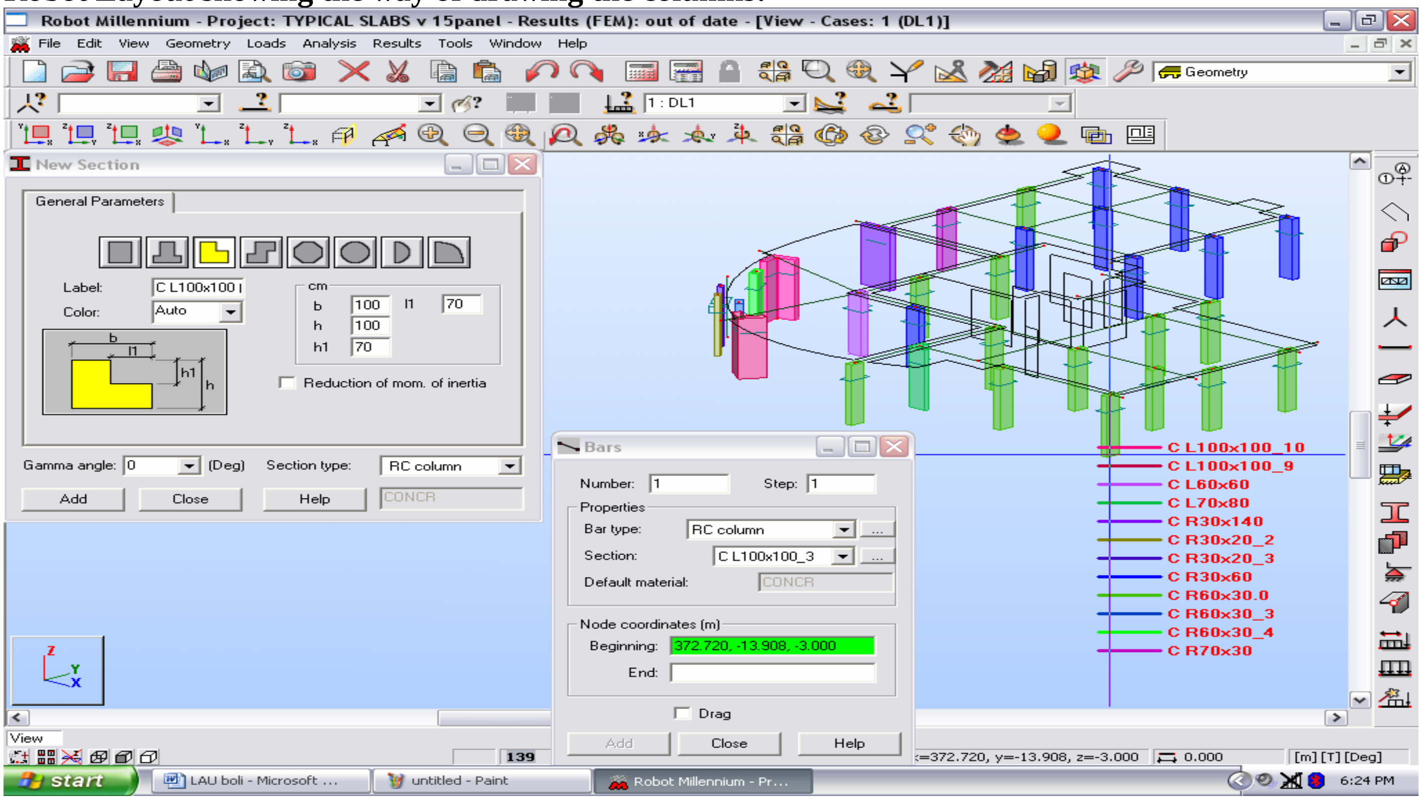
STRUCTURAL MODELING

The building was modeled using by importing an AutoCAD dxf file into the ROBOT Millennium to get the locations of columns, the location and length of beams, as well as the slabs contours shown below.

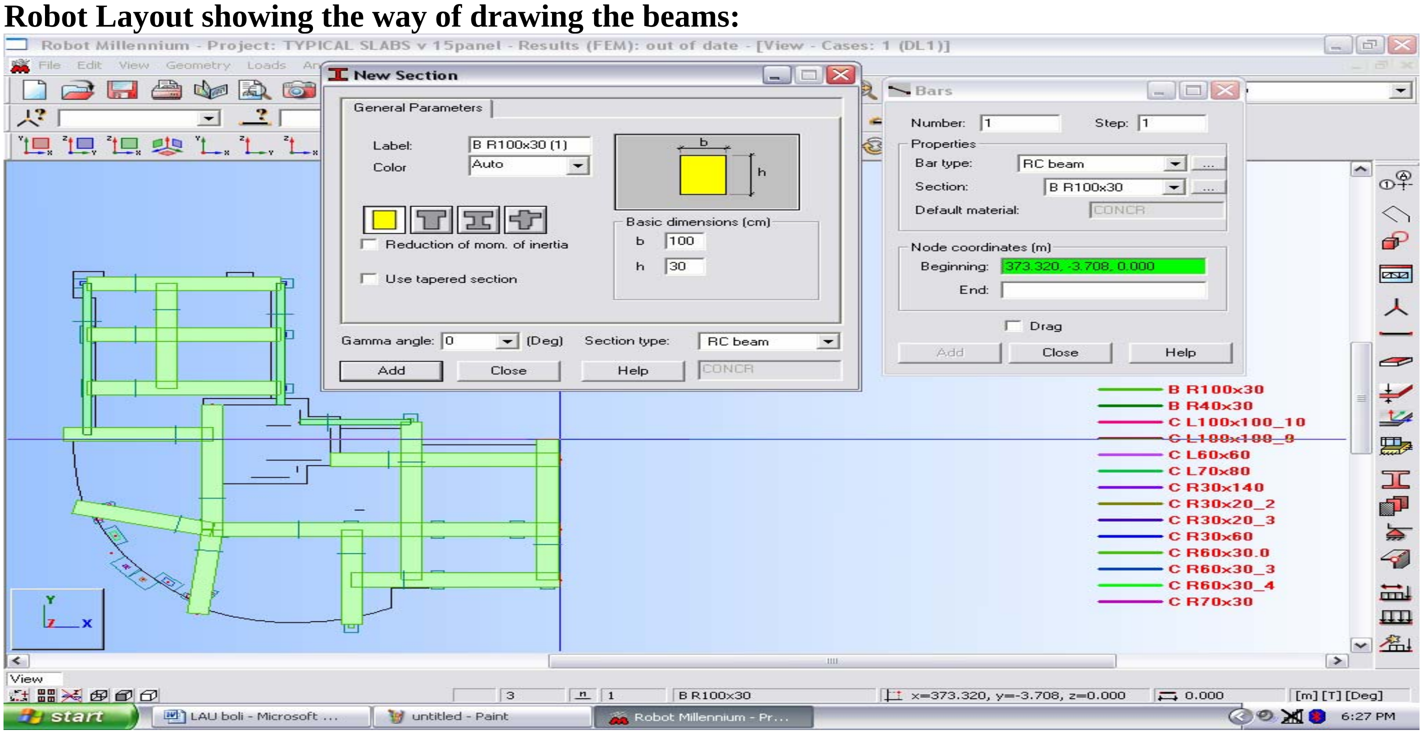


After that, the columns and beams are drawn using their architectural dimensions following the architectural drawings received from the architect. Below are drawings of beams and columns layouts.

