COMPARISON OF DIFFERENT APPROACHES FOR SHEARWALL MODELLING

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Comparison Of Different Approaches For Shearwall Modelling

By

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ABSTRACT

Shear walls are the most important elements for a building. Especially in Albania as a seismic place, shear walls are very used due to the resistment of the forces coming from the earthquake. Different techniques utilizing either shell elements or combination of frame elements can be used. Modeling shearwalls is very important issue for static and dynamic analyses of building structures. This study consist in finding the most effective way of modeling shearwalls in structural analyses of building. The program used for this purpose, is the Etabs design program. It is obtained by analyzing a 14-storey vertical structure in elevation, a dual system frame + shear wall. For this case, three models of shearwall, beam with rigid arm, plates with columns and plates only are going to be compared. Referred to the satisfactorily idealized of the first model (beam with rigid arm), the two other models are going to be compared with it, in order to reflect the good behavior of shearwall element. The best model is the simplest one that still provides the required results with acceptable accuracy. As a primary basis of comparison is the displacement at the top floor of the structure and then are taken into consideration the other results obtained of the internal forces of the wall and frame element. It can be said that, based on these results, the second model (plates with column) is the appropriate one.

Keywords: shear wall, seismic, shell elements, beam with rigid arm.

Abstrakti i tezës paraqitur bordit Administrativ të Universitetit Epoka në përmbushje të kërkesave për Master Shkencor

Krahasimi i modeleve te ndryshme te mureve betonarme

Nga

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Maj 2014

ABSTRAKT

Muret beton/arme janë ndër elementët strukturorë më të rëndësishëm të një godine. Sidomos Shqipëria, si një vend sizmik, i ka përdorur gjithmonë muret b/a për ti rezistuar forcave horizontale të tërmetit. Duke shfrytëzuar si elemente shell ashtu edhe elementin frame mund, mund të përdoren teknika të ndryshme. Modelimi i mureve b/a është çështje shumë e rëndësishme për analiza statike dhe dinamike të strukturave të ndërtimit. Ky studim konsiston në përcaktimin e mënyrës më efektive të modelimit të mureve b/a, në analizat strukturore të ndërtimit. Programi i përdorur për këtë qëllim, është programi Etabs i projektimit. Është marrë në studim një strukturë vertikale 14 - katëshe e lartë, një sistem dual frame + mur b/a. Për këtë rast, janë krahasuar tre modele të murit b/a: tra me krah rigjid, pllakë me kollona dhe vetëm pllakë. Referuar modelit të parë të idealizuar e të kënaqshëm (traut me krah rigjid), të dy modelet e tjera janë krahasuar me të, për të marrë në këtë mënyrë sjelljen optimale të mureve b/a. Modeli më i mirë është ai model që siguron rezultatet e kerkuara me saktesitë e pranueshme. Si bazë kryesore në krahasim, është zhvendosja në katin më të lartë të strukturës dhe më pas krahasohen dhe rezultatet e tjera të marra nga forcat e brendshme të murit dhe të elementit frame. Mund të thuhet se, bazuar në këto rezultate, modeli i dytë (pllakë me kolona) është modeli më i përshtatshëm.

Fjalë kyçe: mure beton/arme, sizmicitet, elementë shell,tra me krah rigjid.

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Special thanks to his family for patience and continues support.

Aldi RUSI

APPROVAL SHEET

I certify that an Examination Committee has met on date of viva to conduct the final examination of **Aldi RUSI** on his MSc in Civil Engineering Term Project entitled "**Comparison of different approaches for shearwall modelling**".

Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the project is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Epoka University or other institutions.

ALDI RUSI

Date:____________

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INTRODUCTION

1.1 General

For the regions of high seismicity, the use of shearwalls in building structures to resist the lateral forces, is very common in engineering practice. Using shear walls has shown good behavior of the building from the seismic force. The shear walls as an important structural element in the resistment due to the action of the vertical and lateral forces, especially in multi-storey buildings, have occupied an important place. Given this also from the conclusions drawn from earthquakes and its effect to the buildings. Lateral loads can develop high stresses, produce sway movement or cause vibration. Therefore, it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces.

In Albania, a considerable number of buildings have reinforced concrete structural systems. The finite elements (FE) method is used as an effective tool for static and dynamic analysis of structures. The shear walls are modeled by either a composition of frame elements or a mesh of shell elements. Due to its simplicity, the equivalent frame method is especially popular in design offices for the analysis of multistorey shear wall-frame structures. Modeling shear walls with frame members instead of shell elements can reduce the total degrees of freedom, which results a significant decrease in computer running time. Modeling shearwalls with frame elements are used very extensively in building analysis due to its simplicity and the capability to use linear and nonlinear features of the existing design software. Using shell elements for shear walls was enhanced after the extensive researches done in the last decades for stable and compatible shell formulations with the three-dimensional finite element models. In general, shell elements with six degrees of freedom per node are ideal for the analysis of planar structural elements [9].

1.2 Statement of the problem

Albania as a seismic region, generally uses the shear walls in the buildings structure. In the figure 1.1 is given the map of seismicity in Albania. Albania is listed as a moderate seismic zone. The designing of this important element (shear wall) is a very important issue and is still being talked nowadays. The engineers has modeled the shear walls in different ways using the finite elements (FE) [2]. Professor Naved Anwar has made a study where he compares the 8 type of models with each other. Specifically,the research compares the shear wall with shell elements(plates with columns and beams, plates with beams, plates with columns, plates only) where beams columns are designed as a solid element, with shear walls using beam elements(single bracing, double bracing, column with rigid zone, columns with flexible zones). Different papers have used the wide column analogy for comparison between models in order to get to an conclusion. This study consist with the comparison of three models (beam with rigid arm, plates with columns, plates only) of shearwall. In the equivalent frame method, which is also known as wide column analogy, each shear wall is replaced by an satisfactory idealized frame structure consisting of a column and rigid beams located at floor levels. The column is placed at the wall's centroidal axis and assigned to have the wall's inertia and axial area. The rigid beams that join the column to the connecting beams are located at each framing level. A sample model is shown in Figure 3.1. In this method, the axial area and inertia values of rigid arms are assigned very large values compared to other frame elements. To be convinced that shearwall with boundary elements (plates with columns) is an appropriate way of designing of shearwall, it is going to be made a series of comparisons starting from a simple model (beam with rigid arms) to that of shearwall with plates only.

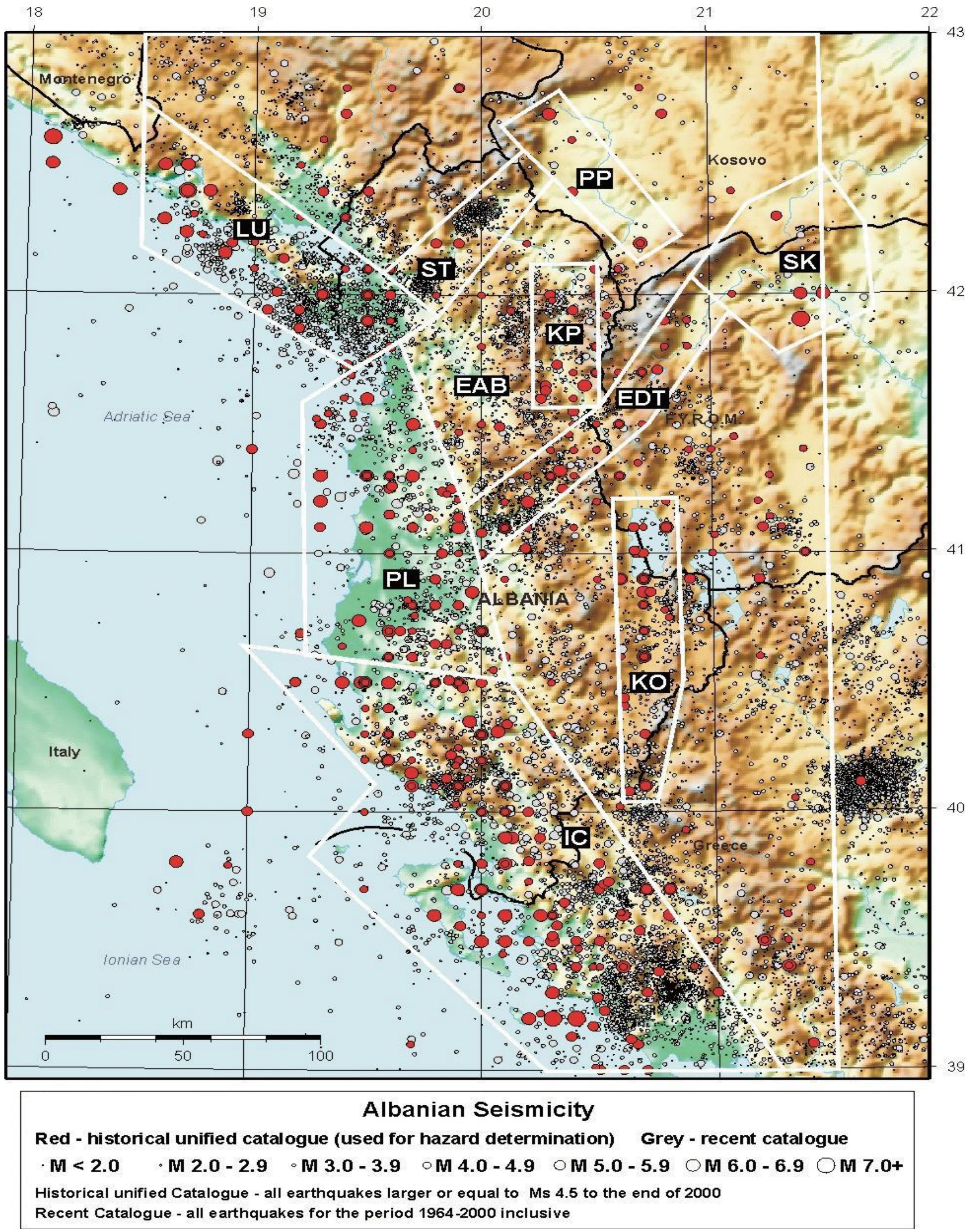


Figure 1.1 Historical earthquakes around Albania

1.3 Aim and objective

A 14 story building is taken in the study. A linear analysis is going to be used for this case. Through modeling of a shear wall by three different models, the data will be taken for each of these models and will be compared in order to understand the reaction of this vertical structure under the effect of a design spectrum and to choose the best model for designing a shear wall. In the first model the shear wall is designed as a beam with rigid arm, the second model deals with a shear wall with columns, the third one is a shear wall only. Then through a numerical analysis, the impact of separation on small elements (mesh) of shear wall will be provided. The aim is to produce mesh able geometry properly representing the analyzed problem. The 14 story building is going to pass the conditioned that Eurocode asks for the period and displacement of the building. After that from the result of stresses and forces at the base, will be made the comparison of the data that will be generated for each case and the results will be presented in tabular or graphical view, in order to show some valuable conclusions from this study.

1.4 Scope of project

The data and key parameters (extracted from Etbas) are going to be analyzed and compared. They are listed below.

- **a)** The natural period of vibrations;
- **b)** Displacement at the top of the structure;
- **c)** Respective drifts;
- **d)** Internal forces (Fx, My) of shear wall;
- **e)** Vertical forces at the base
- **f)** Stresses at the base.

1.5 Organization of the thesis

This project is organized in five chapters, the first chapter was written about introduction and scope of this issue and following chapter one, chapter two was purposed as literature review about shear walls and reinforcement in shear walls. The third chapter deals with the gathering and then the input of the data in the Etabs program. The fourth-chapter was the modeling of a shear wall by three different models and understand the reaction of this vertical structure under the effect of a design spectrum. The chapter five deals with the conclusions and recommendation.

Chapter 2

LITERATURE REVIEW

2.1 General

A shear wall is a wall composed of braced panels (also known as shear panels) to counter the effects of lateral load acting on a structure. Shear walls are vertical elements of the horizontal force resisting structure. A propped shear wall is a unique steel and concrete bracing system for retrofit seismic strengthening of existing buildings that combine friction damping with the best aspects of steel braces and concrete shear walls. This system creates a high performance lateral bracing system that is less expensive and less architecturally intrusive than either steel braced frames or concrete shear walls acting alone [21].The way in how to distinguish a shear wall element from the column element, would be in their dimensions. Eurocode specify that if one dimension (of the cross section) is more than four times of the other dimension, it is considered as a shear wall.

Wind and seismic loads are the most common loads braced wall lines are designed to counteract. It is noticed that in the absence of this structural element, in the building are shown more damages and further in the presence of this structural element the damages have been smaller. In this case it is seen that the damages have appeared from the establishment of stirrups, mainly in the spaces between them. An effective reinforcement of a shear wall would bring a very good seismic performance of the building to the earthquake [20]. In conclusion, we state that shear wall is a key element in the designing of buildings in seismic places where Albania is also included.

This type of construction has been practiced since the 1960s in urban regions for medium- to high-rise buildings (4 to 35 stories high). Shear wall buildings are usually regular in plan and in elevation [12]

However, in some buildings, lower floors are used for commercial purposes and the buildings are characterized with larger plan dimensions at those floors.
Shear walls are the main vertical structural elements with a dual role of resisting both the gravity and lateral loads. Wall thickness varies from 140 mm to 500 mm, depending on the number of stories, thermal insulation requirements. [12].
In general, these walls are continuous throughout the building height; however, some walls are discontinued at the street front or basement level to allow for commercial or parking spaces. Usually the wall layout is symmetrical with respect to at least one axis of symmetry in the plan.

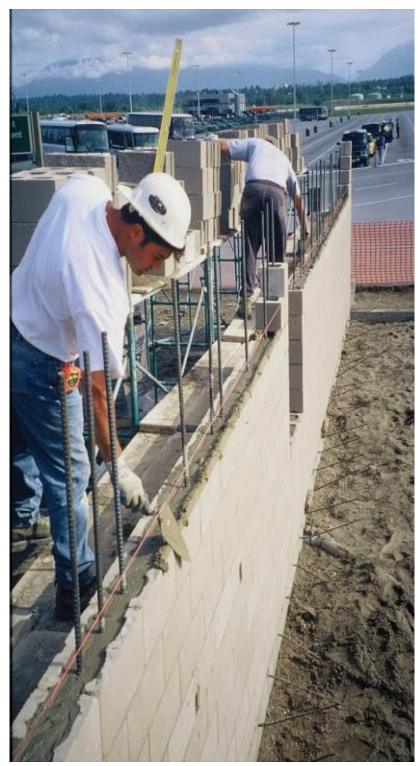


Figure 2.1 Typical shear wall buildings [3]

2.2 The effect of the earthquake in shear wall buildings

According to earthquake performance, buildings using shear wall are considered to be earthquake-resistant. Several reports indicate their good behavior in past earthquakes. On March 3, 1985, a magnitude 7.8 earthquake hit the central zone of Chile where most of the reinforced concrete buildings were located [6].

According to the reports, damage was due to inadequate wall density in the longitudinal direction, inadequate amount and detailing of wall reinforcement, and the lack of lateral confinement in the walls and the boundary elements [10].

Figure 2.2 March 3,1985 earthquake, Viña del Mar WHE Report 4, Chile [11]

Figure 2.3 Building collapse in 1977 Vrancea earthquake WHE Report 78, Romania [11]

Possible deficiencies that might adversely affect the seismic performance of this type of construction include: reduced wall density, soft-story mechanism, and torsion effects.

In Chile, thinner walls are used in recent years and buildings are characterized with a smaller wall density. Also, some shear walls are reduced in length at the street or basement level to accommodate a commercial or a parking space.

In Colombia, there is a tendency to use very thin walls with only one layer of reinforcement in new buildings; this can generate stability problems and cause buckling failure at the wall compression zone [11].

Additionally, the most likely locations of possible earthquake damage are the end regions of spandrel beams that generally experience large shear stresses.

2.3 Seismic factors of shear wall buildings

Indicators that can be used to characterize shear wall buildings include the stiffness or mass distribution in plan or elevation. Also, some additional quantitative parameters have been used, such as the ratio of the total building height (H) over the fundamental period (T) (H/T), story drift, P-Δ effect, top floor displacement, coupling index, redundancy index, and ductility capacity [15].

All these parameters have been derived from a modal spectral analysis or a pushover analysis. Wall density indicates the magnitude of lateral stiffness of shear wall buildings. It can be determined as a ratio of the wall area in each principal direction to the floor plan area.

In general, wall density in shear wall buildings is rather high and the walls are rather uniformly distributed in the two principal directions. As a consequence, such buildings are rather stiff, lateral displacements or drifts are limited and the damage to nonstructural elements is minimized [19].

For example: the total wall density in both directions in shear wall buildings in Kyrgyzstan is on the order of 15%, and the wall density in one direction is equal to 70–80% of the wall density in the other direction.

The typical wall density in Turkish buildings is 4% in each direction (varies between 2–6%).

In Chili, a large majority (95%) of buildings construct in the period from 1960 to 2000 have wall density in one direction larger than 1.5% with an average of 2.8%.

In Romania, the wall density is 6.6–7.2% in each direction. Some types of buildings in Romania are characterized with a single, centrally located wall in the longitudinal direction and eight walls in the transverse direction, thus resulting in a significantly smaller wall density in the longitudinal direction (1.4%) as compared to the transverse direction (4.8%).

The wall density in Colombia is 3–5%, and the wall density in one direction is equal to 70–80% of the wall density in the other direction [1].

Below is given an example of finding the wall density. In the figure 2.4 is shown a symmetric distribution of shear walls in plan. Shear wall thickness is 50cm. There are 6 spans of 6m in x directions and 3 spans of 5m in y axis. The total floor plan area is S= 374 m^2. The wall density in x, y direction will be:

x: 5mx0.5m=2.5m2

5mx0.5m=2.5m2

9mx0.5m=4.5m2

9.5m2/374m2=0.025=2.5%

y: 8mx0.5m=4m2

8mx0.5m=4m2

8m2/374m2=0.021=2.1%

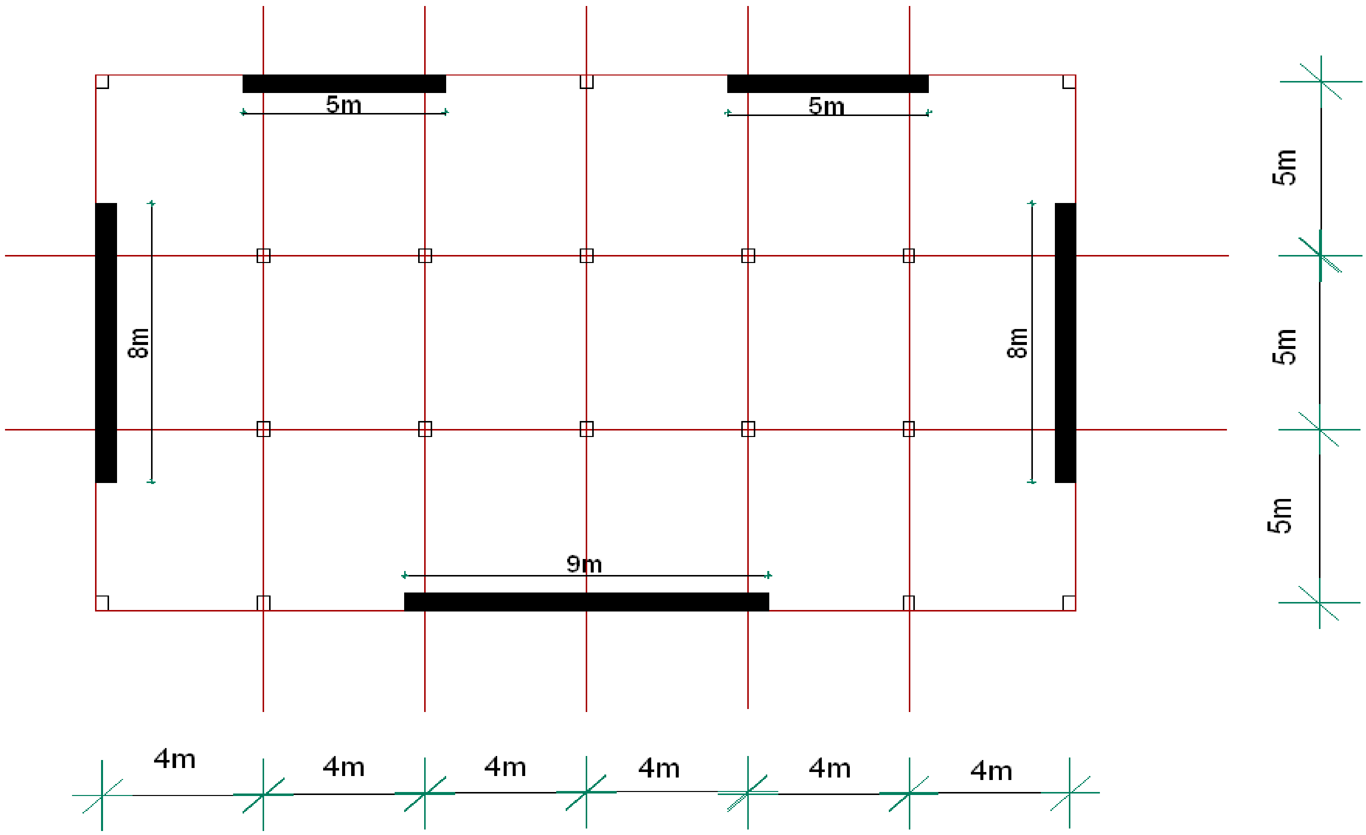


Figure 2.4 Wall density in a symmetric shear wall distribution

The ratio of the total building height over the fundamental period ($\frac{H}{T}$) also indicates the rigidity of a building. For example, buildings with $\frac{H}{T} < 40$ m/sec are considered to be flexible, whereas rigid buildings are characterized with $\frac{H}{T} > 70$m/sec [1].