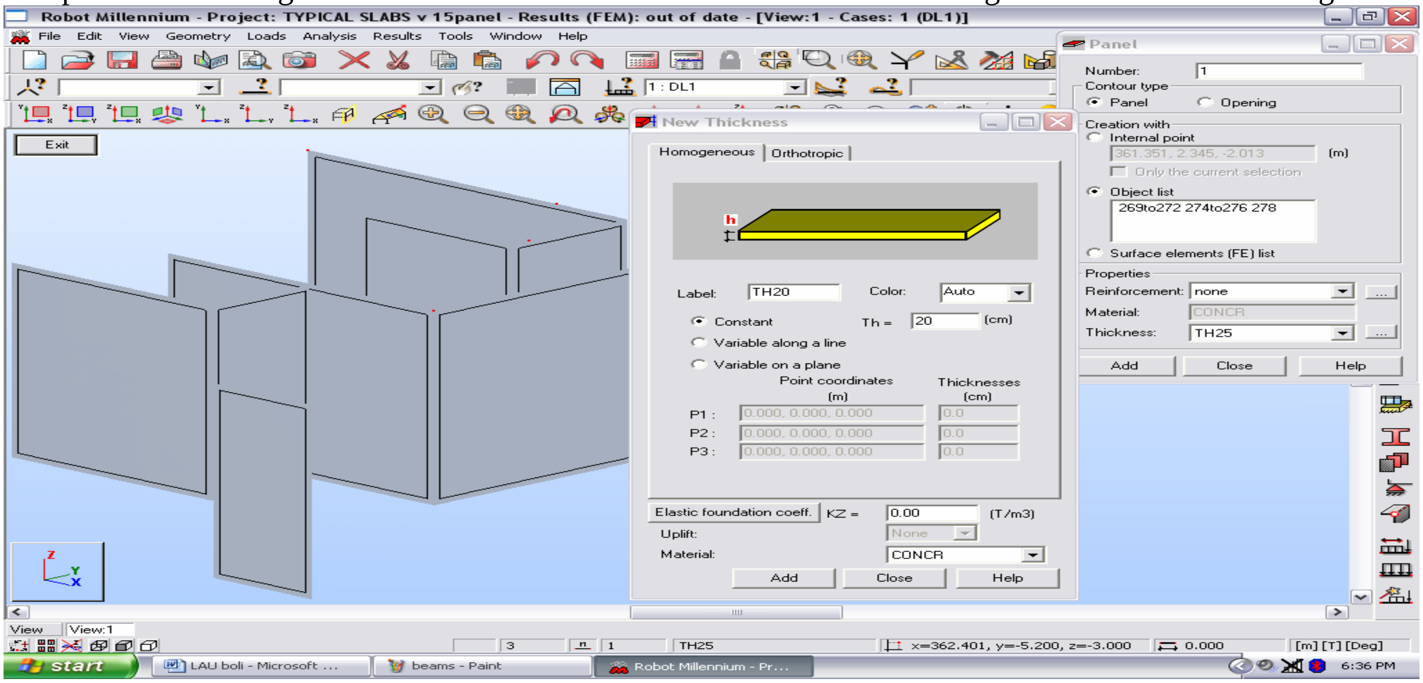
Robot Layout showing the way of drawing the columns:



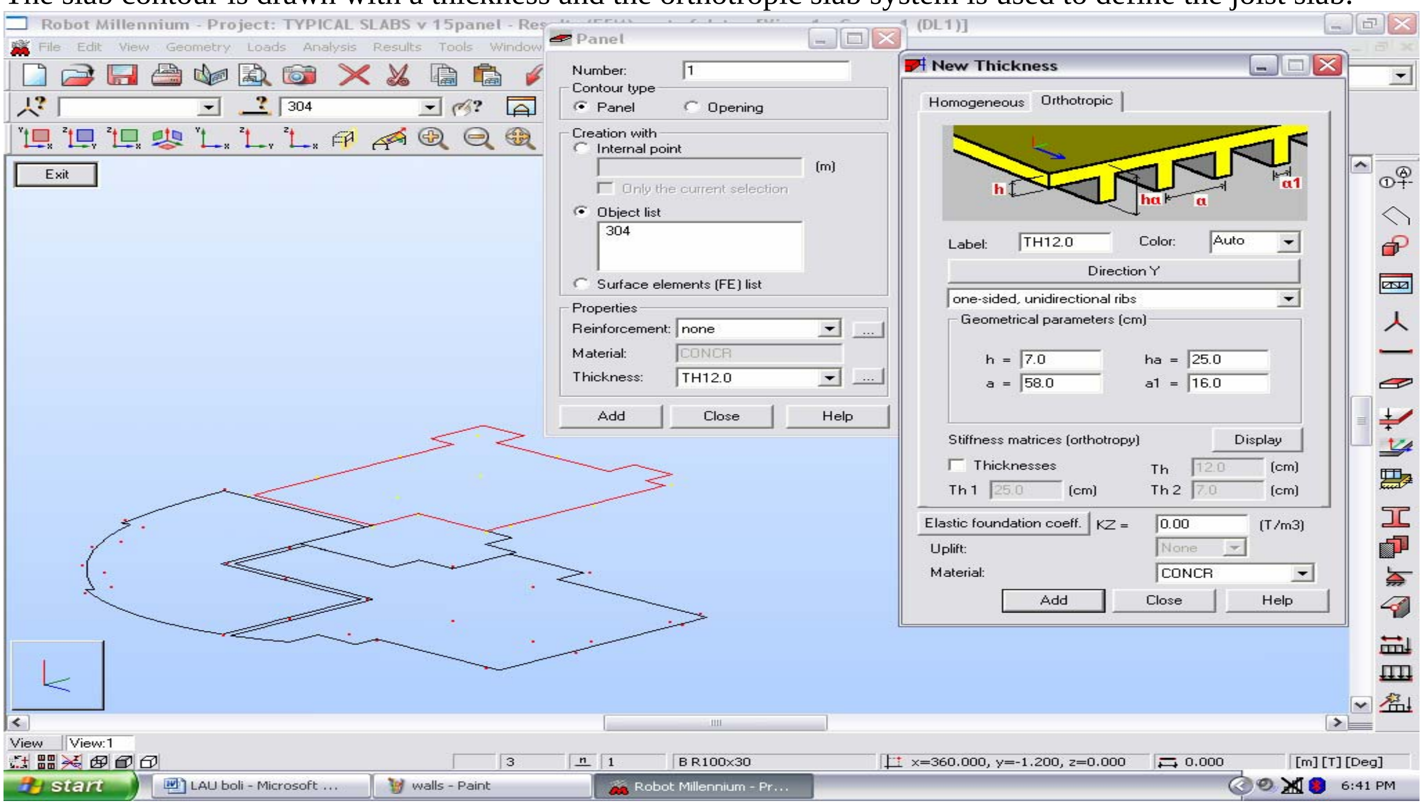
Robot Layout showing the way of drawing the beams:



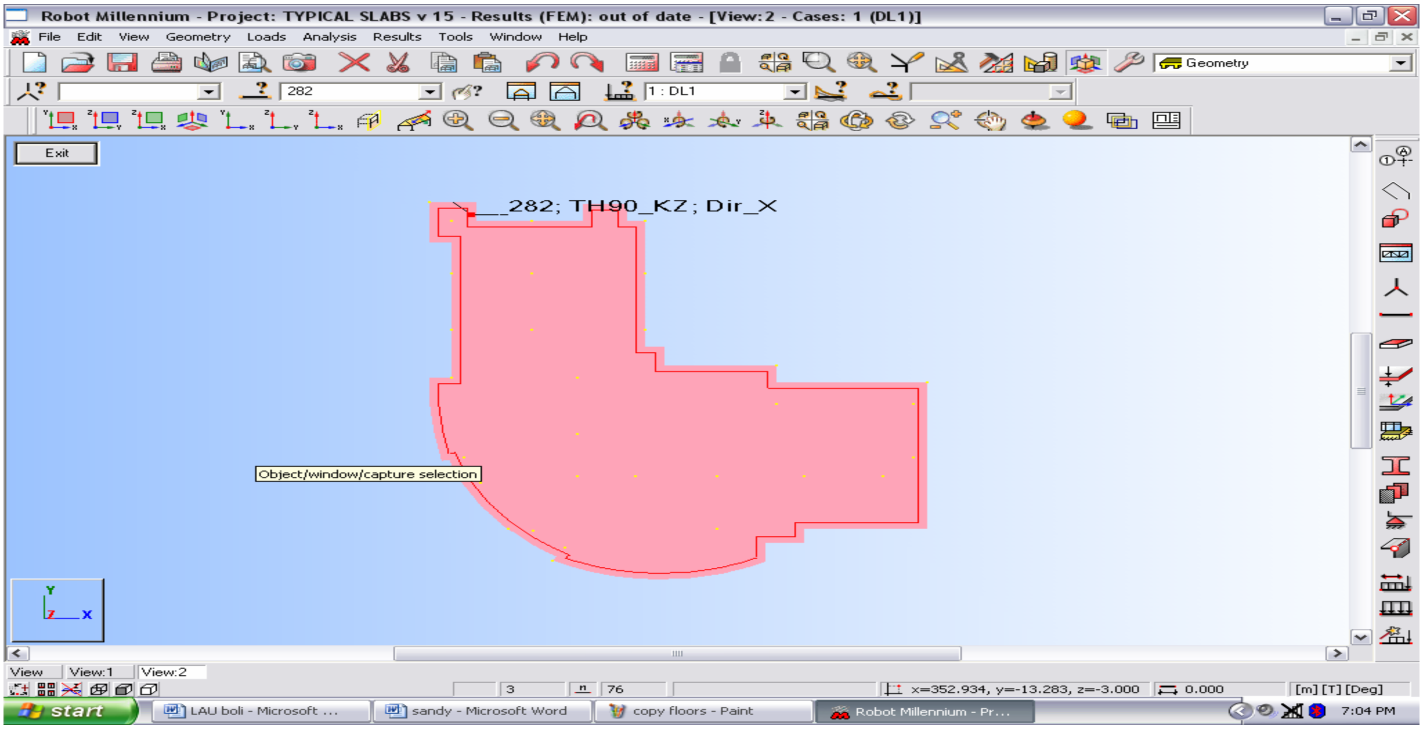
The panels resembling the shear walls are drawn with the thickness according to the architect's drawings.



The slab contour is drawn with a thickness and the orthotropic slab system is used to define the joist slab.



MAT FOUNDATION

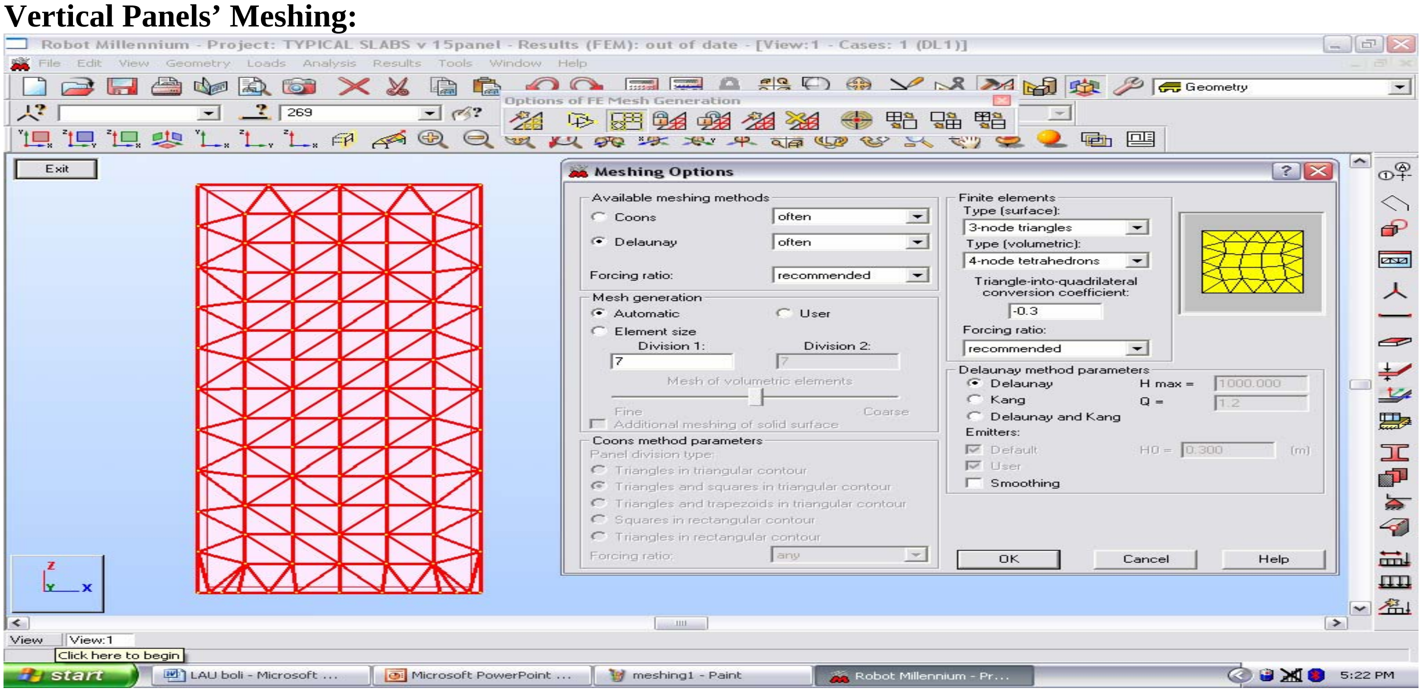


A consolidation test on a soil specimen retrieved from the middle of the saturated clay layer sandwiched between the planned foundation and the rock, has indicated that the soil is slightly over consolidated with bearing capacity of clay = 2.2 kg/cm^2.