From the observed structural performance in past earthquakes in Chile, the relation between $\frac{H}{T}$ and the type of damage has been developed (see Table 2.1 below).

Table 2.1 H/T vs damage relation, shear wall buildings [1]

H/T (m/sec)	Building behavior	Reported damage
> 70	Very rigid buildings	None
50 – 70		Non structural damage
40 – 50		Light structural damage
30 – 40	Very flexible building	Moderate structural damage

The building resistance in case of predominant shear behavior is indicated by the wall density per floor (d/n).

d- wall density n- number of stories in a building.

2.4 Structure of shear wall

In the designing of a shear wall element, we should take into consideration these following steps:

First step is the definition of the dimensions and its shape, according to the stiffness, building geometry, bending plan and the shear force.

Second step is the definition of foundation below the shear wall, knowing that shear wall will transmit big overturning moments to the foundation and this one will transmit it to the earth under the building. For this in the EuroCode there are specific definition that should be taken into consideration along the designing of the foundation against seismic effect.

Third step the boundary elements are very necessary for the edge of the wall. Boundary elements are the zones in the end of the cross section of the wall and it's reinforced as a column because the stress is in its maximum value. In the figure 2.5 is shown which would be the the best way in how to distribute the shear walls in plan. The first one is not a desirable because of the locations of shear walls. They must be symmetric to each other and their center of rigidity should be as near as possible to the center of mass of the structure. The opposite can be said about the second figure where shear walls are symmetric about both axes. Automatically the center of regitidy(CR) and center of mass(CM) are going to be at the same point. Shear walls are more effective if they are located in the perimeter of the building because of the twisting effect.

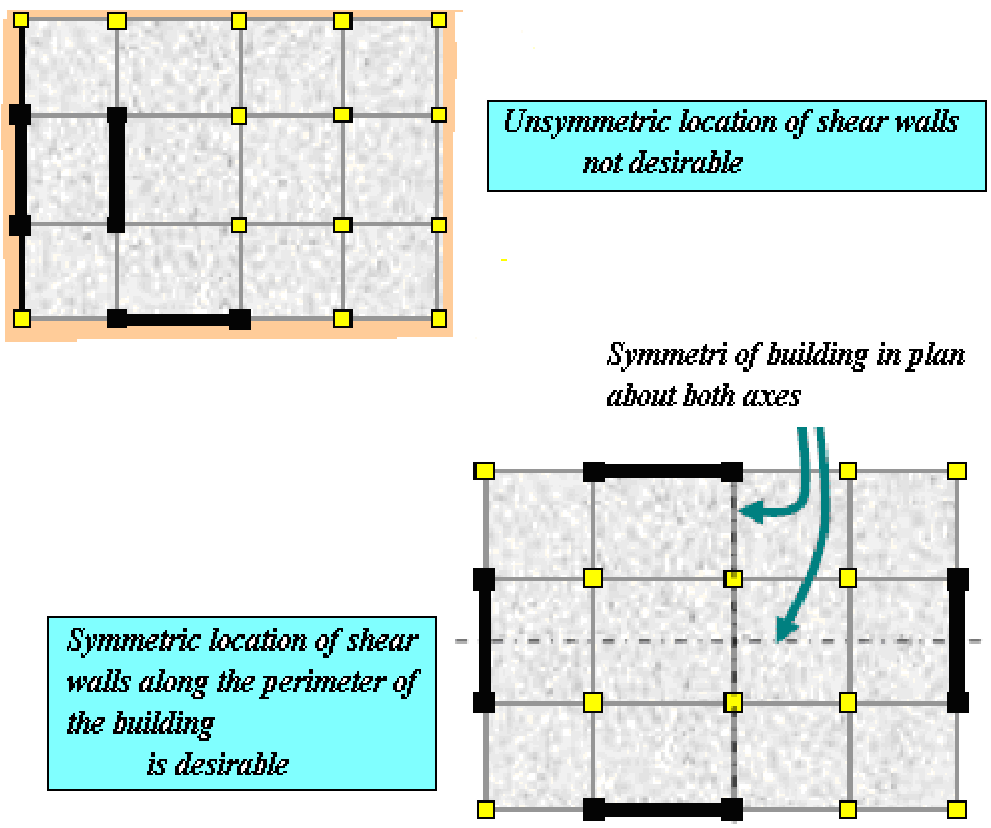


Figure 2.5 The plan distribution of shear walls [13]

Shear walls have an oblong form in their cross section where one dimension is larger than the other.
In the figure 2.6 are given some different geometries of shear walls:

1- Rectangular
2- L-shaped
3- C-shaped
4- RC hollow core (around elevators)

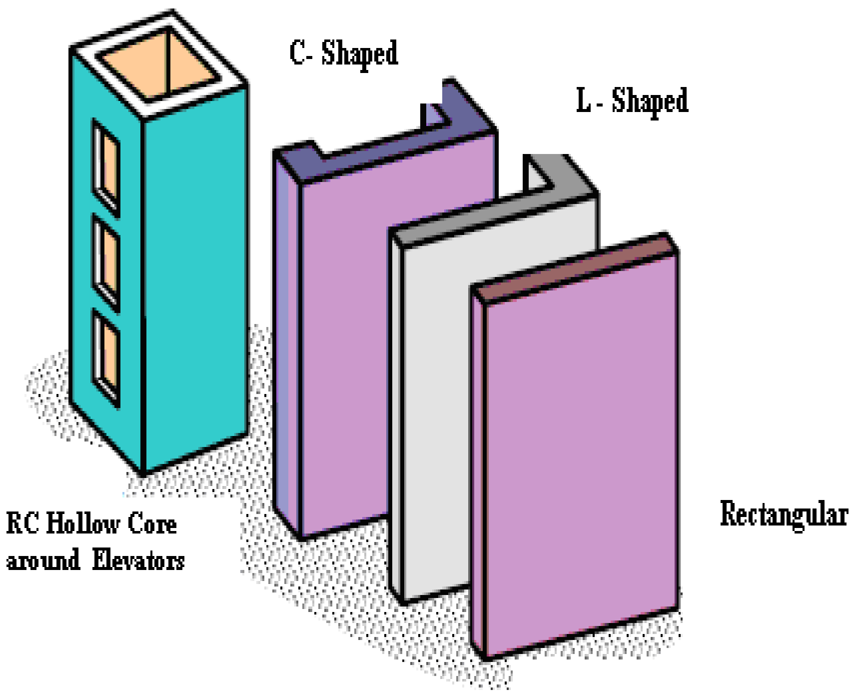


Figure 2.6 Different geometries shear walls in RC building [13]

The detailing of the reinforcement in the shear wall, is very important to the seismic performance. Steel bars are to be provided in shear walls in regularly spaced vertical and horizontal grids (figure 2.7a). The vertical and horizontal reinforcement in the wall can be placed in one or two parallel layers called curtains. The horizontal steel bars needs to be anchored at the ends of walls.

The vertical steel bars should be distributed uniformly across the wall cross section [12].

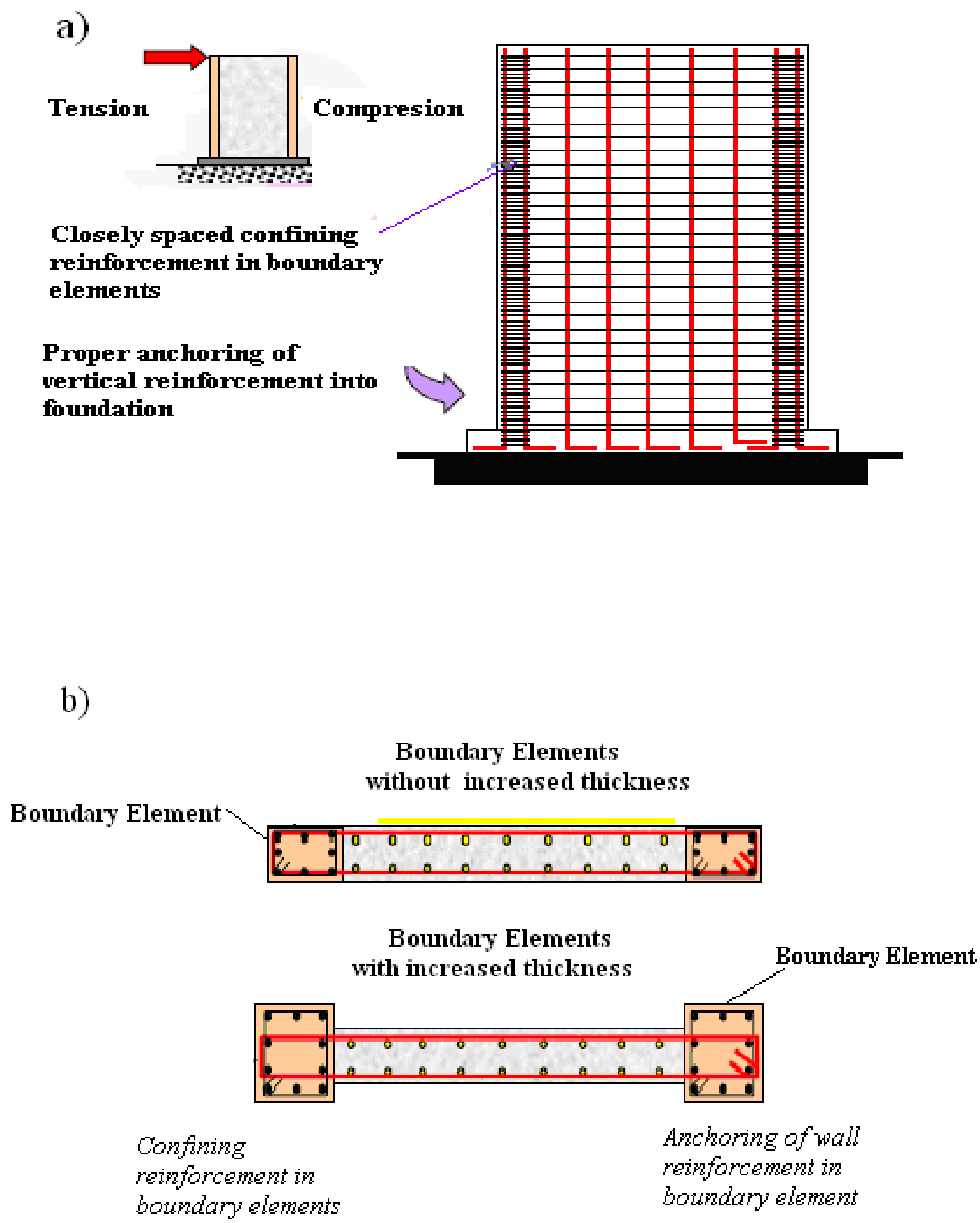


Figure 2.7 Layout of main reinforcement in shear wall [12]

The edge of shear walls, under the overturning effect caused by the lateral earthquake forces, will experience compressive and tensile stresses. So the concrete must be reinforced in order to sustain these load reversal without losing strength (figure 2.7b). The end regions of the wall with increased confinement are called boundary elements. The thickness of the boundary element (in the end zone of shear wall) is sometimes increased [17]. These RC walls (with boundary element) have higher bending strength and horizontal shear force carrying capacity and less damage occurs than walls without boundary elements.

2.5 Some types of shear wall, referring to its form in plan and Elevation

Below in the figure 2.8 are listed some type of shear walls. The first one is a closed shear wall. The second one is an opening shear wall, the third is a coupled shear wall divided by a fugue. The same happens in the fourth picture where the shear wall is closed. In the last one it is made of three closed shear walls, so it is going to be divided by two fugues. The openings can be due to the elevators or windows.

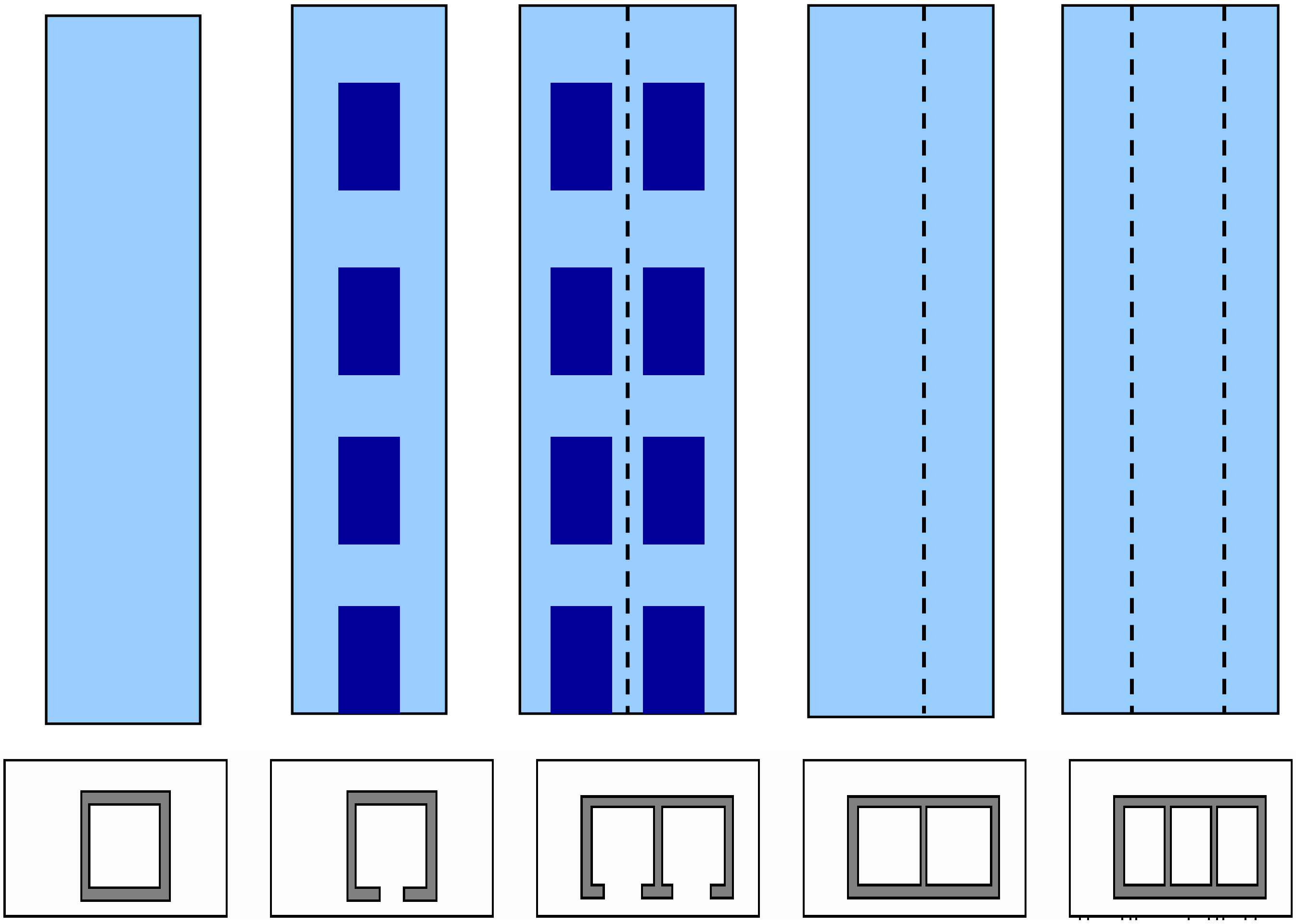


Figure 2.8 Basic type of shear wall [4]

Different building that contains this structure elements must complete the regularity conditions in plan and elevation. Below are shown some figures of buildings with reinforced concrete core. The third picture would be the best way in this kind of plans. It is divided by a fuge.

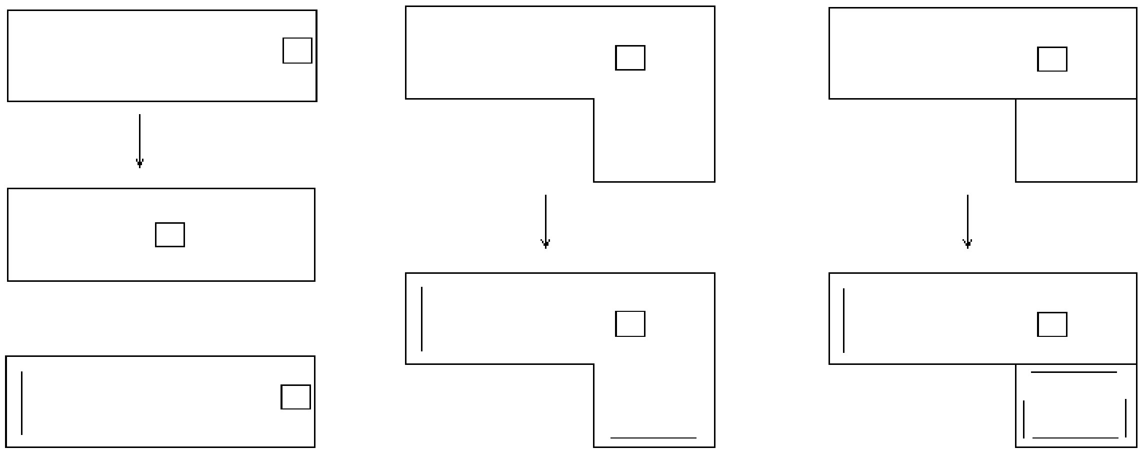


Figure 2.9 Shear walls in plan [4]

2.6 Internal forces in shell elements (according to Etabs)

The six faces of a shell element are defined as the positive 1 face, negative 1 face, positive 2 face, negative 2 face, positive 3 face and negative 3 face as shown in the figure 2.10 below. In this definition, the numbers 1, 2 and 3 correspond to the local axes of the shell element. The positive 1 face of the element is the face that is perpendicular to the 1-axis of the element whose outward normal (pointing away from the element) is in the positive 1-axis direction. The negative 1 face of the element is a face that is perpendicular to the 1-axis of the element whose outward normal (pointing away from the element) is in the negative 1-axis direction. The other faces have similar definitions. The positive 3 face is sometimes called the top of the shell element in ETABS, particularly in the output, and the negative 3 face is called the bottom of the shell element.