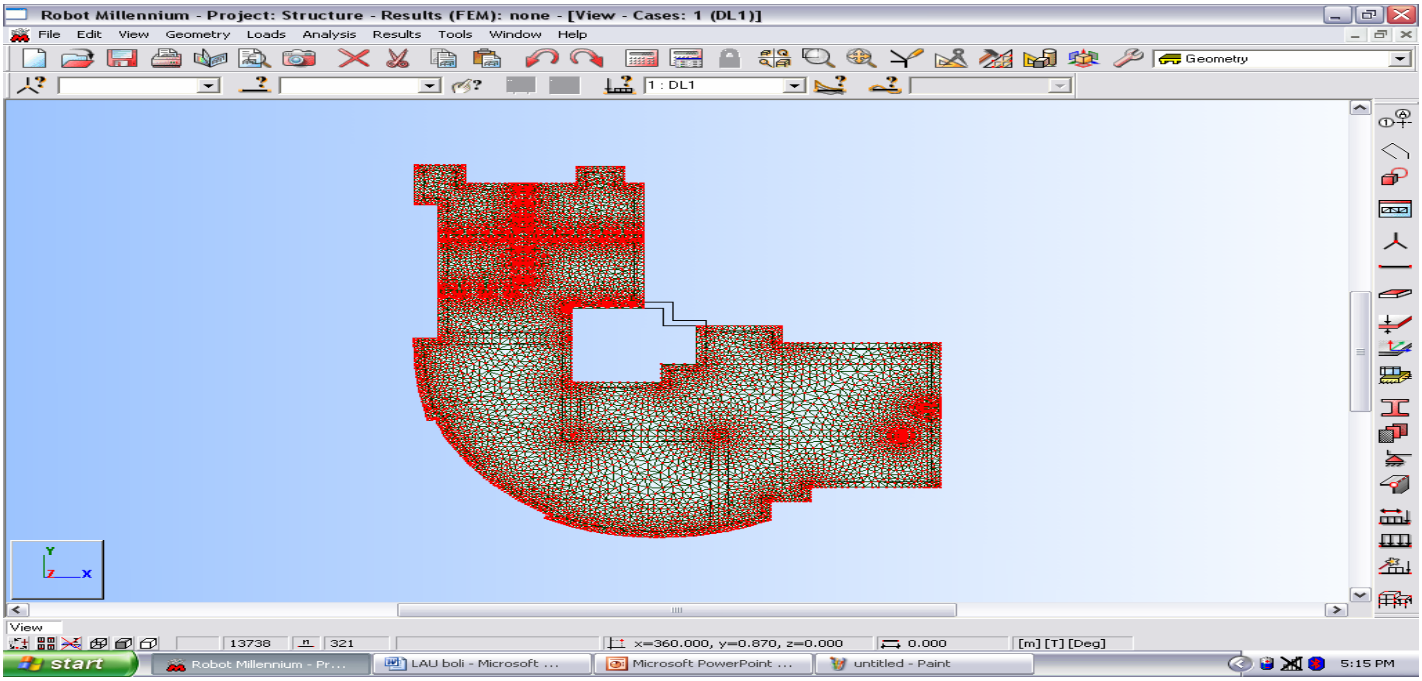
MESHING

After defining the sections and assigning the columns, beams, walls and slabs now we have to perform the meshing for the walls and slabs. It is very important to note that we should perform meshing for the vertical elements followed by that for the horizontal. The method is chosen according to the following windows:

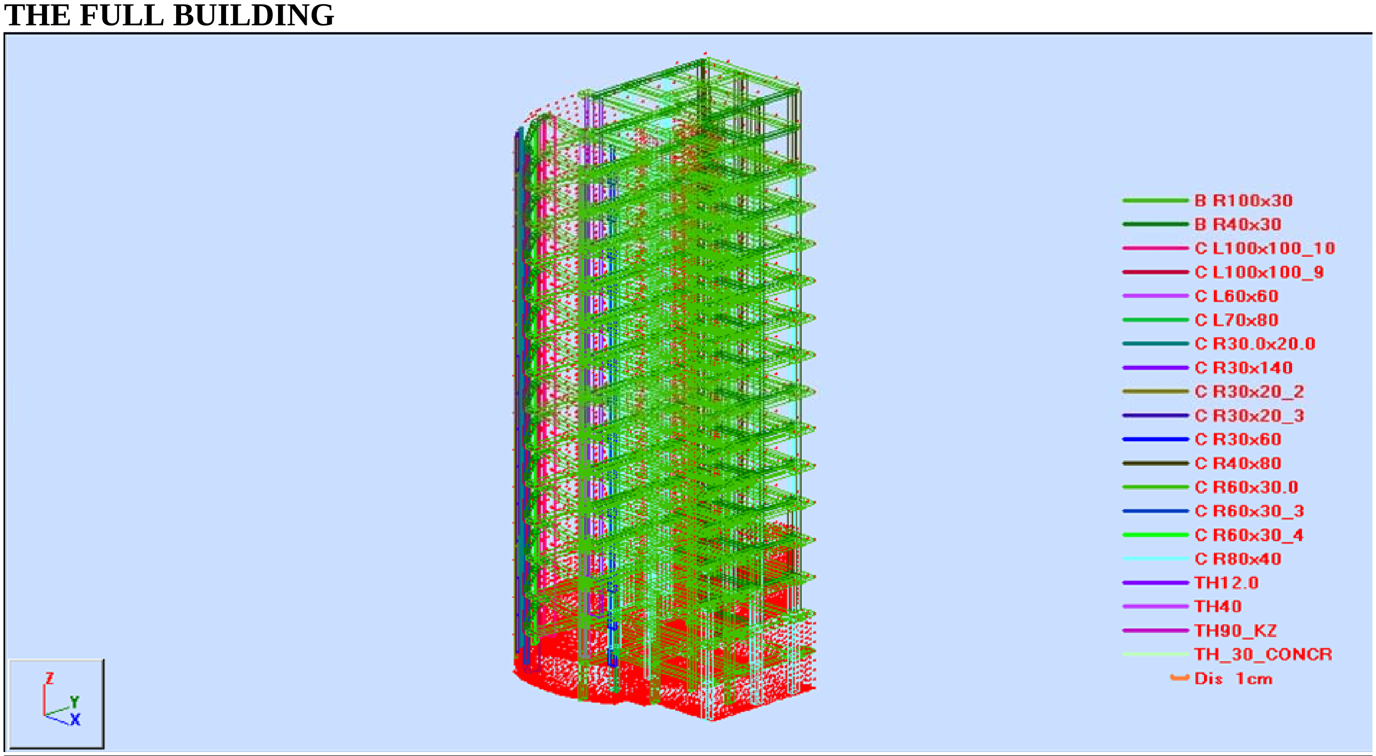
Vertical Panels' Meshing:



Horizontal Panels' Meshing:



THE FULL BUILDING



LOAD ASSIGMENT

After defining the sections and assigning the columns, beams and slabs now we have to assign the loads on each slab. Gravity loads that act on a structure can be divided into three broad categories: dead loads, live loads, and environmental loads. Dead loads are those that are constant in magnitude and fixed in location. Usually the major part of the dead load is the self weight of the structure. This can be calculated with good accuracy from the design configuration, dimensions of the structure, and density of the material. For buildings, floor fill, finish floors, and plastered ceilings are usually included as dead loads, and an allowance is made for suspended loads such as piping and lighting fixtures.

The dead loads calculated in the designed building are as follows

DL=W self load + W partitions plaster

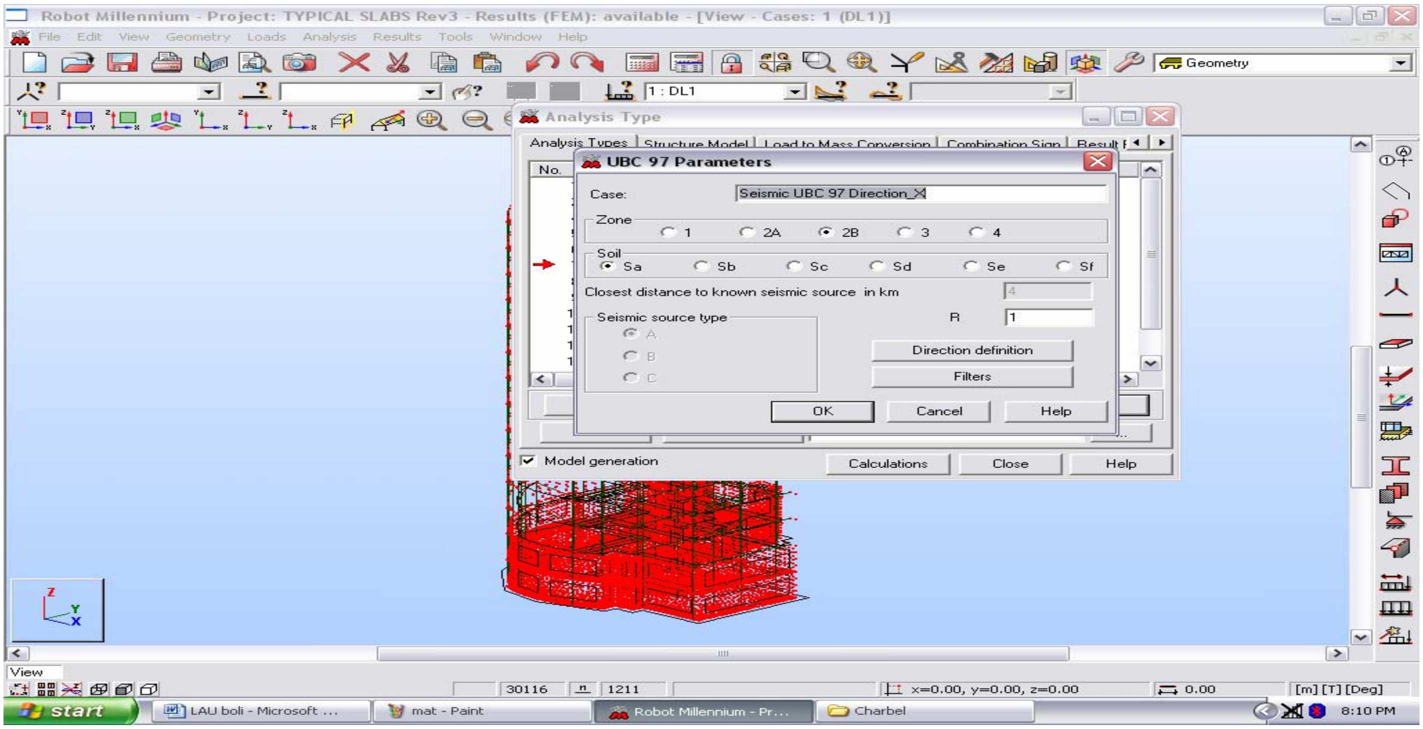
DL= W self load + 300 Kg/m2

Live loads consist chiefly of occupancy loads in buildings. They may be fully or partially in place or not present at all .In addition to these uniformly distributed loads, it is recommended that, as an alternative to the uniform load, floors be designed to support safely certain concentrated loads if these produce a greater stress.

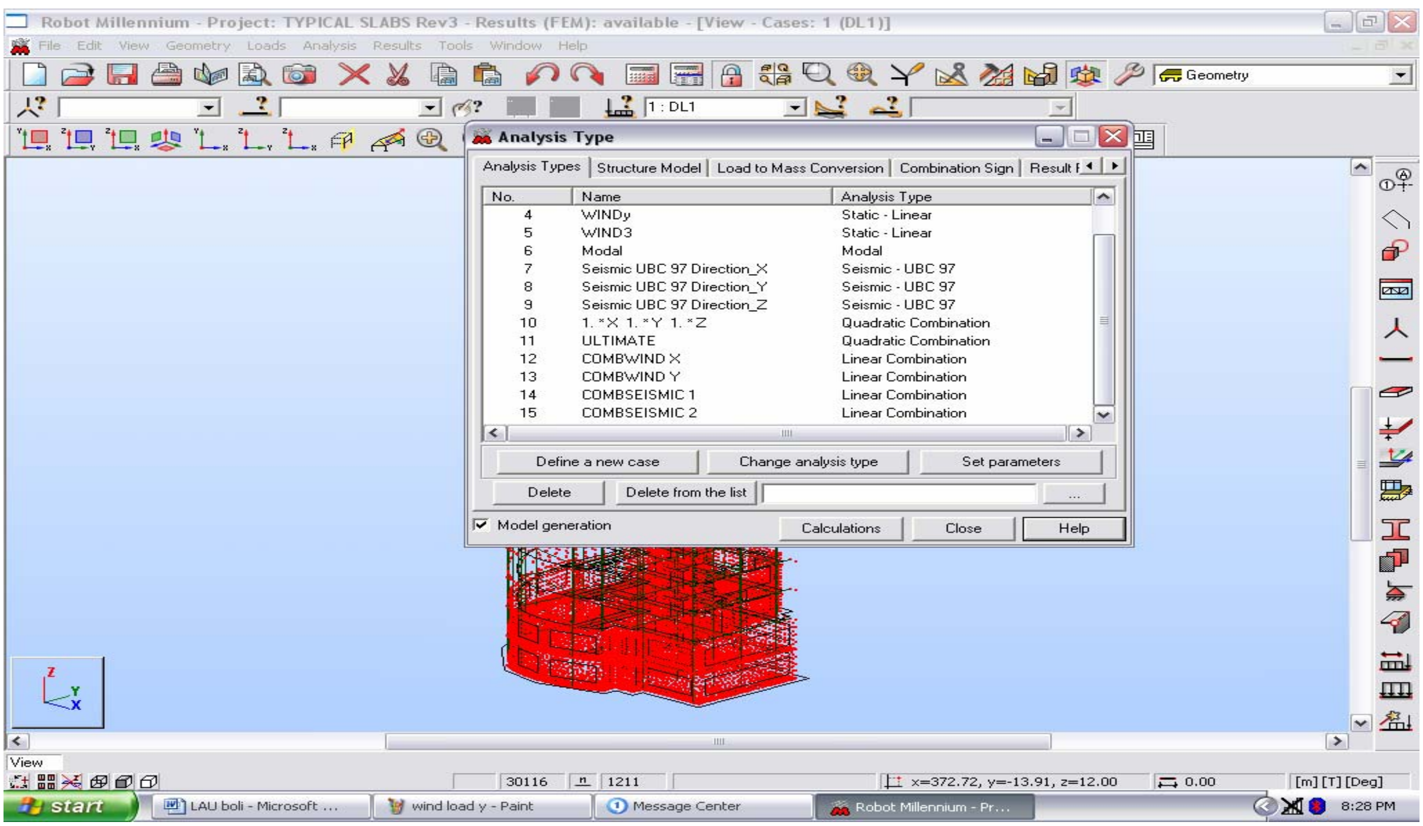
Referring to the UBC 97 code we find the live loads for different occupancies .For garages the live load is 250 kg/m2. So the assigned live loads for all the basements and the lower ground floors are 250 kg/m2.For the other floors that serves as office floors the live load referring to the code is 485 kg/m2 (used 500 kg/m2). Environmental loads consist mainly of snow loads, wind pressure and suction, earthquake loads (i.e. inertia forces caused by earthquake motion),soil pressures on subsurface portions of structures, loads from possible pounding of rainwater on flat surfaces, and forces caused by temperature differentials. Like live loads environmental loads at any given time are uncertain both in magnitude and distribution. Lateral loads are divided into two main parts: wind loads and seismic loads. Most building codes specify design wind pressures per square foot of vertical wall surface. Depending upon locality, these equivalent static forces vary from about 10 to 50psf. According to the UBC 97 code, the wind pressure in the Mediterranean over the Lebanese coast is 100 Kg/m^2.