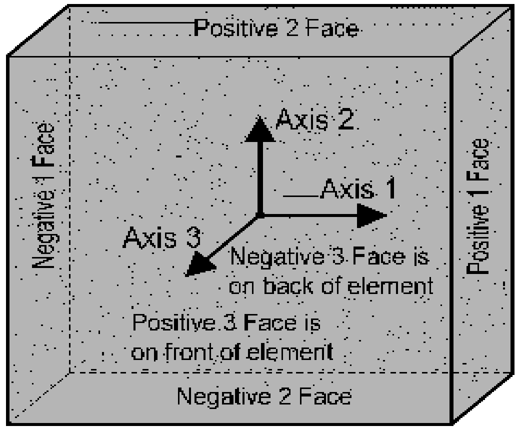


Figure 2.10 Face of shell element

The shell element internal forces, like stresses, act throughout the element. They are present at every point on the midsurface of the shell element. ETABS reports values for the shell internal forces at the element nodes. It is important to note that the internal forces are reported as forces and moments per unit of in-plane length. The basic shell element forces and moments are identified as F11, F22, F12, M11, M22, M12, V13 and V23. That would also be an F21 and M21, but F21 is always equal to F12 and M21 is always equal to M12, so it is not actually necessary to report F21 and M21. The figure 2.11 below shows internal F11 forces acting on the midsurface of a shell element. In the figure, the force distribution labeled (a) represents an actual F11 force distribution. The force distribution labeled (b) shows how ETABS calculates only the internal forces at the corner points of the shell element. These stresses could be calculated at any location on the shell element. It is chosen to calculate them only at the corner points because that is a convenient location and it keeps the amount of output to a reasonable volume.

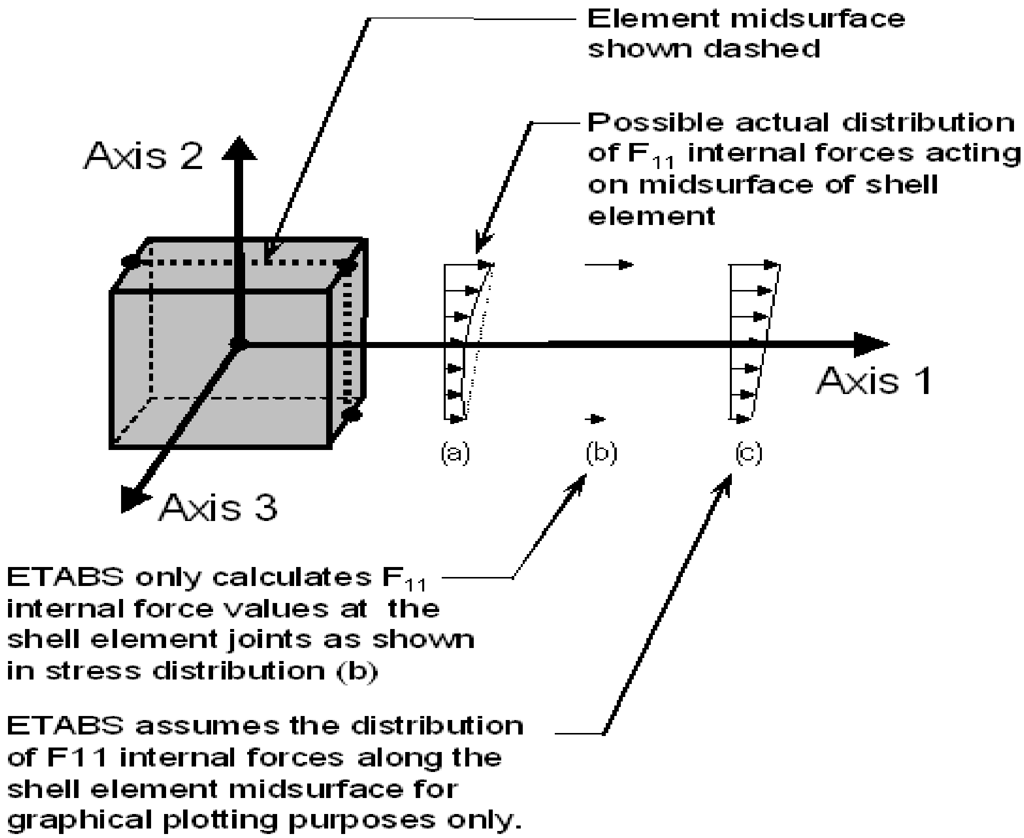


Figure 2.11 Internal forces acting on the midsurface

The force distribution labeled (c) in the figure above shows how ETABS assumes that the F11 forces vary linearly along the length of the shell element between the calculated F11 force values at the element nodes for graphical plotting purposes only. The figure 2.12 below illustrates the positive directions for shell element internal forces F11, F22, F12, V13 and V23.

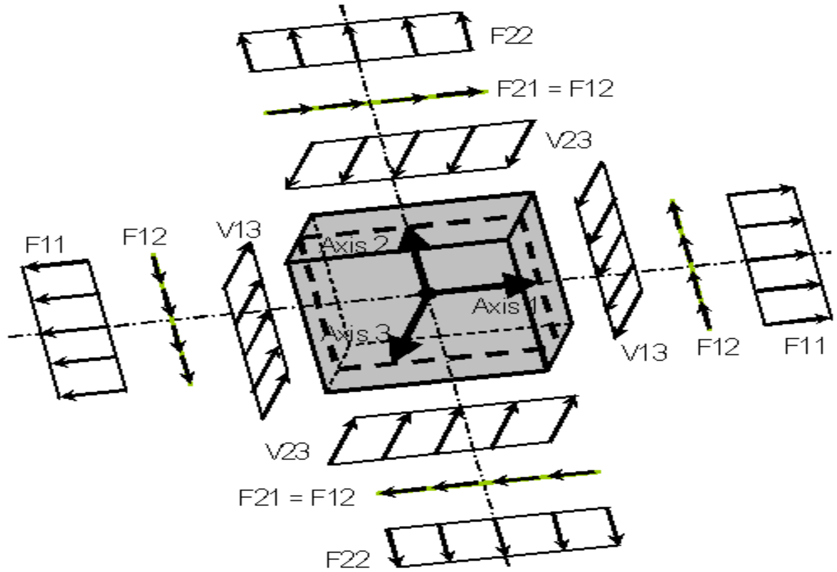


Figure 2.12 Positive directions for shell element internal forces

The figure 2.13 below illustrates the positive directions for shell element internal moments M11, M22 and M12. These shell element internal moments are moments per unit length acting on the midsurface of the shell element.

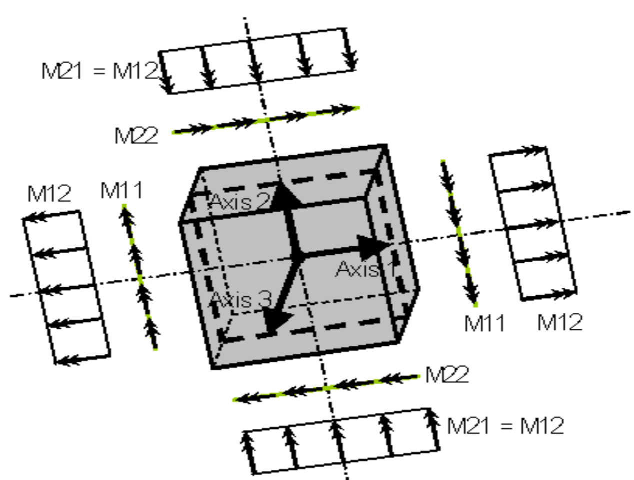


Figure 2.13 Positive directions for shell element internal moments

Shell internal stresses are reported for both the top and the bottom of the shell element. The top and bottom of the element are defined relative to the local 3-axis of the element. The positive 3-axis side of the element is considered to be the top of the element. Thus in Figure "a" above, internal stresses at the top of the element include stresses at the joints labeled A and C and internal stresses at the bottom of the element include stresses at the joints labeled B and D. The figure 2.14 below clearly illustrates the points where ETABS reports the shell element internal stress values.

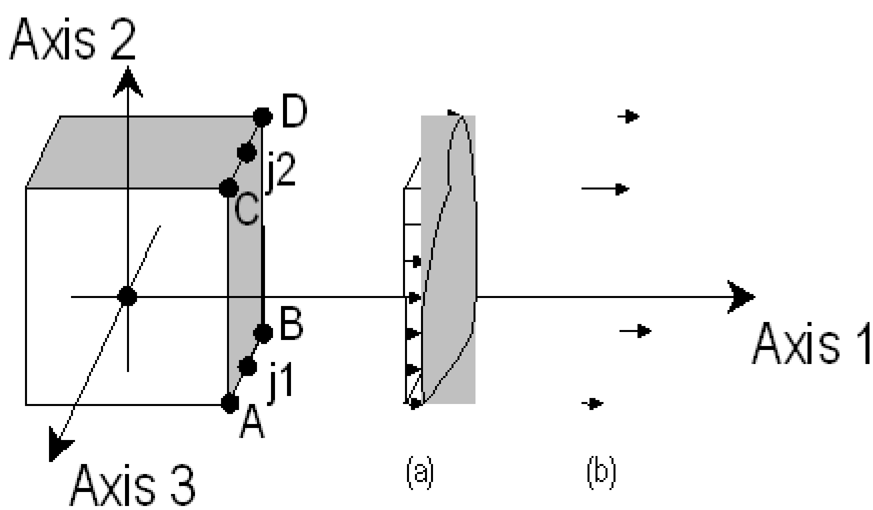


Figure 2.14 The shell element internal stress values

2.7 Reinforcement in shear walls

Shear walls are reinforced with vertical and horizontal steel bars in a uniform way and also with vertical steel bars in boundary elements. Below are given some ways of shear wall reinforcement in cross-section. Firstly the boundary elements are going to be reinforced in order to ensure:

- The needed ductility in order to reach the concrete confine in these zones;
- To ensure the bearing capacity of the element.

Then the rest of reinforcement is distributed in a uniform way. As it is shown in figure 2.15 below, in the boundary elements of the wall the S stirrups are put in order to tie the steel bars with each other. In the second case, there are used U stirrups in opposite way to each other. And in the third case the confine of the concrete is reached just by close stirrups.

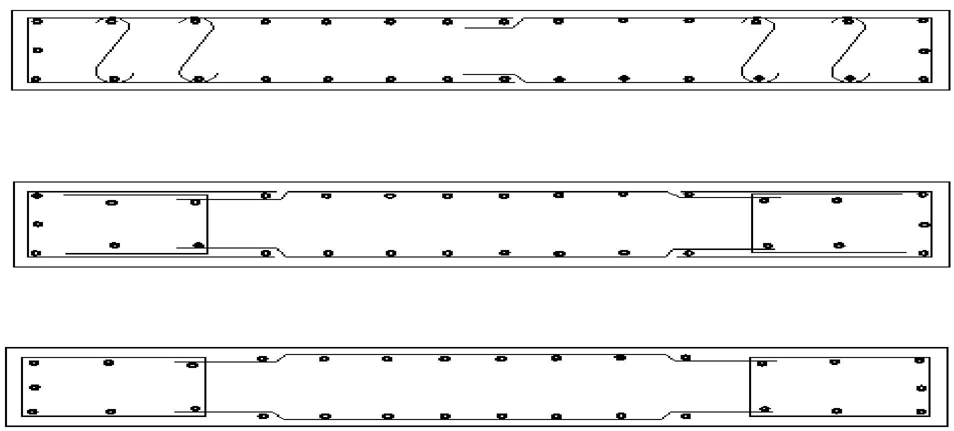


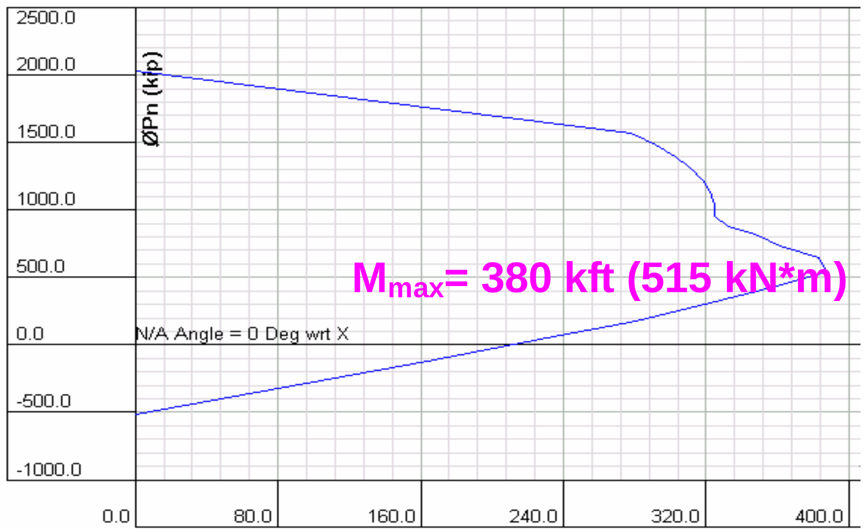
Figure 2.15 Best ways of how to reinforce a shear wall [4]

In order to give an idea two cases are examined below:

Case I – a wall who is reinforced in a uniform way,

Case II – the same wall but the boundary element is reinforced as a column.

The comparison between the 2 cases is given below by the interaction diagram where the percentage of the reinforcement (steel bars) is the same 1%. In the first case the steel bars are distributed in an uniform way, the opposite can be said about the second one where the steel bars are focused at the end region of the wall (foot the same amount of steel bars).



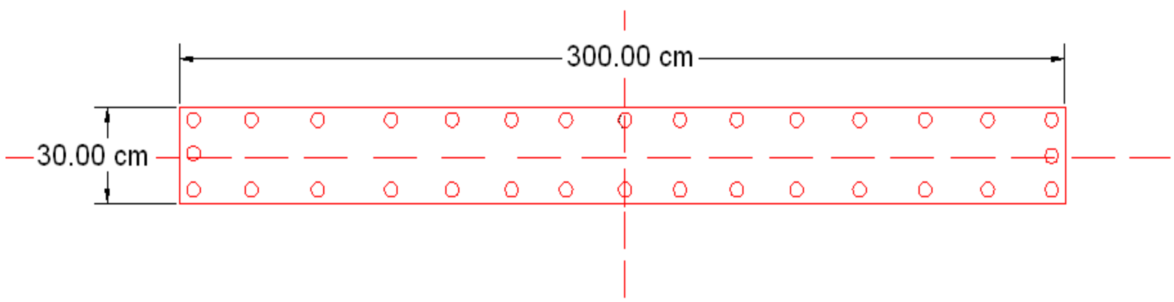
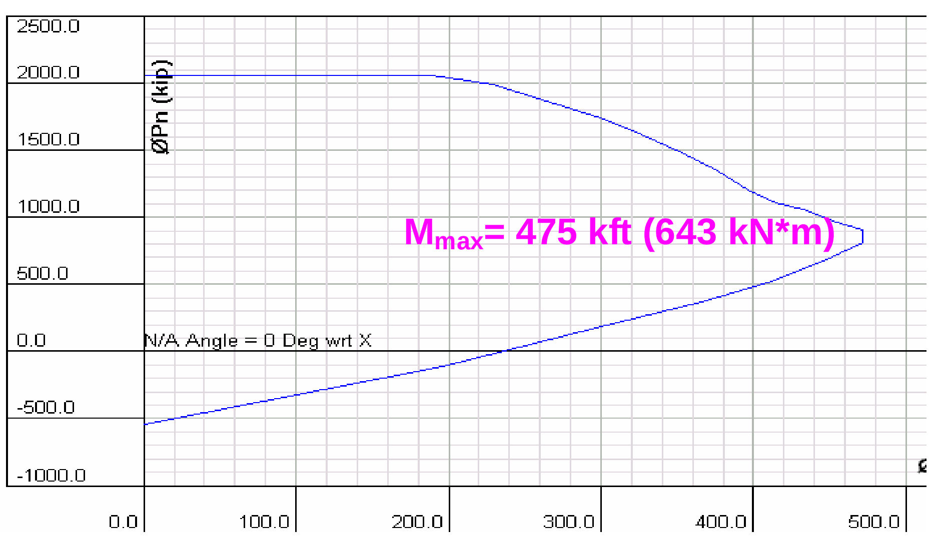


Figure 2.16 Effect of rebar layout [4]



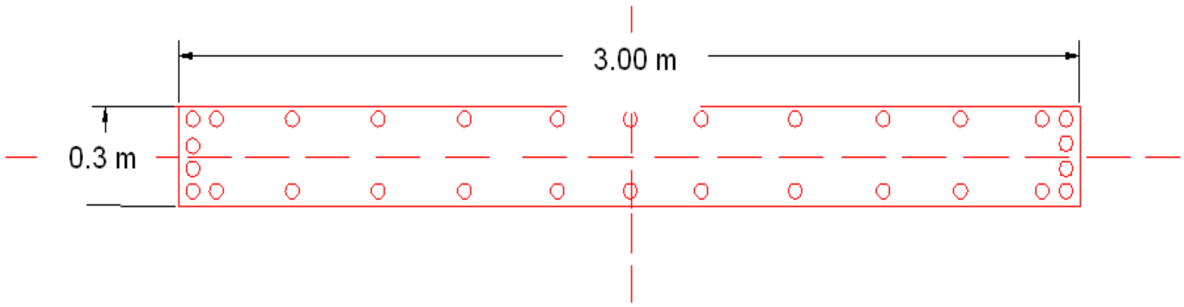


Figure 2.17 Effect of rebar layout [4]

For every point taken in both graphs, the second graph will always show bigger values of bearing capacity than the first graph. As it seems in the second case for the same wall but reinforced in a different way, its bearing capacity is 25% bigger than in the first case [4].

2.8 Relation between strength and stiffness for concrete shearwall

A method of design for earthquake is the assumption that the stiffness of the lateral load-resisting elements can be determined from the known dimensions of their cross sections, and that the strengths can then be assigned in proportion to this stiffness. It is true that the stiffness of a lateral load-resisting element made of a homogeneous material and strained only in the elastic range depends only on the gross section size of the element [16]. Additional factors influence the stiffness and strength of a reinforced concrete element. These factors include:

(a) axial load on the structure,

(b) the amount of steel and its distribution and

(c) the cracking of concrete under tension.

The CSA A23.3-94, in its provisions for the design of reinforced concrete structures against earthquake-induced loads, recommends an effective moment of inertia, $\mathbf{I_{eff}}$ equal to $0.7\mathbf{I_g}$ for columns and walls, where $\mathbf{I_g}$ is the gross moment of inertia of the section.

Paulay and Priestley (1993) have suggested an effective moment of inertia for shear walls in the range:

$$0.3\mathrm{Ig} < \mathbf{Ieff} < 0.5\mathrm{Ig}$$

The flexural stiffness of an element depends on its geometry as well as on the moment-curvature relationship for a cross-section of the element. Such relationships are therefore developed here for a number of different shear wall cross-sections. Two of the shear wall cross-sections studied are rectangular as shown in figure 2.18 and figure 2.19. Each of these two cross-sections has a length, $\mathbf{l_w}$, and thickness, $\mathbf{b_w}$ [8].

In figure 2.18 the reinforcing steel is placed in two layers and distributed uniformly across the length. The first and last sets of bars are placed at a distance ***dc*** from the nearest concrete face. The remaining bars are placed at an even spacing of ***s***. In figure 2.19 a portion of the steel is concentrated at a distance ***db***, while the remaining is evenly distributed.