Seismic forces maybe found for a particular structure by elastic or inelastic dynamic analysis, considering expected ground acceleration and the mass, stiffness, and damping characteristics of the construction. However, often the design is based on equivalent static calculated from provisions. The base shear is found by considering such factors as locations, type of structure and its occupancy, total dead loads and the particular soil condition. The total lateral force is distributed to floors over the entire height of the structure in such a way as to approximate the distribution of forces obtained from a dynamic analysis. So after describing all the kinds of loads applied to the structure we can summarize them in the following way: the gravity loads are the dead loads and live loads, while the lateral loads are the wind loads and seismic loads.

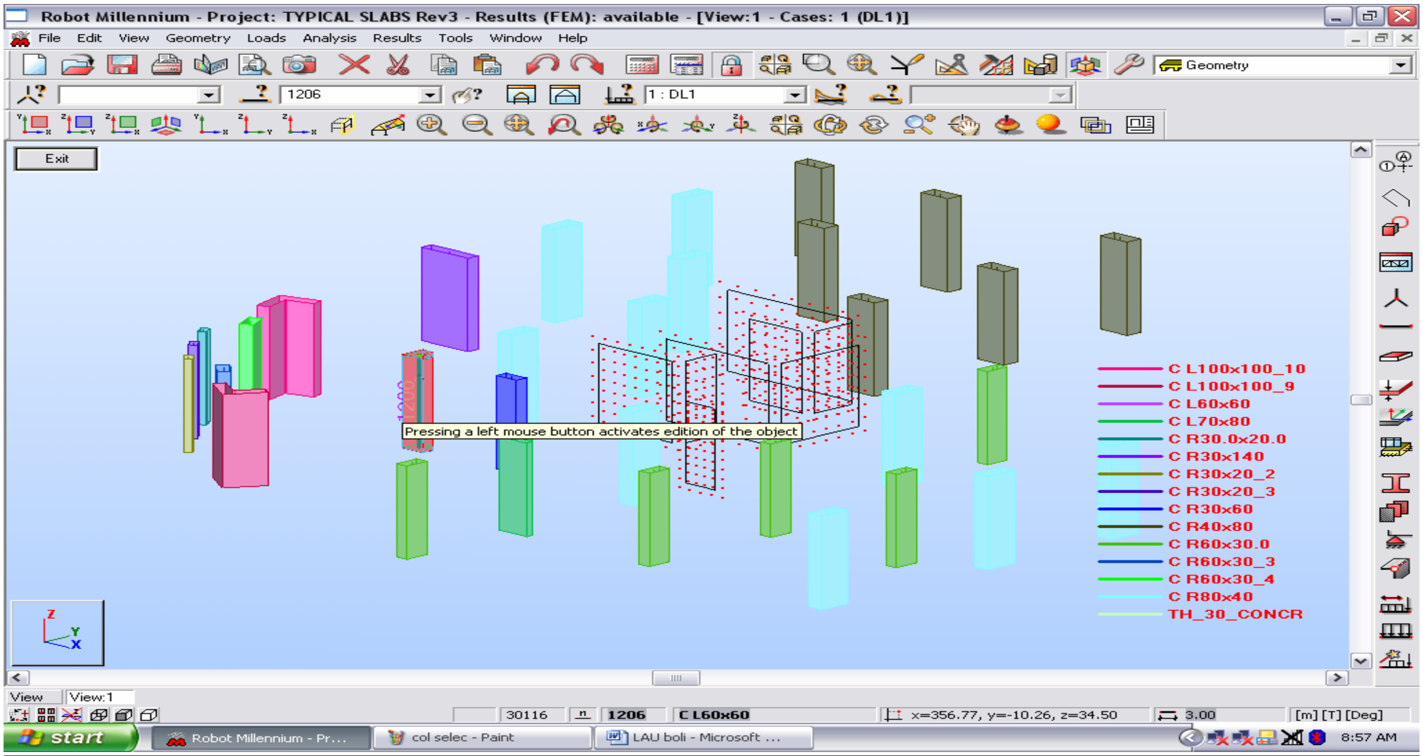
The lateral loads are applied accordingly, the wind pressure on all the walls where wind hit and then pass through (100 kg/m2), and the seismic forces are applied on the whole building according to UBC 97. So in this way the loads were calculated and assigned on slabs, walls, and on the whole building and they where distributed uniformly over the whole applied areas. The following are some 3D pictures that show how the loads are distributed on different areas. Now that the model is complete and all the loads are assigned according to four defined load cases stated above in details and showing the basis of analysis for each load by referring to specific code, the model is ready to be designed. We run the program no error shows, we go to the design icon and ask the program to design a concrete frame section. But we have to choose the load combinations we want the program to design upon. In our model 3 main load combinations were chosen to design upon.

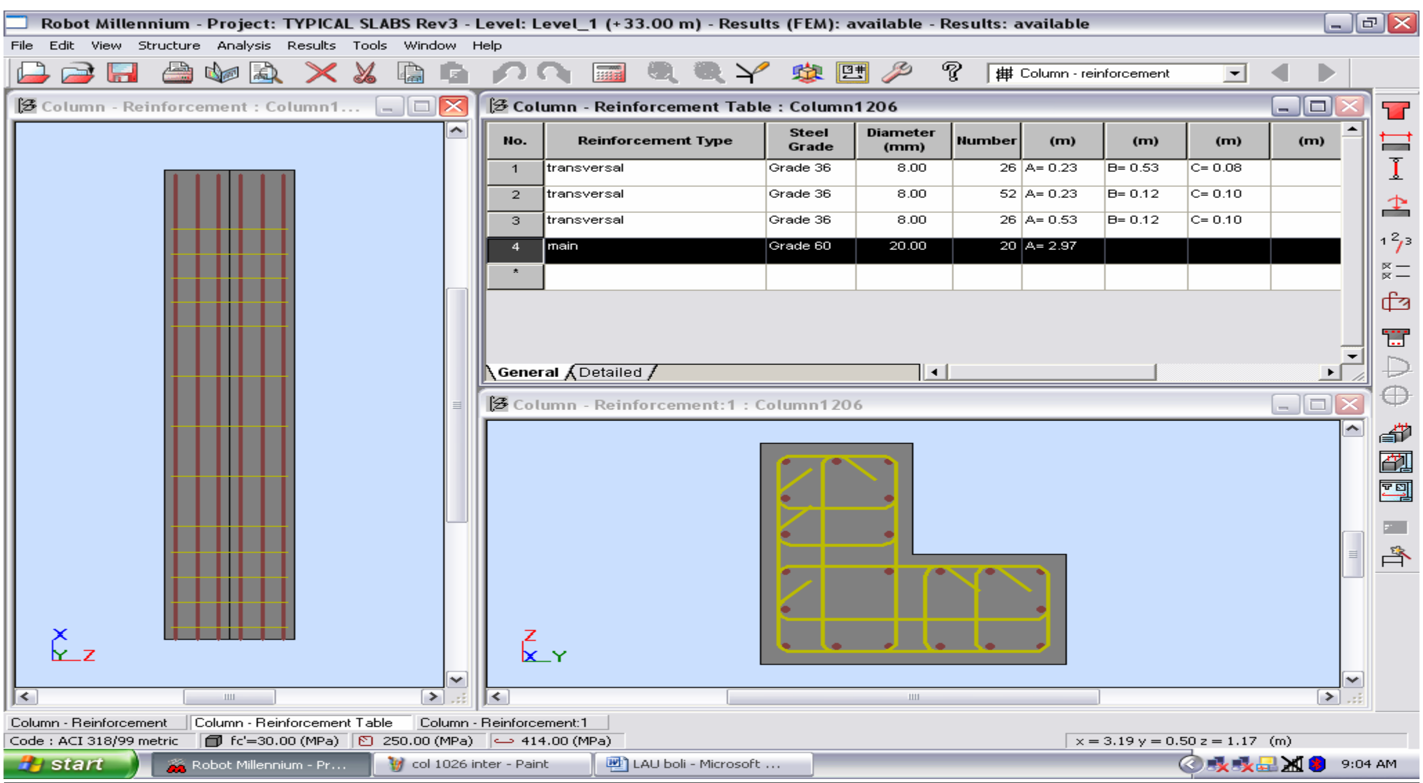


LOAD COMBINATIONS



COLUMN DESIGN





TYPICAL ROBOT CALCULATION NOTES

1 Level:

- Name : Level_1 (+33.00 m)
- Reference level : 33.00 (m)
- Fire rating : 0 (h)
- Environment class : mild

2 Column: Column1206 **Number: 1**

2.1 Material properties:

- Concrete : fc' = 30.00 (MPa)
  Unit weight : 2447.32 (kG/m3)
- Longitudinal reinforcement : Grade 60 fy = 414.00 (MPa)
- Transversal reinforcement : Grade 36 fy = 250.00 (MPa)

2.2 Geometry:

2.2.1 L 60.00 x 60.00 (cm)
Cut 30.00 x 30.00 (cm)
2.2.2 Height: L = 3.00 (m)
2.2.3 Slab thickness = 0.30 (m)
2.2.4 Beam height = 0.30 (m)
2.2.5 Cover = 3.00 (cm)

2.3 Calculation options:

- Calculations according to : ACI 318/99 metric
- Precast column : no
- Pre-design : no
- Slenderness taken into account : yes
- Ties :to slab
- Sway structure
- Story number (counted from top to bottom) : n = 1

2.4 Loads:

Case	Nature	Group	γf	N (T)	Myu (T*m)	Myl (T*m)	Myi (T*m)	Mzu (T*m)	Mzl (T*m)	Mzi (T*m)
ULTIMATE	design	1206	1.00	39.46	-1.01	0.89	-0.38	-4.03	-4.14	1.42
COMBWIND X	design	1206	1.00	42.59	-3.69	3.43	-1.48	-3.80	3.92	1.57
COMBWIND Y	design	1206	1.00	42.32	-1.67	1.53	-0.65	-2.22	2.52	1.01
COMBSEISMIC 1	design	1206	1.00	51.53	-8.38	10.06	-3.14	-13.20	-2.92	4.57
COMBSEISMIC 2	design	1206	1.00	26.24	1.94	-0.81	0.67	-1.55	5.04	-1.68

γf - load factor

2.5 Calculation results:

2.5.1 Slenderness analysis

Direction Y: Sway structure
Direction Z: Sway structure

	l_u (m)	$k*l_u$ (m)	k
Direction Y:	3.00	3.00	1.00
Direction Z:	3.00	3.00	1.00

$k*l_{uy}/r_y$ =18.09 Short column (slenderness not taken into account).
$k*l_{uz}/r_z$ =18.09 Short column (slenderness not taken into account).

2.5.2 ULS Analysis

Design combination: COMBSEISMIC 1
N = 51.53 (T) My = 10.06 (T*m) Mz = -13.20 (T*m)

- Eccentricity:

		e_y (cm)	e_z (cm)
static	e_0:	-25.63	19.53
total	e_{tot}:	25.65	19.53

Reinforcement - required area: A = 26.58 (cm2)
Ratio: μ = 2.33 %

2.6 Reinforcement:

Main bars (Grade 60):

- 20 ϕ20.00 l = 2.97 (m)

Transversal reinforcement (Grade 36):

stirrups: 26 ϕ8.00 l = 1.68 (m)

pins 52 ϕ8.00 l = 0.45 (m)
26 ϕ8.00 l = 0.75 (m)