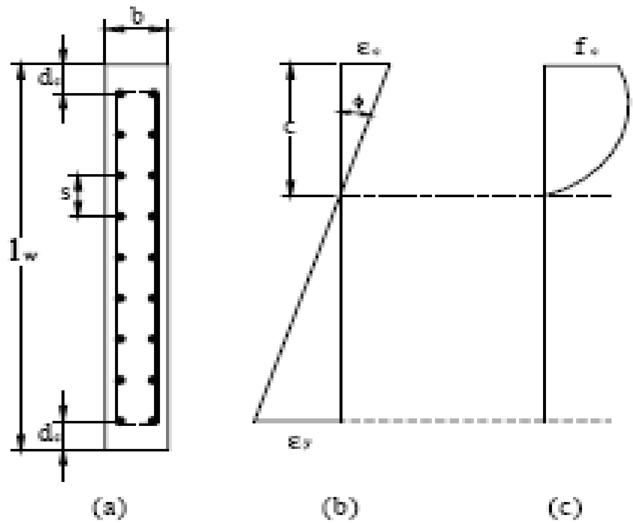


Fig. 2.18 Wall section with distributed steel [8]

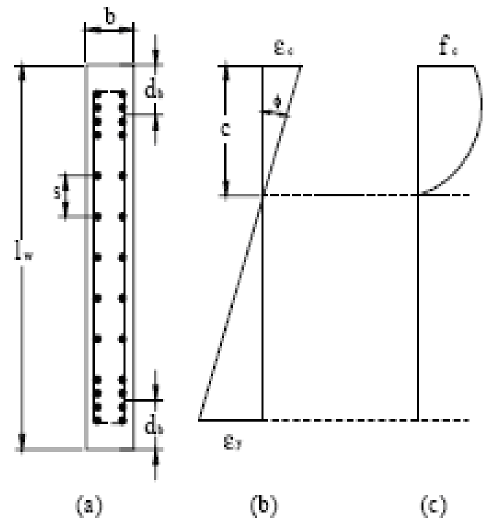


Fig. 2.19 Wall section with end concentrated steel [8]

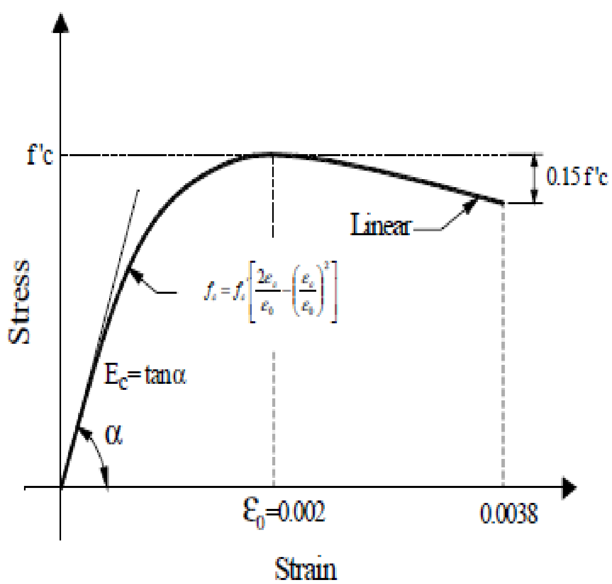


Fig. 2.20 Stress-strain relationship for concrete [8]

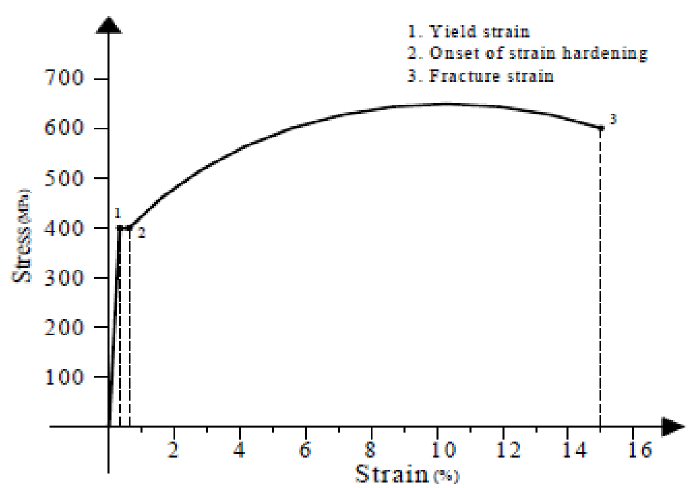
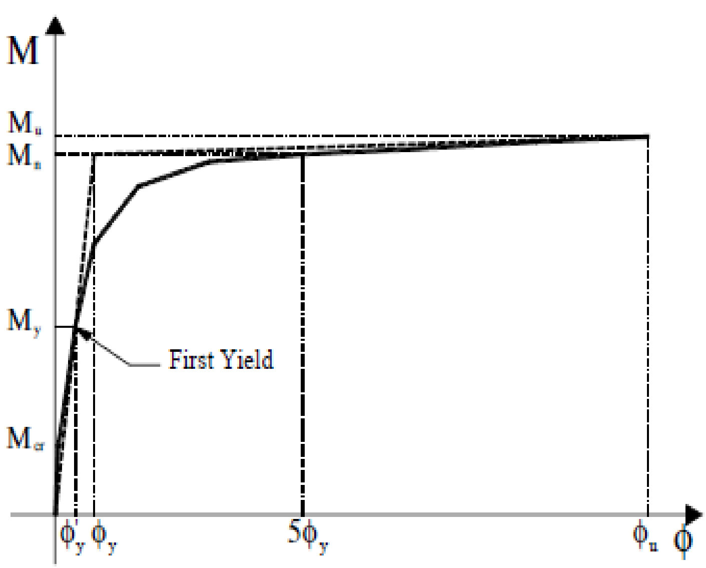


Fig. 2.21 Stress-strain steel [8]

A representative moment-curvature relationship for the cross-sections in figures 2.18, 2.19 is shown in figure 2.22. Moment-curvature relationships are derived for their full range, from zero moment to moment at which the concrete cracks in tension, to the first yield in steel, and then through progressive yielding of steel layers until failure of the cross-section caused by steel fracture or concrete crushing.

As long as the tensile strain in concrete does not exceed the tensile strain at cracking, the affected concrete carries the tensile stress, which is approximately proportional to the strain, and the slope of moment-curvature curve is equal to E_cI_t, where E_c is the modulus of elasticity of concrete and I_t is the moment of inertia of the transformed section. When the applied moment reaches a value M_{cr}, the concrete below the neutral axis is cracked and is assumed not to carry any stress. With increasing applied moment, the strains in concrete and reinforcing steel increase until the steel in the layer that is farthest from the neutral axis starts to yield in tension. The curvature of the section at first yield in Fig 2.23 is denoted by Φ'_y and the corresponding moment by M_y according to the Fig 2.22.



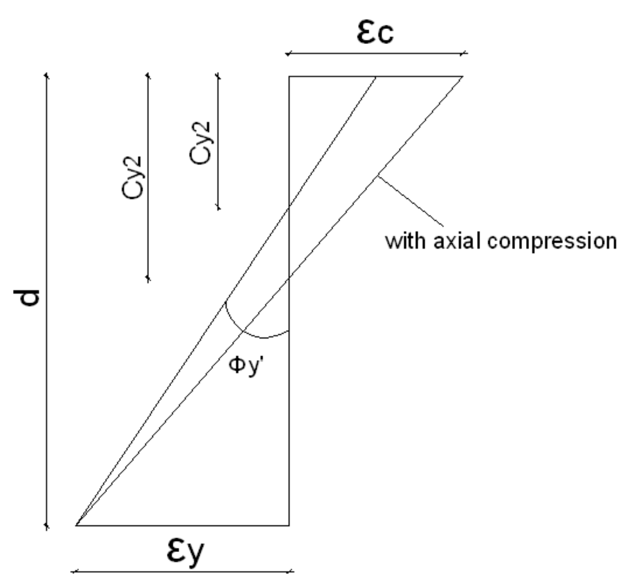


Fig.2.22 Moment-curvature relationship for a rectangular wall [8] **Fig 2.23** First yield curvature[13]

The first branch of the curve is obtained by drawing a straight line from the origin passing through the point (My, φy) and terminating at point (Mn, φy)

where Mn is the nominal flexural strength and φy is the yield curvature of section. A number of alternative methods have been proposed for defining the point (Mn, φy). Point (Mn, φy) is selected so that a horizontal straight line through (Mn, φy) intersects the moment-curvature curve at 5 φ y. Thus

$$\varphi_y = \varphi'_y \frac{M_n}{M_y}$$

The yield curvature is represented in the following dimensionless format

$$K_1 = \varphi_y \frac{l_w}{\varepsilon_y}$$

The variation of K1 with the steel ratio and axial load is presented in figures 2.24 (**a** and **b**) for rectangular walls with distributed and end concentrated steel, respectively. It is observed that the dimensionless yield curvature K1 is comparatively insensitive to the axial load. The curvature does vary with the steel ratio, increasing with an increase in that ratio. However, the variation is not very large. If the minimum steel ratio of 0.25% is excluded, the yield curvature for a wall with distributed reinforcement can be expressed as

$$\varphi_y l_w = 2.1\varepsilon_y \pm 15\%$$

For a wall with some of the steel concentrated at ends and the rest uniformly distributed, yield curvature can be expressed as

$$\varphi_y l_w = 1.85\varepsilon_y \pm 10\%$$

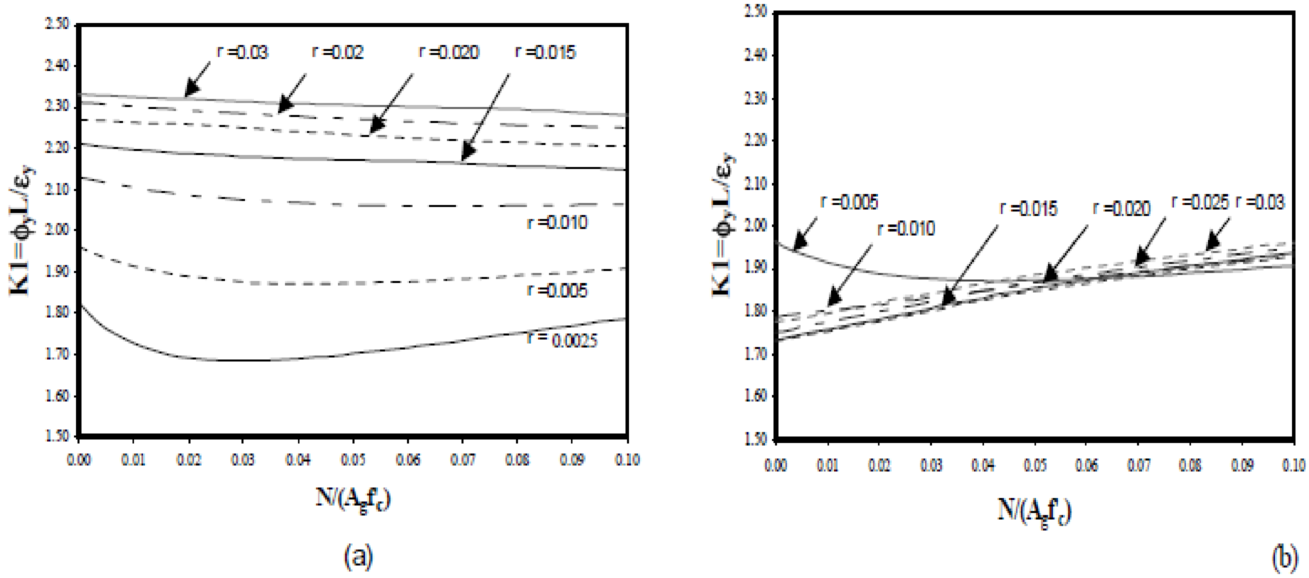


Fig.2.24 Variation of yield curvature of a rectangular wall with axial load and steel ratio **(a)** distributed reinforcement **(b)** end concentrated reinforcement [8]

The effective flexural rigidity is thus given by

$$E_c I_{eff} = \frac{M_y}{\varphi'_y} = \frac{M_n}{\varphi_y}$$

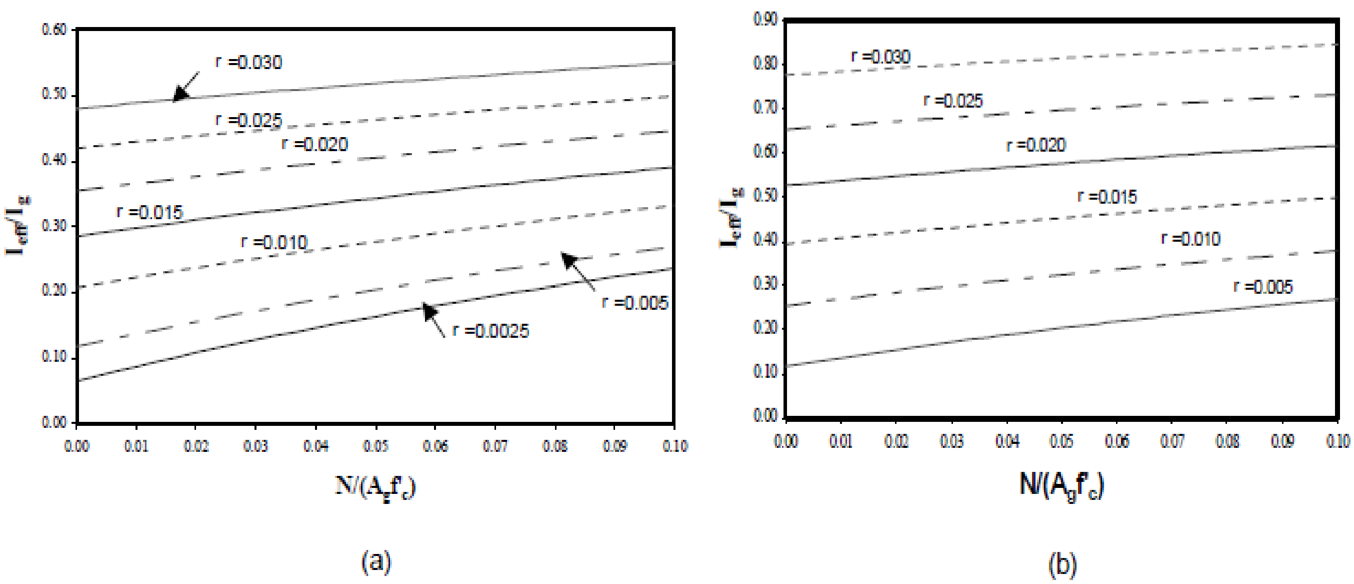


Figure 2.25 Ratio of effective moment of inertia to gross moment of inertia of a rectangular wall **(a)** distributed reinforcement **(b)** end concentrated reinforcement [8]

The effective flexural rigidity depends on both the axial load ratio $N/f\,cAg$ and the longitudinal steel ratio ρ. The variation of the ratio $Ieff/Ig$, where $I_g=bl_{w3}/12$ is the gross moment of inertia, with variation in the axial load and longitudinal steel ratio is presented in figures 2.25 (**a** and **b**) for distributed and end concentrated steel, respectively. For distributed steel, $Ieff/Ig$ varies from 0.07 to 0.5 as the steel ratio varies from 0.25% to 3%. The ratio $Ieff/Ig$ also varies with the axial load, but the variation is not very significant. For shear walls with a part of the steel concentrated at the ends, the ratio $Ieff/Ig$ varies from 0.12 to 0.85.

For a cantilever wall, the yield deflection is given by

$$\delta_y = \left(\frac{K_1 \varepsilon_y}{l_w}\right) \frac{h_e^{\,2}}{3}$$

where he is the effective wall height, which depends on the distribution of lateral load across the height. For a single-storey building with lateral load applied to the roof, he would be equal to the total wall height, hw.
The formula above implies that it is not necessary to know the wall strength to calculate its yield displacement; knowledge of wall length and height and steel strain at yield is sufficient [8].

Chapter 3

METHODOLOGY

3.1 General

In order to resist the horizontal forces, shear walls as structural elements, are widely used by engineers. Nowadays the 3D modeling is widespread and its analysis by using finite elements method with shell elements. Shearwall modeling requires a mesh division in order to get realistic behavior. The advantage of using shell elements is the ability to model very long, interacting and complex shearwalls within the three dimensional model. As it is mentioned before shear wall can play a significant role to reduce the earthquake force.

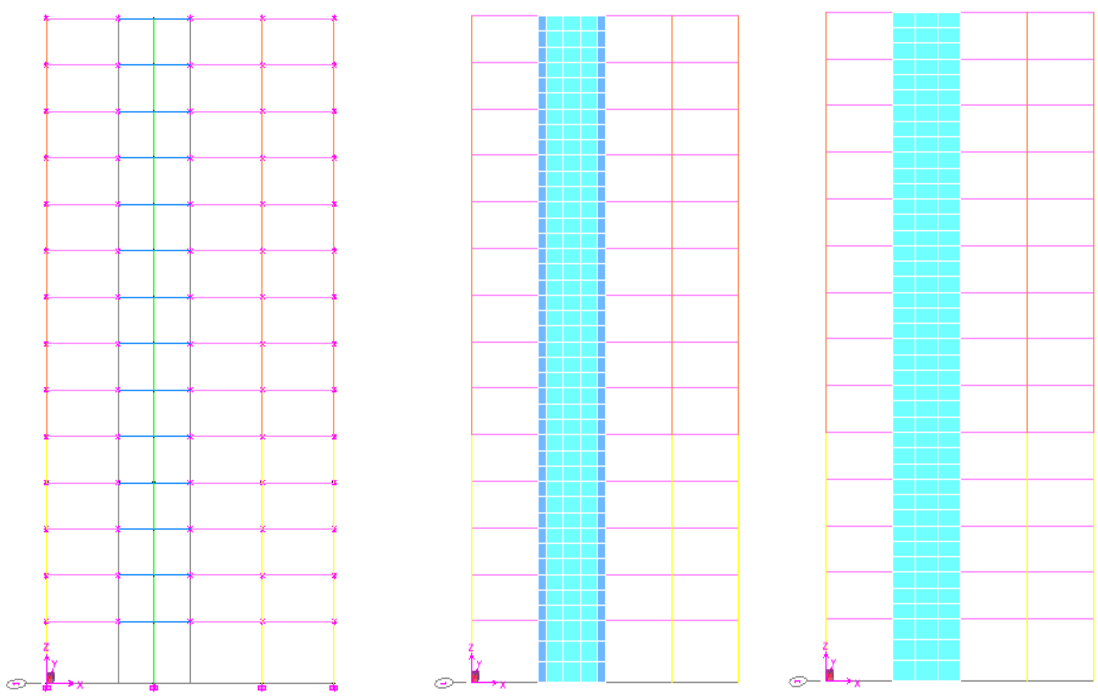
3.2 Planning of study

The purpose of this study is to find the best way in how to model a shear with shell elements (dual-system). For this case, it is obtained a 14-storey vertical structure in elevation, a system frame + shear wall. The design and analysis is performed by using ETABS software. Will also be pursued with different wall modeling ranging,beam with rigid arm,plates with columns and plates only. Analysis are based on the size of the partition (mesh) of the wall and mathematical formulations of finite elements. The planar element model has shown an appropriate and efficient result, bringing compatibility with the real behavior of the wall. In this study, in the modeling of the shear wall, we are going to see the impact of separation (mesh and the size of dimensions of mesh) using a quadratic finite element shell, with three degrees of freedom per node.

3.3 Gathering information and data

The shear wall is part of a 14 storey vertical structure mixed with frame + shear wall. Key elements of this structure are taken with the relevant sections below:

- Type floor height -- 3 m
- The height of the first floor --------------------------------- 4 m
- Number of spaces under the direction X ------------------ 4 m
- Span of shear wall -- 4m
- Distance between spaces ------------------------------------- 5 m
- Wall thickness (Shear wall) ------------------------------- 30 cm
- Cross-section of the column (5 floors) ---------------- (70x70) cm
- Cross-section of the column (9 other floors) --------- (60x60) cm
- Cross-section of the beams ---------------------------- (30x50) cm



(a) (b) (c)

Figure 3.1 Models of typical structural elements

a) Beam with rigid arm A_1 **b)** Plates with columns A_2 **c)** Plates only,A_3

This building is not an existed one. It is modeled only for this study. Sections of the elements above are taken roughly as they are not part of this study analysis. Results are obtained from modal analysis (response spectrum ANALYSES).

3.4 Modeling by Etabs

Columns and beams are modeled as frame elements with 3 degree of freedom per node, referred to the global axis x,z. The shear wall is modeled as a shell element with 3 degrees of freedom per node, to ensure the compatibility between the elements. The thickness of the wall is the same to all floors (30 cm). The structure is assumed to be fixed at the base. The columns that surround the shear wall are modeled as e shell element (50x60 cm).The wall thickness is 25cm.