3 Material survey:

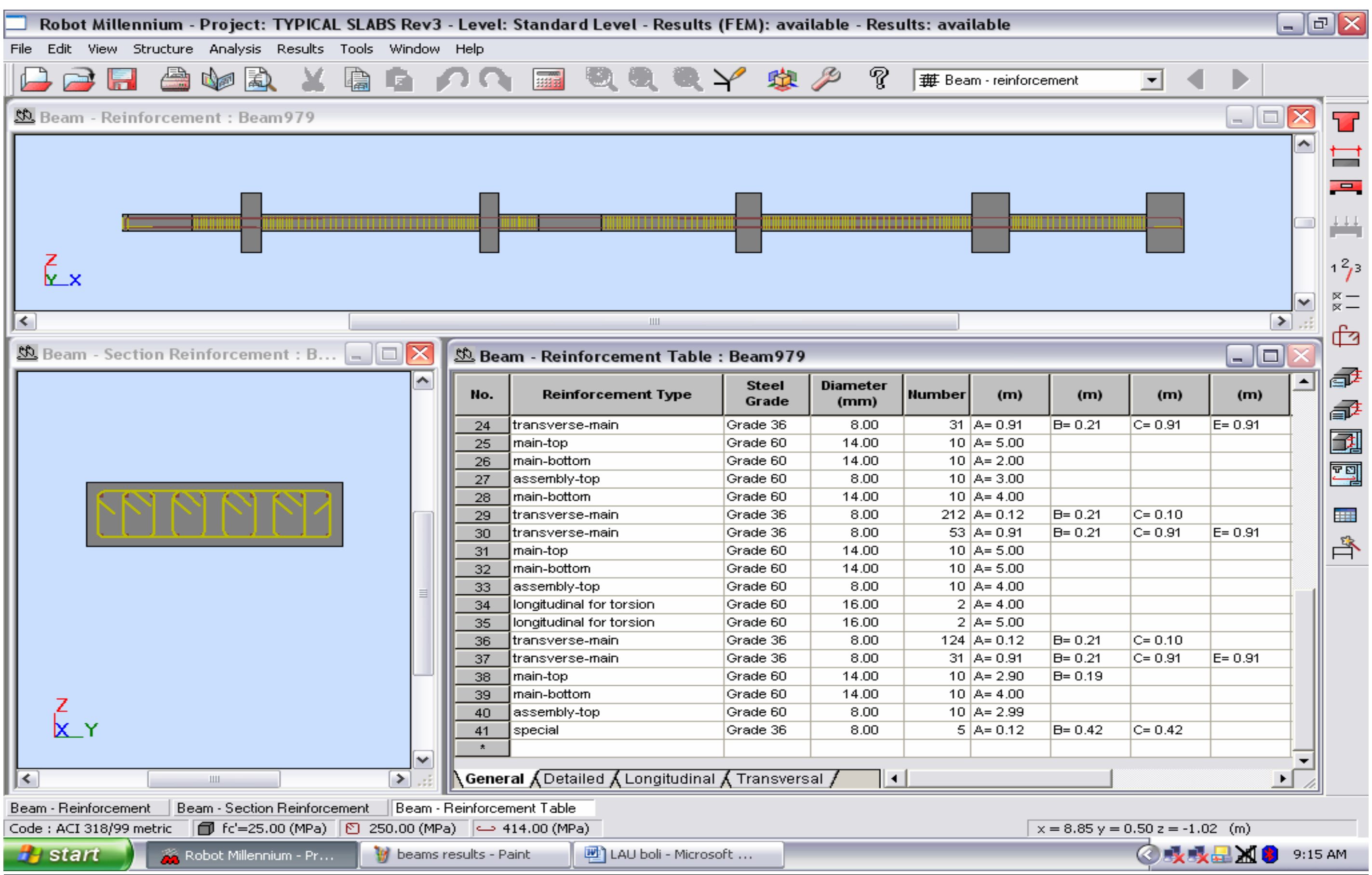
- Concrete volume = 0.73 (m3)
- Formwork = 6.48 (m2)
- Steel Grade 60
  - Total weight = 146.54 (kG)
  - Density = 201.01 (kG/m3)
  - Average diameter = 20.00 (mm)
  - Reinforcement survey:

Diameter	Length (m)	Weight (kG)	Number (No.)	Total weight (kG)
20.00	2.97	7.33	20	146.54

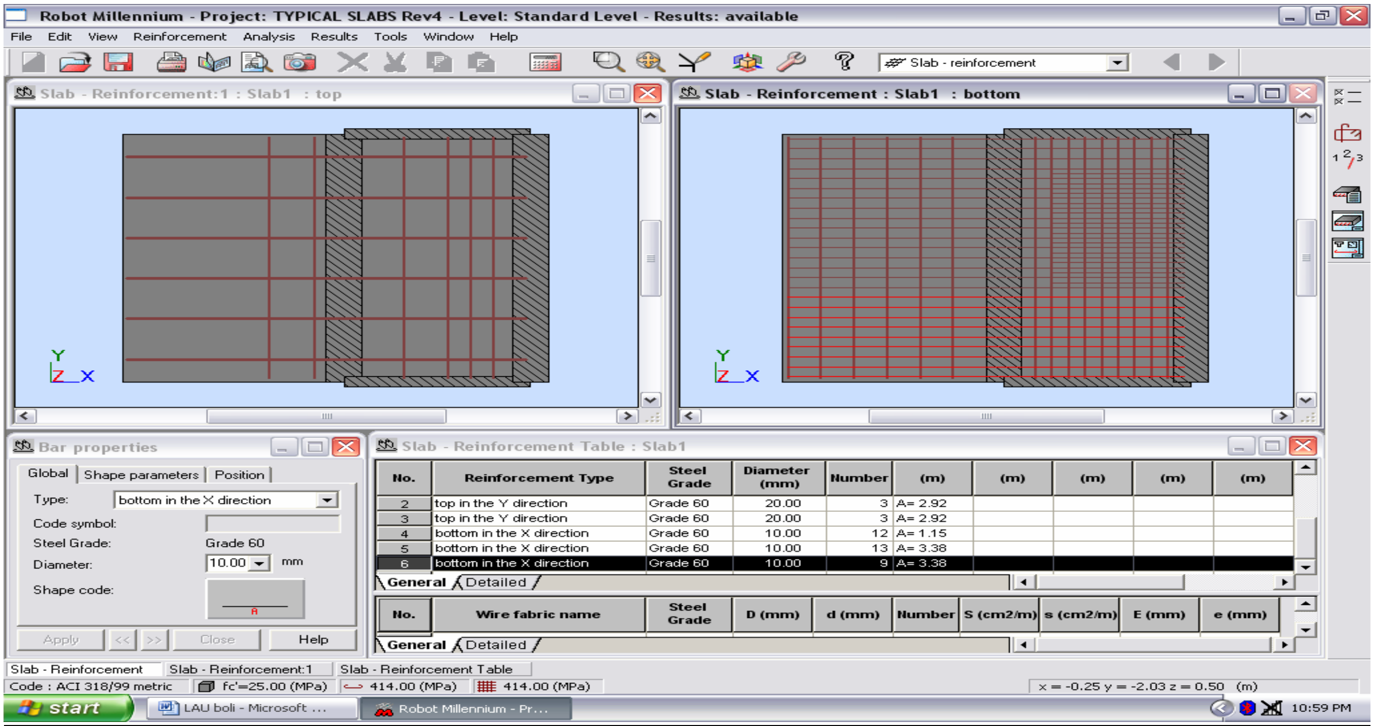
- Steel Grade 36
  - Total weight = 34.09 (kG)
  - Density = 46.76 (kG/m3)
  - Average diameter = 8.00 (mm)
  - Reinforcement survey:

Diameter	Length (m)	Weight (kG)	Number (No.)	Total weight (kG)
8.00	0.45	0.18	52	9.15
8.00	0.75	0.29	26	7.66
8.00	1.68	0.67	26	17.28

BEAM DESIGN



SHEAR WALL DESIGN



CONCLUSIONS

A complete design of a building using ROBOT was accomplished by showing the different features of the program: how to copy the maps from AutoCAD to ROBOT, and then enter the columns, beams, walls, and slabs for each floor and assign the lateral and gravity loads on the slabs and walls. The load cases assigned should be well defined before being assigned by showing all the references used to enter the needed data for defining the loads (from codes and tables).After inputting all of the above data and doing the appropriate meshing for each area, the analysis was performed, then one can start exporting some columns and beams and check if the design conforms with the design criteria or not. It is always recommended to check the results with some hand calculations.
Major lessons learned are that one can perform a full CAD design and walk through the design and make changes as would be shown and recalculate the full impact of these changes.

REFERENCES:

1. **ROBOT Millennium , Structural Analysis and Design Software**, User Manual, ISS, San Francisco, C CA 94217, USA

2. **ACI Building Code,** American Concrete Institute, , Farmington Hills, MI 48333, USA.

3. **Uniform Building Code,** International Conference of Building Officials, Whittier, CA 90601, USA.