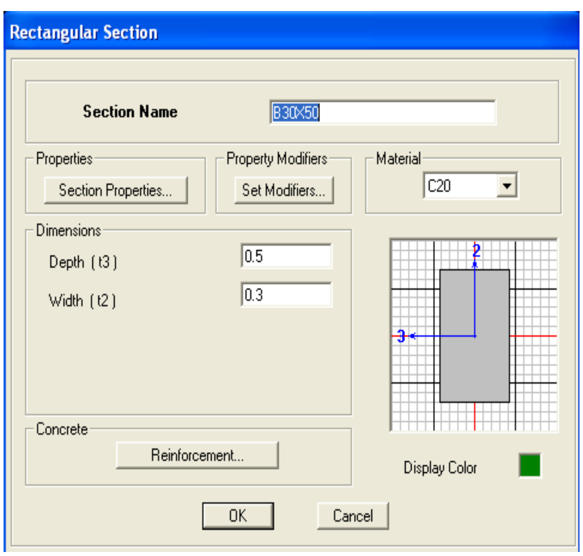


Figure 3.2 Beam section 30x50cm

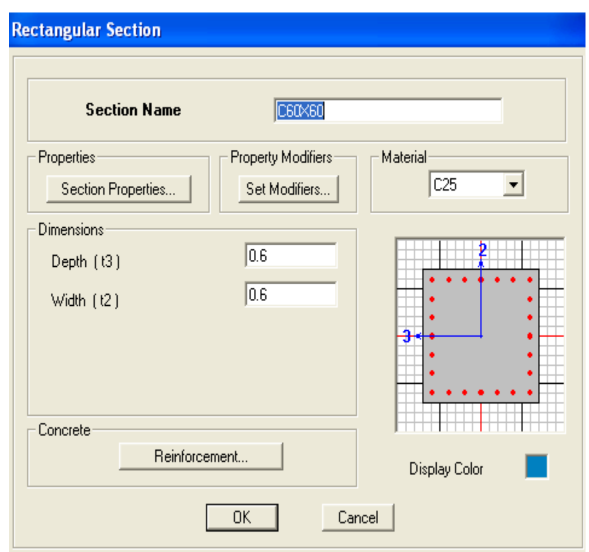
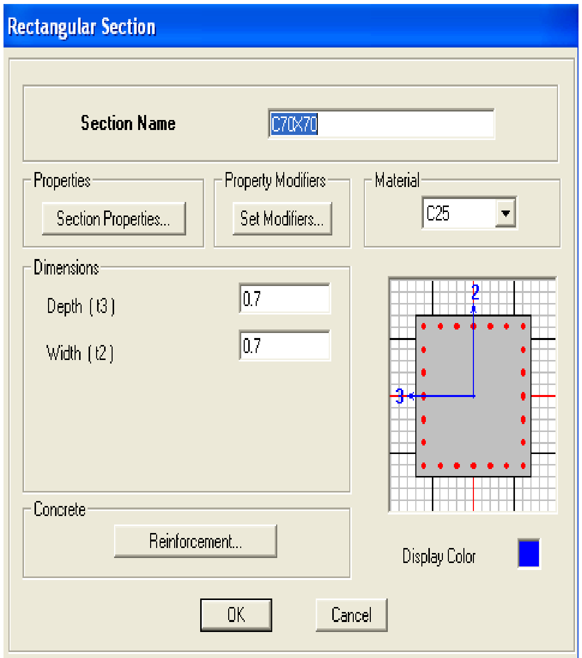


Figure 3.3 Column section 60x60cm



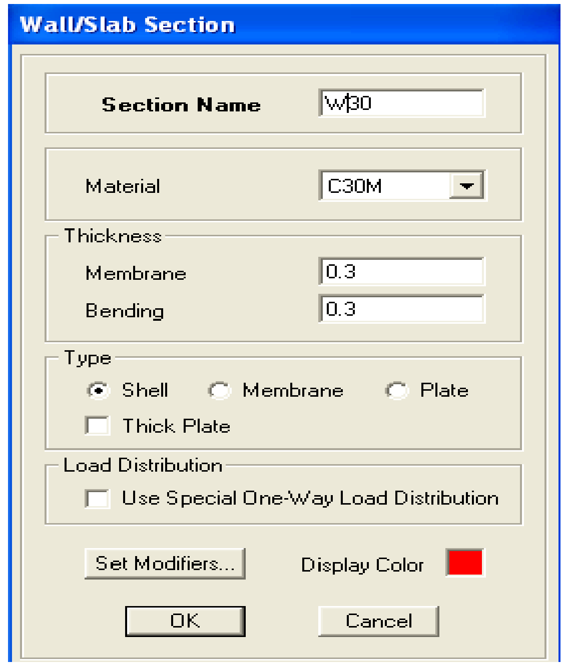


Figure 3.4 Column section 70x70cm

Figure 3.5 Wall thickness 30cm

The beam (30x50) and columns uses C20 as a define material.

The shear wall and the shell elements use C25 as a define material.

In this study it is used an effective stiffness. (Appendix 2)

Table 3.1 Material property C20 (Tm)

No.	Material Property data for C20	Values
1	Mass per unit volume	0.25
2	Weight per unit volume	2.45
3	Modulus of Elasticity	2900000
4	Coeff of Thermal Expansion	9.900E-06
5	Shear modulus	1208333.33
6	Specific conc comp strength	2000
7	Bending reinf yield stress,fy	44000
8	Shear reinf yield stress,fys	35000
9	Poisson’s Ratio	0.2

Table 3.2 Material property C25 (Tm)

No.	Material Property data for C25	Values
1	Mass per unit volume	0.25
2	Weight per unit volume	2.45
3	Modulus of Elasticity	3150000
4	Coeff of Thermal Expansion	9.900E-06
5	Shear modulus	1312500
6	Specific conc comp strength	2500
7	Bending reinf yield stress,fy	44000
8	Shear reinf yield stress,fys	35000
9	Poisson's Ratio	0.2

Thickness of the rectangular rigid arm section is considered the same as the wall itself. Rigid arm with one height storey depth give the most consistent results[9].

For the beam frame into wall, the depth is equal with the width of the wall =500cm and the width equal to the thickness of the wall =30cm. For the rigid arm, the depth is equal to the height of the storey =300cm and the width is equal to the thickness of the wall =30cm.

From the dynamic analysis which is subject to the four models, all structural elements (such as columns and beam) have their own masses. This mass is applied to each floor and automatically the ETABS program generates through these masses, the dynamic forces at each floor, according to the spectrum given below.

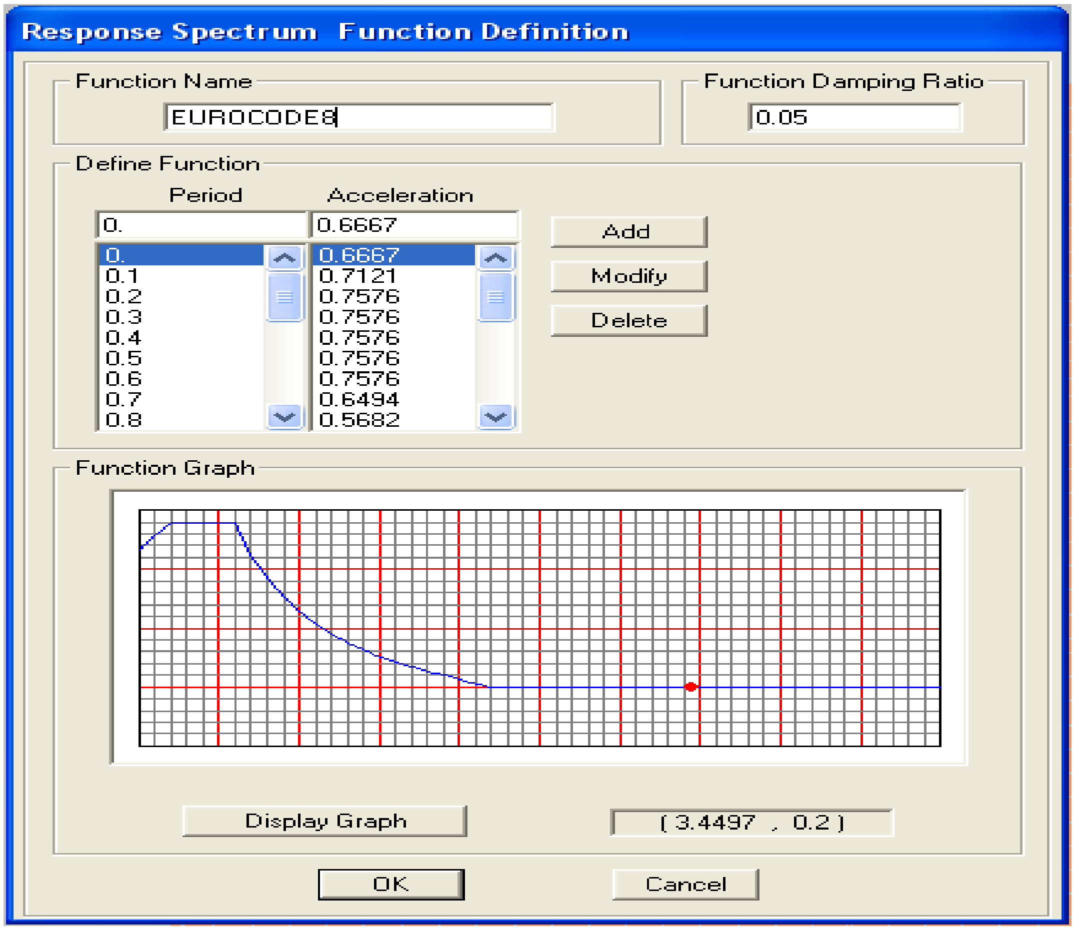


Figure 3.6 Response spectrum Type 1 (Eurocode 8)

Figure above shows the function of the spectrum where the function damping ratio is 0.05 (5%) [14]. The elastic response spectrum type 1 is used. The values provided in our study are explained in the Appendix 1. Also in dynamic analysis is accepted dynamic force coefficient equal to 1 (scale factor) and the structural behavior of the structure coefficient equal to 1. The type 1 elastic response spectrum is used (Appendix 1).For each of the cases included in the study, are extracted the following results which are reflected in the respective graphs.

3.5 Analysis

The response spectrum analysis is performed by using ETABS software. An effective stiffness is used for all the members of the structure. A mesh division is preformed for the models. The analysis is checked when initially performed and then checked again at the end of the project. The results of analysis of building with different types of modeling are presented in the next chapter.

3.6 Summary of methodology

The ETABS software is used to confirm the structural performance and analysis techniques. To achieve the objectives of this study, a linear analysis has been done. The finite element approaching and analytical modeling techniques are efficient tools for the study to make sure that a proper model is being established, thus, it is able to represent the overall structural system. Nowadays, the computer engineering programs have the ability of analysis of seismic loads more effectively [18].

Finding the best way in how to model a shear wall using shell elements, has been done by comparing 3 different type of shear wall models. The structure was modeled using Etabs program.

Chapter 4

RESULTS AND ANALYSIS

4.1 Design and analyze

To see the behavior of this wall against vertical forces, this structure is subject to a dynamic analysis using a designing spectrum with the following information:

- Ground acceleration ag ------------------------ 0.2 g
- Soil category (by EC-8)------------------------- B
- Behaviour structure factor ----------------- 5.4

Most of the engineer here in Albania use ground acceleration 0.3 and soil category B(gravel or stiff clay).

The *behavior factor*, by Eurocode 8, is computed with the relationship:

$$q = Kw \times qo$$

$$qo = 4.5 \times \frac{\alpha_u}{\alpha_i}$$

where:

⇒ **qo** is the base value of the behavior factor, which depends on the type of structural choice. Above is given the value 4.5 which coincides with the value of this factor for dual systems. In relation with the design structure ductility for DCH, this factor is determined by the above formula;

⇒ **αu/αi** it takes value 1.2 for dual systems;

⇒ **Kw** is a factor that reflects the impact of the prevailing form of possible destruction in structural systems for dual systems (code considers this factor with the value 1).

So replacing the values of all the factors mentioned above, behavioral factor takes the following value:

$$q = 1 \times 4.5 \times 1.2 = 5.4 \quad (5.1, \text{prEN 1998-1:200x})$$

Combination used in this analysis is:

Dead Static Load ------- →1

Live Static Load ------ → 0.3

Spectra ----------------- →1

To see the impact of the separation of shell element with small square elements, there are reviewed two cases:

<u>The first case which coincides with the first model</u>: the wall is considered as a single panel for each floor.

<u>The second case which coincides with the second model</u>: the panel of each floor is divided in five vertical lines.

<u>The third case which coincides with the third model</u>: the panel of the wall is divided 5x4 square part.

<u>The fourth case which coincides with the fourth model</u>: the panel of the wall is divided 10x8 square part.

In table below are given the respective results obtained from the analysis by mesh sizes.

Table 4.1 The first mode vibration and drift at the top in function of mesh size

Structure model	Load Combinations	Period of the first modes	Lateral deflection(mm)
1x1 division model	comb1	0.6897	21
5x1 division model	comb1	0.6919	21.1
5x4 division model	comb1	0.7029	21.4
10x8 division model	comb1	0.726	22.2

By increasing the size of mesh, the periods and drifts increases to.

In figure below is given the distribution of vertical stress in function of mesh size.

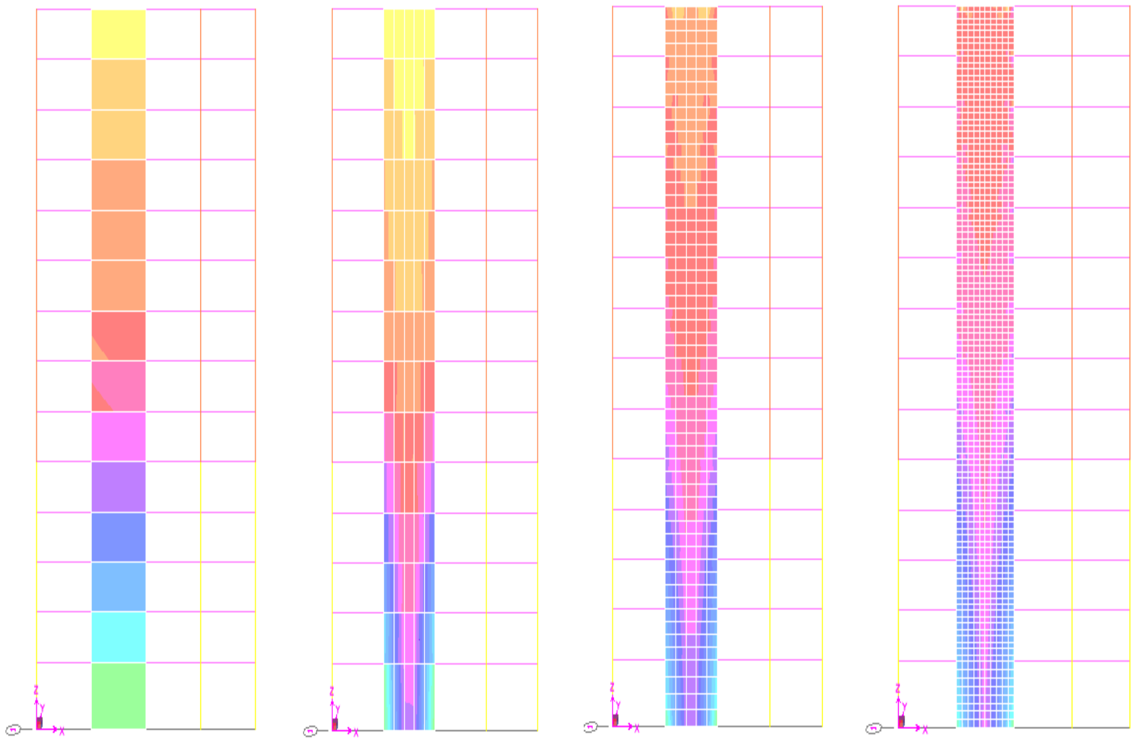


Figure 4.1 The distribution of vertical stress in function of mesh size.

In the table below are given the internal forces based on the mesh division. Based forces increases with the division, but to a constant value. Differences between the extreme shear force and the moment does not exceed 6% (for shear force) and 2% (for bending moment).

Table 4.2 Internal forces for the four divisions of the wall panel with mesh

Structure type	Load Combinations	Global forces Fx (ton)	Global moments My (tonxm)
1x1 division model	comb1	26.8	450.0
5x1 division model	comb1	26.5	446.5
5x4 division model	comb1	26.0	444.8
10x8 division model	comb1	25.2	447.5

Shear walls can be adequately modeled with shells sized at 1/3 or 1/4 of the floor-to-floor height [5]. Partition wall panels of each floor is taken every 1m in both directions. The third case (5x4 division) is choosen.

The behavior of a shear wall modeled in 3 different types:

The first type - beam with rigid arm

The second type - plates with columns.

The third type - plates only.

As a result of this dynamic analysis, obtained a series of data and based on them compare the following parameters:

- The first three periods of the natural vibration of the structure;
- Floor mass participation in the first vibration of the structure;
- Displacement of floors;
- The values of internal forces (bending moment and shear force) at each floor level of the shear wall;
- Values of the stress and forces at the base.

4.2 The first three periods of the natural vibration of the structure

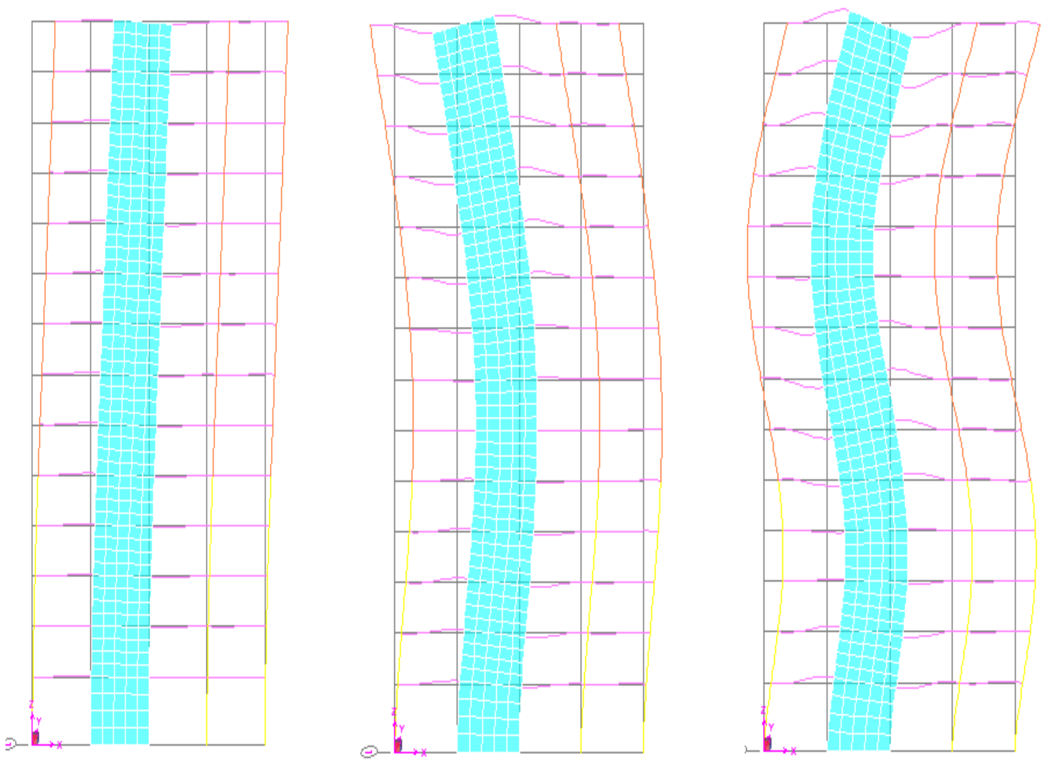
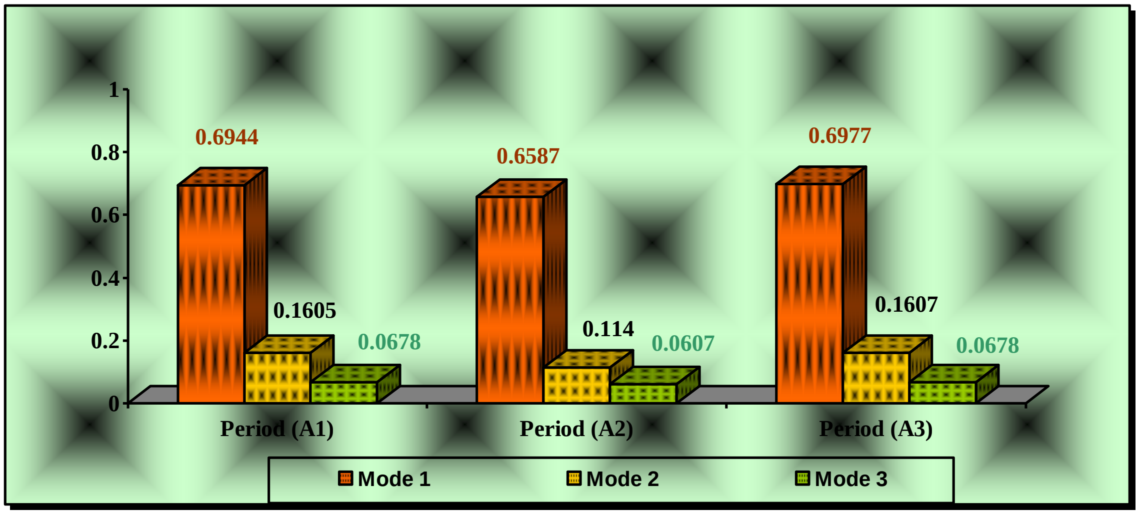


Figure 4.2 The first three periods of the natural vibration of the structure

Identification of the major periods of vibration of the structure is very important in dynamic analysis. For more, should be noted that the first period of shaking of the structure defines the horizontal forces acting on each floor.

In dynamic analysis, three main periods of vibration are given for the four different models of the shear wall. For the first period, as it is apparent from the chart below, the biggest difference that is observed between the models (between model A2 and A3) does not exceed 6%. For the second period and the third one, the difference goes to 30% and 11%.

Graph 4.1 Vibrations periods for 3 models



From the comparison of the three models, it is obvious that the second model (plates with columns) would be the best one because its period has lower value.

4.3 Floor mass participation in the first vibrations of the structure

In spectral analysis, should be introduced some mode calculations as a necessary guarantee of this analysis. Many design codes, including Eurocode 8, require that the number of modes involved in the analyses, catches the value of 90% of the total mass of the structure. The following tables give this information for the models taken under consideration.

As it is shown from the tables, the number of modes for the four models, is 3. So it means that taking into considerations only 3 modes in the analysis, represent over 90% of the total mass of the structure.

Tables 4.3 Floor mass participation in the first vibration of the structure

MODEL A1		
Mode	**UX**	**Sum UX**
1	67.0184	67.0184
2	17.9305	84.9489
3	7.2139	92.1628
4	3.6182	95.7811
5	0	95.7811
6	0	95.7811
7	0	95.7811
8	0	95.7811
9	0	95.7811
10	0	95.7811
11	1.8463	97.6273
12	0	97.6273

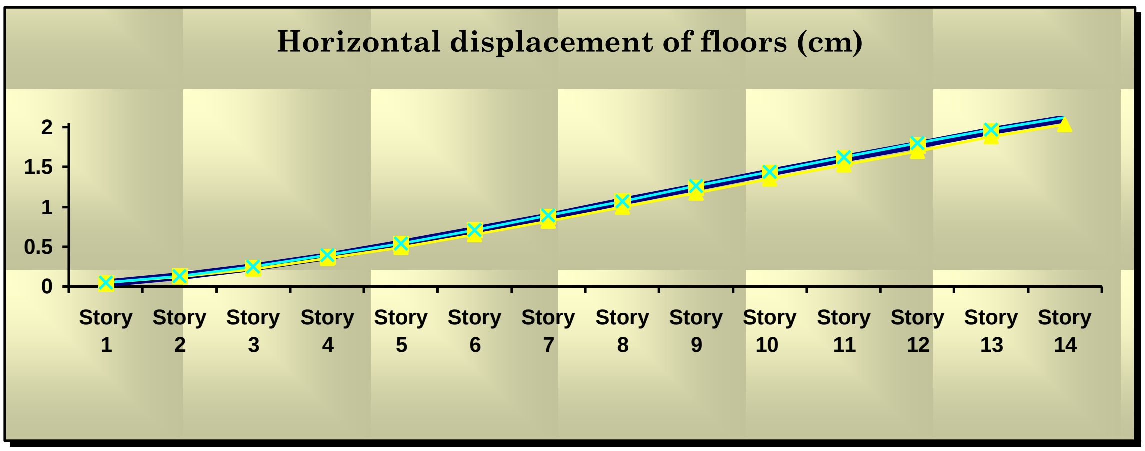
MODEL A2		
Mode	**UX**	**Sum UX**
1	66.2178	66.2178
2	19.0476	85.2654
3	7.3407	92.606
4	3.4954	96.1015
5	1.5509	97.6524
6	0	97.6524
7	0	98.0296
8	0	98.0296
9	0	98.0296
10	0	98.0296
11	0	98.0296
12	0	98.1397

MODEL A3		
Mode	**UX**	**Sum UX**
1	66.953	66.953
2	18.0278	84.9808
3	7.2242	92.205
4	0	92.205
5	0	92.205
6	0	95.7997
7	0	95.7997
8	0	95.7997
9	0	95.7997
10	0	95.7997
11	0	95.7997
12	0	95.7997

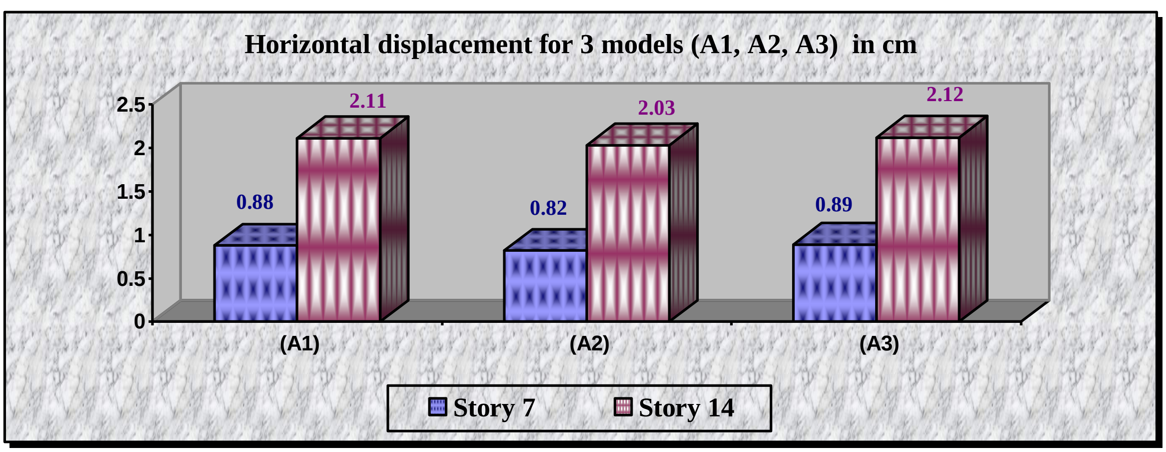
4.4 Floors displacement

At this point, there are given the results of horizontal displacement of floors, presented in the graphs, which makes possible the comparison of these values. For the three models taken under consideration, the maximum relative difference between the two models is 6%.

Graph 4.2 Horizontal displacement of floors



Graph 4.3 Horizontal displacement for story 7 and 14



In relation to the values of displacement on the top, Eurocode 8 gives this formula:

$$q \times d_e \leq \frac{1}{200} \times H$$

$q = 5.4 \qquad H = 43$ m

For d_e=2.15m, which coincides with the highest value of horizontal displacement at the top, this condition is fulfilled. A very important factor in the analysis of this type, expect the displacement at the top, is the drift of floors. Eurocode 8 defines drift floor as a difference of the displacement of the respective floors. The formula for the determination of this factor is given as follows:

$$d_s = q \times d_e$$

$$v \times d_r \leq 0.005 \times h$$

where:

h - is the hight of the floor

$\mathbf{d_r}$ - is the drift

$\mathbf{d_s}$ - is the design drift

$\mathbf{d_e}$ - is the elastic drift

v - is the reductive coefficient

Replacing ν = 0.5,the above formula takes the form:

$$d_r \leq \frac{h}{100}$$

Accounting software program, ETABS, in which are modeled and analyzed the four structures, drift value is given as the ratio of the difference of displacement with the respective floor height where is defined this factor. So the value of the drift taken from the ETABS multiplied by a factor of behavior should be compared only with the value. Expressed by the formula it would be:

$$d_r \times q \leq \frac{1}{100}$$

Below are given in tabular form the drifts for the four models taken into the study. The max value of the floor drift, is controlled by the above formula and is totally fulfilled. Also the drifts of floors for the three models are within the allowed values that specifies Eurocode.

Table 4.4 The respective drifts for the three models

MODEL A1

Floors	Name	Combination	Drift by X
STORY14	Max Drift X	COMB1	0.000548
STORY13	Max Drift X	COMB1	0.000569
STORY12	Max Drift X	COMB1	0.000581
STORY11	Max Drift X	COMB1	0.000597
STORY10	Max Drift X	COMB1	0.000609
STORY9	Max Drift X	COMB1	0.000615
STORY8	Max Drift X	COMB1	0.000612
STORY7	Max Drift X	COMB1	0.000597
STORY6	Max Drift X	COMB1	0.000573
STORY5	Max Drift X	COMB1	0.000524
STORY4	Max Drift X	COMB1	0.000464
STORY3	Max Drift X	COMB1	0.000381
STORY2	Max Drift X	COMB1	0.000277
STORY1	Max Drift X	COMB1	0.000124

MODEL A2

Floors	Name	Combination	Drift by X
STORY14	Max Drift X	COMB1	0.000570
STORY13	Max Drift X	COMB1	0.000581
STORY12	Max Drift X	COMB1	0.000591
STORY11	Max Drift X	COMB1	0.000597
STORY10	Max Drift X	COMB1	0.000598
STORY9	Max Drift X	COMB1	0.000596
STORY8	Max Drift X	COMB1	0.000586
STORY7	Max Drift X	COMB1	0.000565
STORY6	Max Drift X	COMB1	0.000533
STORY5	Max Drift X	COMB1	0.000485
STORY4	Max Drift X	COMB1	0.000423
STORY3	Max Drift X	COMB1	0.000345
STORY2	Max Drift X	COMB1	0.000249
STORY1	Max Drift X	COMB1	0.000119

MODEL A3

Floors	Name	Combination	Drift by X
STORY14	Max Drift X	COMB1	0.000566
STORY13	Max Drift X	COMB1	0.000581
STORY12	Max Drift X	COMB1	0.000597
STORY11	Max Drift X	COMB1	0.000611
STORY10	Max Drift X	COMB1	0.000619
STORY9	Max Drift X	COMB1	0.000619
STORY8	Max Drift X	COMB1	0.000616
STORY7	Max Drift X	COMB1	0.000600
STORY6	Max Drift X	COMB1	0.000573
STORY5	Max Drift X	COMB1	0.000526
STORY4	Max Drift X	COMB1	0.000464
STORY3	Max Drift X	COMB1	0.000381
STORY2	Max Drift X	COMB1	0.000277
STORY1	Max Drift X	COMB1	0.000131

4.5 Values of internal forces (bending moment and shear force) at each level floor of the shear wall

At this point are given the values of internal forces generated by spectral analysis. Results are shown in the following graphs. The conclusion that can be drawn from the comparison of these data is that for the second model A2 where drifts are smaller, the opposite occurs with the internal forces, they have greater value. By analogy for A3 flexible model where the drift is greater, the interior forces have small value. In terms of relative differences expressed in% of the shearing force on the basis of the wall, this value does not exceed 16% and for the moment value this difference becomes 27%.

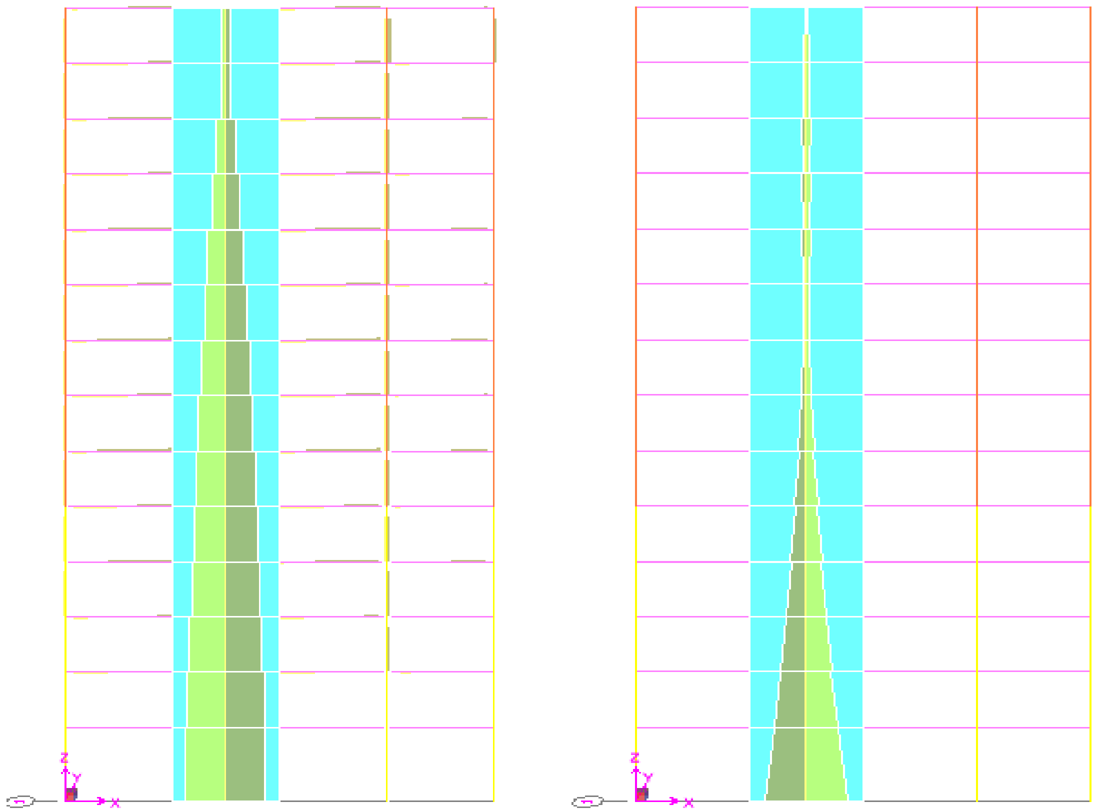
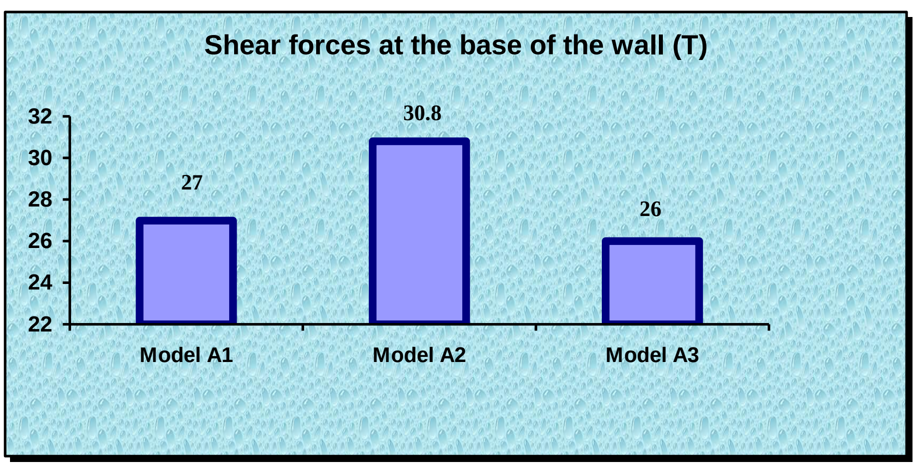
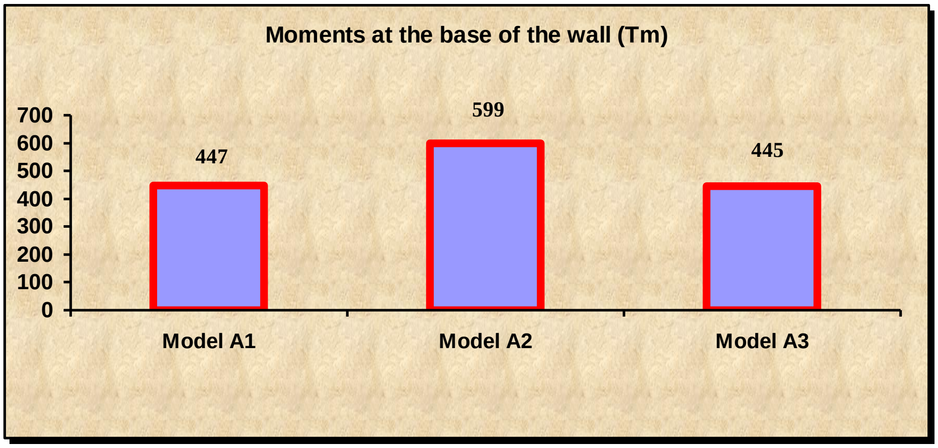


Figure 4.3 Internal forces Fx and My of shear wall

Graph 4.4 Shear forces at the base of the wall



Graph 4.5 Moment at the base of the wall

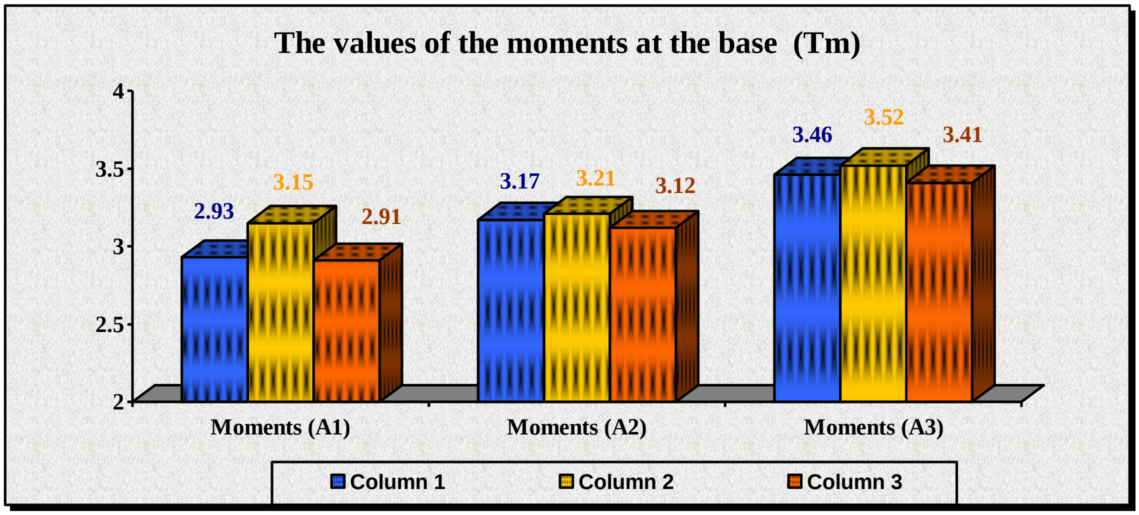


As it is showed in the graphs above, the value of the shear forces and moments in the wall for the second model (plates with columns), are less than the two other models.

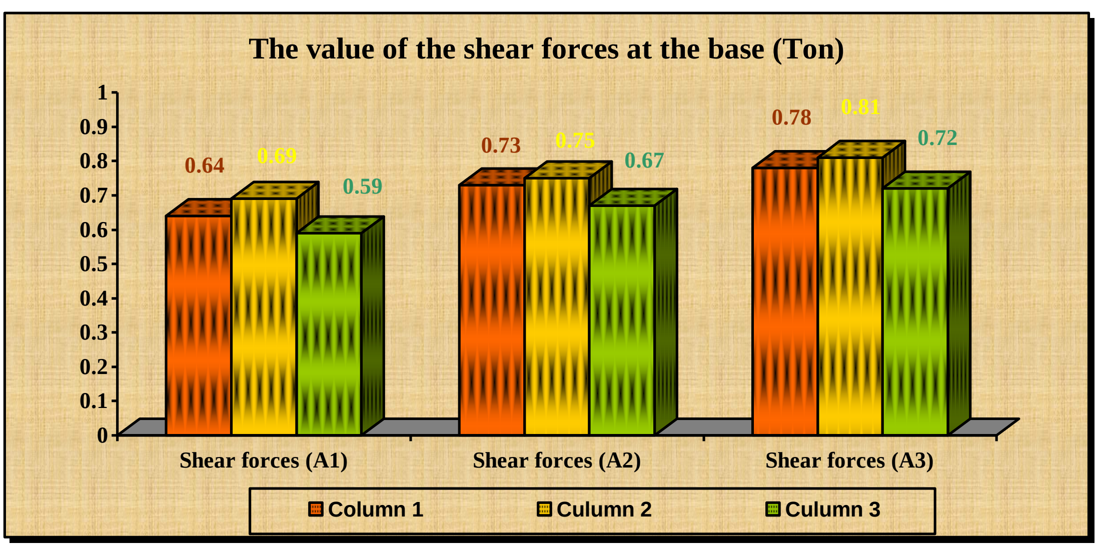
4.6 The values of the internal forces at the base

Base forces (shearing forces and bending moment) for columns and beams of the first floor, are important in seismic analysis and design of structures. Especially in dynamic analysis, the total effect of horizontal inertial forces acting on structure can be determined by the value of these internal forces at the base. The maximum relative differences are:

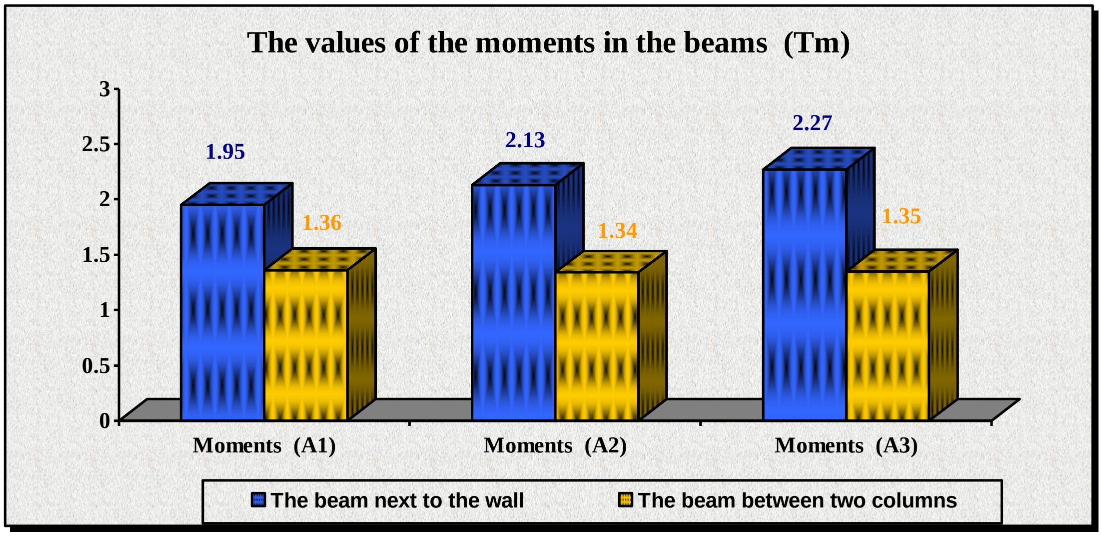
Graph 4.6 The values of the moments at the base for 3 columns



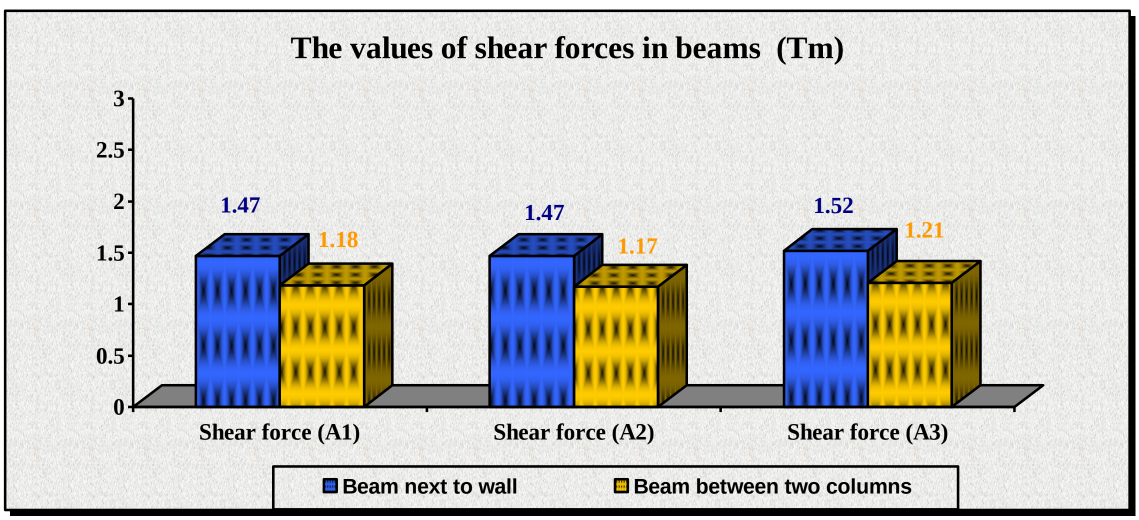
Graph 4.7 The values of the shear forces at the base for 3 columns



Graph 4.8 The values of the moments in the beams



Graph 4.9 The values of the shear forces in the beams



From theses graphs can be determined which is the best model . For the second model (plate with columns) the values of shear and moment in the frame elements are close to the first model,for the same mesh division,in comparison with the third model(plate only).

Table 4.5 The maximum relative differences of internal forces between models

Internal forces	Max relative differences %
V for column 1	9
V for column 2	10
V for column 3	10
M for column 1	11
M for column 2	11
M for column 3	11
V for the beam next to the wall	4
V for beam between 2 columns	5
M for the beam next to the wall	7
M for beam between 2 columns	6

In the figure 4.4 is given the Vertical force distribution for each of the models with finite elements of shear wall.

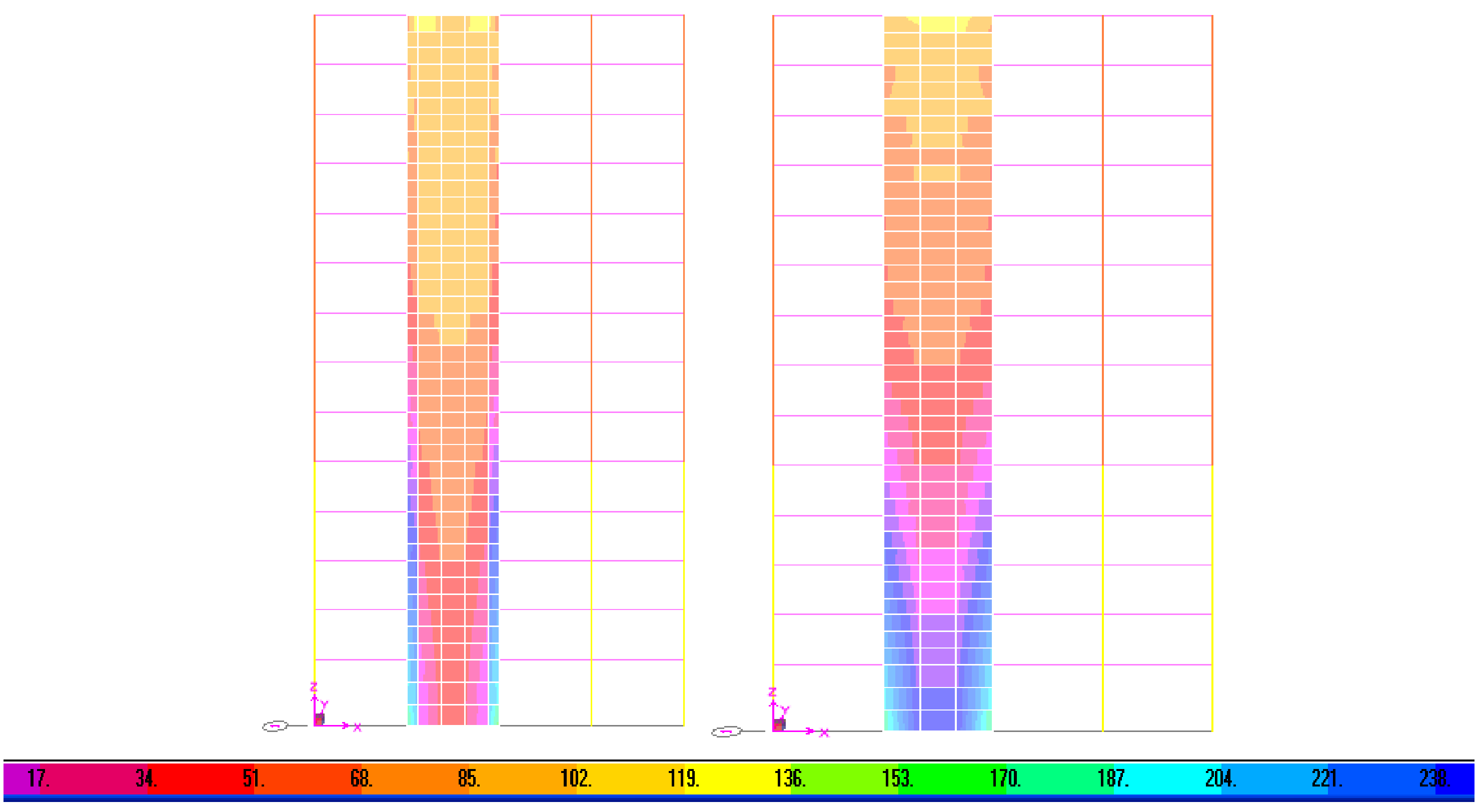
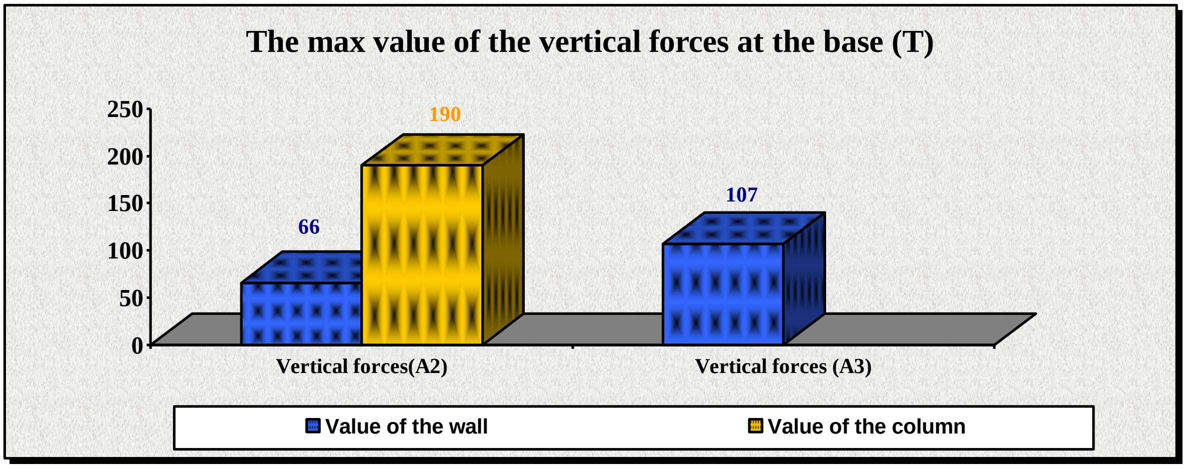


Figure 4.4 Vertical force distribution

(a) Plates with columns **b)** Plates only

Graph 4.10 Maximum vertical forces



As it seems the second model (shear wall with columns) has the lowest value of vertical force at the wall 66T and 190T in the column. These values are taken at the base where the forces are at their maximum.

In the figure 4.5 it is given the stress distribution for the both modells(plate with columns and plate only).

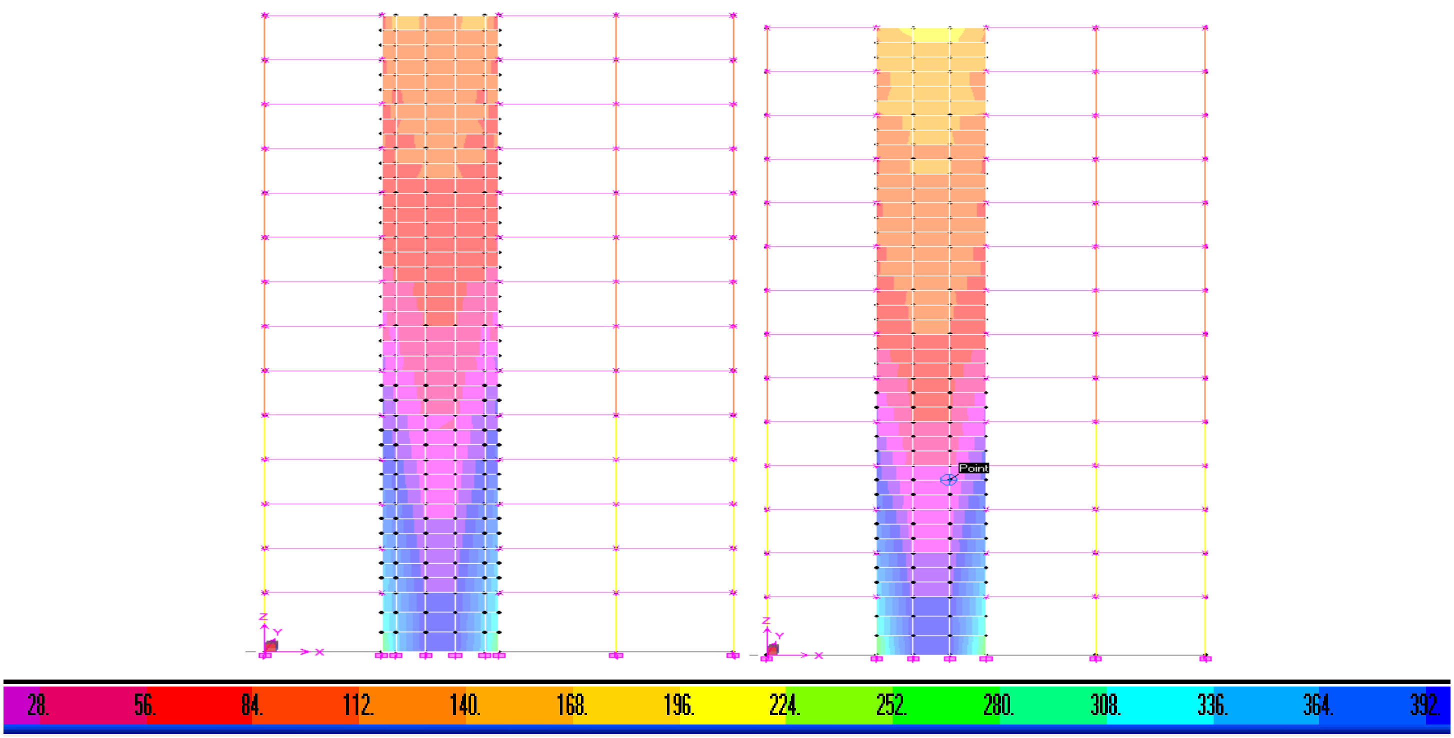
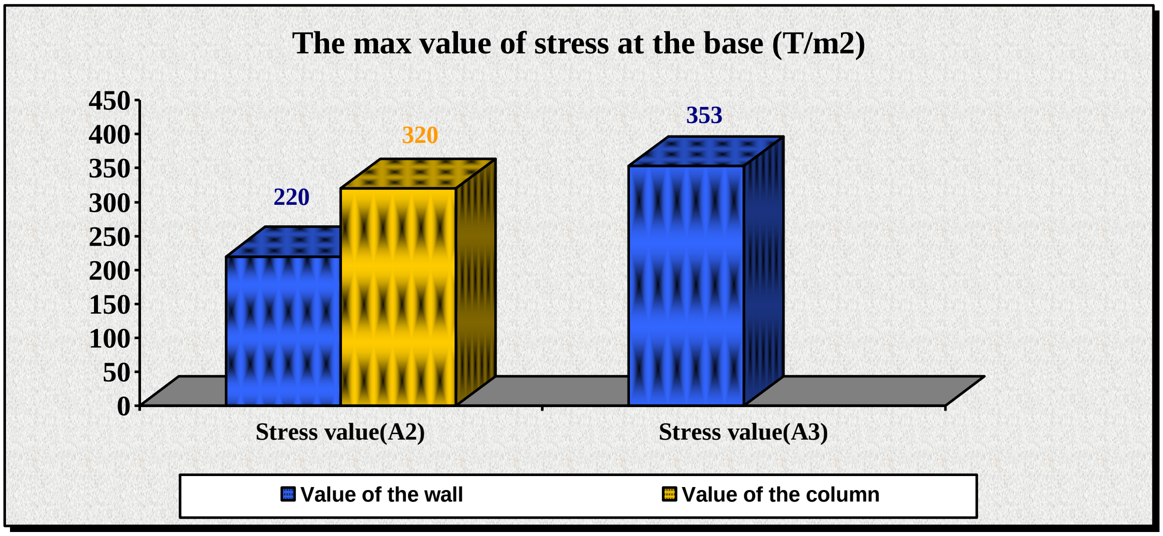


Figure 4.5 Stress distribution

Graph 4.11 Maxiumum stress



The same thing can be said for the stress. The stress for the second model(plate with column) is in lower values than the others.

4.7 DISCUSSION OF RESULT

- Size of mesh division affect the accuracy of the analysis model and the results obtained from this analysis. However, it applies to a certain limit mesh division, as the differences are very small;
- Mesh size do not significantly affect in the values of the highest modes compared between them. This means that a more detailed mesh does not bring a big change in% instead, it would required a greater time for computer calculation and complex analysis.
- When using a large number of mesh divisions, the model becomes more complicated. For this reason, it is used a reasonable mesh size. In the first part of this study, which studies the influence of mesh, there are taken

four different types of dimensions, while in the second part, it is preferred to become a mesh partition that runs in 1ml in two directions (x axis and y axis);

- It can be said that, based on these results, the second model (plates with column) is the appropriate one.
- Moreover, it is enough just the design of a wall only with finite elements such as column (model A2), providing the confine of concrete in these areas and therefore improvement in working conditions of this wall especially in bending, from the side forces that are generated by seismic vibrations of the site;

Chapter 5

CONCLUSIONS

- ✓ Shear walls are an important structural element in the resistment due to the action of the vertical and lateral forces. Using the Etabs design program for a linear frame element (dual-system) under a design spectrum we can ensure these definitions.
- ✓ Appropriate Meshing and labeling of Shear Walls is the key to proper modeling and design of walls. A more detailed mesh does not bring a big change in %, but it would require a greater time for computer calculation and complex analysis. Shear walls can be adequately modeled with shells sized at 1/3 or 1/4 of the floor-to-floor height.
- ✓ The usage of a shear wall with columns can increase the stability of the structural building. The condition for the first three periods is fulfilled for the three models taken into consideration. Also the drift of floors for the three models is within the allowed values that specifies the eurocode 8.
- ✓ After comparing the three models with each other, it is obvious that the second one with columns as a shell element is the appropiate choice (showing better values of forces, stresses, shear forces and moments) according to the idealized satisfactory model (beam with rigid arm). As a result for a better design and modeling of a shear wall its important the usage of columns as a boundary element.
- ✓ It is very important to state that, the second model with column as a boundary element, decreases significantly the values of the internal forces in the wall.

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APPENDIX 1

Table: Values of the parameters describing the elastic response spectrum Type 1 by Eurocode 8

Ground type	*S*	T_B (s)	T_C (s)	T_D (s)
A	**1,0**	**0,15**	**0,4**	**2,0**
B	**1,2**	**0,15**	**0,5**	**2,0**
C	**1,15**	**0,20**	**0,6**	**2,0**
D	**1,35**	**0,20**	**0,8**	**2,0**
E	**1,4**	**0,15**	**0,5**	**2,0**

Horizontal elastic response spectrum

For the horizontal components of the seismic action, the elastic response spectrum S_e (T) is defined by the following expressions:

$$0 \le T \le T_B \qquad S_e\ \ T\ = a_g \cdot S \cdot \left[1 + \frac{T}{T_B} \cdot\ \ \eta \cdot 2,5 - 1\ \right]$$

$$T_B \le T \le T_C \qquad S_e\ \ T\ = a_g \cdot S \cdot \eta \cdot 2,5$$

$$T_C \le T \le T_D \qquad S_e\ \ T\ = a_g \cdot S \cdot \eta \cdot 2,5 \left[\frac{T_C}{T} \right]$$

$$T_D \le T \le 4s \qquad S_e\ \ T\ = a_g \cdot S \cdot \eta \cdot 2,5 \left[\frac{T_C T_D}{T^2} \right]$$

where:

S_e (T) - elastic responsive spectrum;

T - vibration period of linear single –degree-of –freedom system;

a_g - design ground acceleration on type A ground ($a_g = S_e\ \ T\ = \gamma_I a_{gR}$);

T_B, T_C - limits of the constant spectral acceleration branch;

T_D - value defining the beginning of the constant displacement response range of the spectrum;

S - soil factor;

η - damping correction factor with reference value η = 1 for 5% viscous damping.

Table: Ground types by EC8

Ground type	Descripton of stratigraphic profile	Parameters		
		$v_{s,30}$ (m/s)	N_{SPT} (blows/30 cm)	c_u (kPa)
A	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface	**> 800**	**-**	**-**
B	Deposits of very dense sand, gravel or very stiff clay, at least several tens of ***m*** in thickness, characterized by a gradual increase of mechanical properties with depth	**360 - 800**	**> 50**	**> 250**
C	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of ***m***	**180 - 360**	**15 - 50**	**70 - 250**
D	Deposits of loose-to-medium cohesion less soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil	**< 180**	**< 15**	**< 70**
E	A soil profile consisting of a surface alluvium layer with vs values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with vs > 800 m/s			
S_1	Deposits consisting – or containing a layer at least 10 m thick of soft clays/silts with high plasticity index (PI>40) and high water content	**< 100 indicativ e**	**-**	**10 - 20**
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types **A-E** or S_1			

APPENDIX 2

Paulay T and *M.J.N.* Priestley cite:

Effective member moment of inertia

	Range	*Recommended Value*
Rectangular beams	**0,30-0.50*Ig***	**0.40 *Ig***
T and L beams	**0,25-0.45 *Ig***	**0.35 *Ig***
Columns,P>0.5fcAg	**0.70-0.90 *Ig***	**0.80 *Ig***
Columns,P=0.2fcAg	**0.50-0.70 *Ig***	**0.60 *Ig***
Columns,P= -0.05fcAg	**0.30-0.50 *Ig***	**0.40 *Ig***

The stiffness properties of member used in this study are;

Beams: $Ie=0.35Ig$

Exterior columns: $Ie=0.60Ig$

Interior columns: $Ie=0.80Ig$

Tension wall;

$Ie=0.5Ig$

$Ae=0.5Ag$

Compression wall;

$Ie=0.7Ig$

$Ae=Ag$

The stiffness of cantilever beam:

$Ie=(100/fy+Pu/fcAg)Ig$

APPENDIX 3

Support reactions at each point per floor for the first model:

Story	Point	Load	FX	FY	FZ	MX	MY	MZ
STORY14	1	COMB1 MAX	0	0.05	0	0.034	0	0.065
STORY14	1	COMB1 MIN	0	-0.05	0	-0.034	0	-0.065
STORY14	2	COMB1 MAX	0	0.05	0	0.034	0	0.065
STORY14	2	COMB1 MIN	0	-0.05	0	-0.034	0	-0.065
STORY14	3	COMB1 MAX	0	0	0	0	0	0
STORY14	3	COMB1 MIN	0	0	0	0	0	0
STORY14	4	COMB1 MAX	0	0	0	0	0	0
STORY14	4	COMB1 MIN	0	0	0	0	0	0
STORY14	5	COMB1 MAX	0	0	0	0	0	0
STORY14	5	COMB1 MIN	0	0	0	0	0	0
STORY13	1	COMB1 MAX	0	0.23	0	0.034	0	0.29
STORY13	1	COMB1 MIN	0	-0.23	0	-0.034	0	-0.29
STORY13	2	COMB1 MAX	0	0.23	0	0.034	0	0.29
STORY13	2	COMB1 MIN	0	-0.23	0	-0.034	0	-0.29
STORY13	3	COMB1 MAX	0	0	0	0	0	0
STORY13	3	COMB1 MIN	0	0	0	0	0	0
STORY13	4	COMB1 MAX	0	0	0	0	0	0
STORY13	4	COMB1 MIN	0	0	0	0	0	0
STORY13	5	COMB1 MAX	0	0	0	0	0	0
STORY13	5	COMB1 MIN	0	0	0	0	0	0
STORY12	1	COMB1 MAX	0	0.32	0	0.017	0	0.4
STORY12	1	COMB1 MIN	0	-0.32	0	-0.017	0	-0.4
STORY12	2	COMB1 MAX	0	0.32	0	0.017	0	0.4
STORY12	2	COMB1 MIN	0	-0.32	0	-0.017	0	-0.4
STORY12	3	COMB1 MAX	0	0	0	0	0	0
STORY12	3	COMB1 MIN	0	0	0	0	0	0
STORY12	4	COMB1 MAX	0	0	0	0	0	0
STORY12	4	COMB1 MIN	0	0	0	0	0	0
STORY12	5	COMB1 MAX	0	0	0	0	0	0
STORY12	5	COMB1 MIN	0	0	0	0	0	0
STORY11	1	COMB1 MAX	0	0.32	0	0.013	0	0.399
STORY11	1	COMB1 MIN	0	-0.32	0	-0.013	0	-0.399
STORY11	2	COMB1 MAX	0	0.32	0	0.013	0	0.399
STORY11	2	COMB1 MIN	0	-0.32	0	-0.013	0	-0.399
STORY11	3	COMB1 MAX	0	0	0	0	0	0

STORY11	3	COMB1 MIN	0	0	0	0	0	0
STORY11	4	COMB1 MAX	0	0	0	0	0	0
STORY11	4	COMB1 MIN	0	0	0	0	0	0
STORY11	5	COMB1 MAX	0	0	0	0	0	0
STORY11	5	COMB1 MIN	0	0	0	0	0	0
STORY10	1	COMB1 MAX	0	0.3	0	0.009	0	0.376
STORY10	1	COMB1 MIN	0	-0.3	0	-0.009	0	-0.376
STORY10	2	COMB1 MAX	0	0.3	0	0.009	0	0.376
STORY10	2	COMB1 MIN	0	-0.3	0	-0.009	0	-0.376
STORY10	3	COMB1 MAX	0	0	0	0	0	0
STORY10	3	COMB1 MIN	0	0	0	0	0	0
STORY10	4	COMB1 MAX	0	0	0	0	0	0
STORY10	4	COMB1 MIN	0	0	0	0	0	0
STORY10	5	COMB1 MAX	0	0	0	0	0	0
STORY10	5	COMB1 MIN	0	0	0	0	0	0
STORY9	1	COMB1 MAX	0	0.3	0	0.007	0	0.372
STORY9	1	COMB1 MIN	0	-0.3	0	-0.007	0	-0.372
STORY9	2	COMB1 MAX	0	0.3	0	0.007	0	0.372
STORY9	2	COMB1 MIN	0	-0.3	0	-0.007	0	-0.372
STORY9	3	COMB1 MAX	0	0	0	0	0	0
STORY9	3	COMB1 MIN	0	0	0	0	0	0
STORY9	4	COMB1 MAX	0	0	0	0	0	0
STORY9	4	COMB1 MIN	0	0	0	0	0	0
STORY9	5	COMB1 MAX	0	0	0	0	0	0
STORY9	5	COMB1 MIN	0	0	0	0	0	0
STORY8	1	COMB1 MAX	0	0.3	0	0.006	0	0.376
STORY8	1	COMB1 MIN	0	-0.3	0	-0.006	0	-0.376
STORY8	2	COMB1 MAX	0	0.3	0	0.006	0	0.376
STORY8	2	COMB1 MIN	0	-0.3	0	-0.006	0	-0.376
STORY8	3	COMB1 MAX	0	0	0	0	0	0
STORY8	3	COMB1 MIN	0	0	0	0	0	0
STORY8	4	COMB1 MAX	0	0	0	0	0	0
STORY8	4	COMB1 MIN	0	0	0	0	0	0
STORY8	5	COMB1 MAX	0	0	0	0	0	0
STORY8	5	COMB1 MIN	0	0	0	0	0	0
STORY7	1	COMB1 MAX	0	0.3	0	0.005	0	0.372
STORY7	1	COMB1 MIN	0	-0.3	0	-0.005	0	-0.372
STORY7	2	COMB1 MAX	0	0.3	0	0.005	0	0.372
STORY7	2	COMB1 MIN	0	-0.3	0	-0.005	0	-0.372
STORY7	3	COMB1 MAX	0	0	0	0	0	0
STORY7	3	COMB1 MIN	0	0	0	0	0	0
STORY7	4	COMB1 MAX	0	0	0	0	0	0

STORY7	4	COMB1 MIN	0	0	0	0	0	0
STORY7	5	COMB1 MAX	0	0	0	0	0	0
STORY7	5	COMB1 MIN	0	0	0	0	0	0
STORY6	1	COMB1 MAX	0	0.3	0	0.004	0	0.371
STORY6	1	COMB1 MIN	0	-0.3	0	-0.004	0	-0.371
STORY6	2	COMB1 MAX	0	0.3	0	0.004	0	0.371
STORY6	2	COMB1 MIN	0	-0.3	0	-0.004	0	-0.371
STORY6	3	COMB1 MAX	0	0	0	0	0	0
STORY6	3	COMB1 MIN	0	0	0	0	0	0
STORY6	4	COMB1 MAX	0	0	0	0	0	0
STORY6	4	COMB1 MIN	0	0	0	0	0	0
STORY6	5	COMB1 MAX	0	0	0	0	0	0
STORY6	5	COMB1 MIN	0	0	0	0	0	0
STORY5	1	COMB1 MAX	0	0.3	0	0.004	0	0.373
STORY5	1	COMB1 MIN	0	-0.3	0	-0.004	0	-0.373
STORY5	2	COMB1 MAX	0	0.3	0	0.004	0	0.373
STORY5	2	COMB1 MIN	0	-0.3	0	-0.004	0	-0.373
STORY5	3	COMB1 MAX	0	0	0	0	0	0
STORY5	3	COMB1 MIN	0	0	0	0	0	0
STORY5	4	COMB1 MAX	0	0	0	0	0	0
STORY5	4	COMB1 MIN	0	0	0	0	0	0
STORY5	5	COMB1 MAX	0	0	0	0	0	0
STORY5	5	COMB1 MIN	0	0	0	0	0	0
STORY4	1	COMB1 MAX	0	0.29	0	0.005	0	0.368
STORY4	1	COMB1 MIN	0	-0.29	0	-0.005	0	-0.368
STORY4	2	COMB1 MAX	0	0.29	0	0.005	0	0.368
STORY4	2	COMB1 MIN	0	-0.29	0	-0.005	0	-0.368
STORY4	3	COMB1 MAX	0	0	0	0	0	0
STORY4	3	COMB1 MIN	0	0	0	0	0	0
STORY4	4	COMB1 MAX	0	0	0	0	0	0
STORY4	4	COMB1 MIN	0	0	0	0	0	0
STORY4	5	COMB1 MAX	0	0	0	0	0	0
STORY4	5	COMB1 MIN	0	0	0	0	0	0
STORY3	1	COMB1 MAX	0	0.3	0	0.006	0	0.371
STORY3	1	COMB1 MIN	0	-0.3	0	-0.006	0	-0.371
STORY3	2	COMB1 MAX	0	0.3	0	0.006	0	0.371
STORY3	2	COMB1 MIN	0	-0.3	0	-0.006	0	-0.371
STORY3	3	COMB1 MAX	0	0	0	0	0	0
STORY3	3	COMB1 MIN	0	0	0	0	0	0
STORY3	4	COMB1 MAX	0	0	0	0	0	0
STORY3	4	COMB1 MIN	0	0	0	0	0	0
STORY3	5	COMB1 MAX	0	0	0	0	0	0

STORY3	5	COMB1 MIN	0	0	0	0	0	0
STORY2	1	COMB1 MAX	0	0.32	0	0.007	0	0.402
STORY2	1	COMB1 MIN	0	-0.32	0	-0.007	0	-0.402
STORY2	2	COMB1 MAX	0	0.32	0	0.007	0	0.402
STORY2	2	COMB1 MIN	0	-0.32	0	-0.007	0	-0.402
STORY2	3	COMB1 MAX	0	0	0	0	0	0
STORY2	3	COMB1 MIN	0	0	0	0	0	0
STORY2	4	COMB1 MAX	0	0	0	0	0	0
STORY2	4	COMB1 MIN	0	0	0	0	0	0
STORY2	5	COMB1 MAX	0	0	0	0	0	0
STORY2	5	COMB1 MIN	0	0	0	0	0	0
STORY1	1	COMB1 MAX	0	0.3	0	0.034	0	0.373
STORY1	1	COMB1 MIN	0	-0.3	0	-0.034	0	-0.373
STORY1	2	COMB1 MAX	0	0.3	0	0.034	0	0.373
STORY1	2	COMB1 MIN	0	-0.3	0	-0.034	0	-0.373
STORY1	3	COMB1 MAX	0	0	0	0	0	0
STORY1	3	COMB1 MIN	0	0	0	0	0	0
STORY1	4	COMB1 MAX	0	0	0	0	0	0
STORY1	4	COMB1 MIN	0	0	0	0	0	0
STORY1	5	COMB1 MAX	0	0	0	0	0	0
STORY1	5	COMB1 MIN	0	0	0	0	0	0
BASE	3	COMB1 MAX	0.64	0	80.37	0	3.126	0
BASE	3	COMB1 MIN	-0.35	0	38.85	0	-2.733	0
BASE	4	COMB1 MAX	0.61	0	78.93	0	3.094	0
BASE	4	COMB1 MIN	-0.69	0	63.43	0	-3.212	0
BASE	5	COMB1 MAX	0.33	0	70.11	0	2.722	0
BASE	5	COMB1 MIN	-0.59	0	43.14	0	-3.106	0
BASE	20	COMB1 MAX	26.48	0.07	383.12	0.155	444.113	0
BASE	20	COMB1 MIN	-26.43	-0.07	382.18	-0.155	-444.9	0

Support reactions at each point per floor for the second model:

STORY	POINT	LOAD	FX	FY	FZ	MX	MY	MZ
STORY14	1	COMB1 MAX	0	0.12	0	0.012	0	0.125
STORY14	1	COMB1 MIN	0	-0.12	0	-0.012	0	-0.125
STORY14	2	COMB1 MAX	0	0.12	0	0.012	0	0.125
STORY14	2	COMB1 MIN	0	-0.12	0	-0.012	0	-0.125
STORY14	3	COMB1 MAX	0	0	0	0	0	0
STORY14	3	COMB1 MIN	0	0	0	0	0	0
STORY14	4	COMB1 MAX	0	0	0	0	0	0
STORY14	4	COMB1 MIN	0	0	0	0	0	0

STORY14	5	COMB1 MAX	0	0	0	0	0	0
STORY14	5	COMB1 MIN	0	0	0	0	0	0
STORY13	1	COMB1 MAX	0	0.12	0	0.002	0	0.157
STORY13	1	COMB1 MIN	0	-0.12	0	-0.002	0	-0.157
STORY13	2	COMB1 MAX	0	0.12	0	0.002	0	0.157
STORY13	2	COMB1 MIN	0	-0.12	0	-0.002	0	-0.157
STORY13	3	COMB1 MAX	0	0	0	0	0	0
STORY13	3	COMB1 MIN	0	0	0	0	0	0
STORY13	4	COMB1 MAX	0	0	0	0	0	0
STORY13	4	COMB1 MIN	0	0	0	0	0	0
STORY13	5	COMB1 MAX	0	0	0	0	0	0
STORY13	5	COMB1 MIN	0	0	0	0	0	0
STORY12	1	COMB1 MAX	0	0.15	0	0.001	0	0.179
STORY12	1	COMB1 MIN	0	-0.15	0	-0.001	0	-0.179
STORY12	2	COMB1 MAX	0	0.15	0	0.001	0	0.179
STORY12	2	COMB1 MIN	0	-0.15	0	-0.001	0	-0.179
STORY12	3	COMB1 MAX	0	0	0	0	0	0
STORY12	3	COMB1 MIN	0	0	0	0	0	0
STORY12	4	COMB1 MAX	0	0	0	0	0	0
STORY12	4	COMB1 MIN	0	0	0	0	0	0
STORY12	5	COMB1 MAX	0	0	0	0	0	0
STORY12	5	COMB1 MIN	0	0	0	0	0	0
STORY11	1	COMB1 MAX	0	0.19	0	0	0	0.218
STORY11	1	COMB1 MIN	0	-0.19	0	0	0	-0.218
STORY11	2	COMB1 MAX	0	0.19	0	0	0	0.218
STORY11	2	COMB1 MIN	0	-0.19	0	0	0	-0.218
STORY11	3	COMB1 MAX	0	0	0	0	0	0
STORY11	3	COMB1 MIN	0	0	0	0	0	0
STORY11	4	COMB1 MAX	0	0	0	0	0	0
STORY11	4	COMB1 MIN	0	0	0	0	0	0
STORY11	5	COMB1 MAX	0	0	0	0	0	0
STORY11	5	COMB1 MIN	0	0	0	0	0	0
STORY10	1	COMB1 MAX	0	0.2	0	0	0	0.232
STORY10	1	COMB1 MIN	0	-0.2	0	0	0	-0.232
STORY10	2	COMB1 MAX	0	0.2	0	0	0	0.232
STORY10	2	COMB1 MIN	0	-0.2	0	0	0	-0.232
STORY10	3	COMB1 MAX	0	0	0	0	0	0
STORY10	3	COMB1 MIN	0	0	0	0	0	0
STORY10	4	COMB1 MAX	0	0	0	0	0	0
STORY10	4	COMB1 MIN	0	0	0	0	0	0
STORY10	5	COMB1 MAX	0	0	0	0	0	0
STORY10	5	COMB1 MIN	0	0	0	0	0	0
STORY9	1	COMB1 MAX	0	0.19	0	0	0	0.224
STORY9	1	COMB1 MIN	0	-0.19	0	0	0	-0.224
STORY9	2	COMB1 MAX	0	0.19	0	0	0	0.224
STORY9	2	COMB1 MIN	0	-0.19	0	0	0	-0.224
STORY9	3	COMB1 MAX	0	0	0	0	0	0
STORY9	3	COMB1 MIN	0	0	0	0	0	0
STORY9	4	COMB1 MAX	0	0	0	0	0	0

STORY9	4	COMB1 MIN	0	0	0	0	0	0
STORY9	5	COMB1 MAX	0	0	0	0	0	0
STORY9	5	COMB1 MIN	0	0	0	0	0	0
STORY8	1	COMB1 MAX	0	0.18	0	0	0	0.211
STORY8	1	COMB1 MIN	0	-0.18	0	0	0	-0.211
STORY8	2	COMB1 MAX	0	0.18	0	0	0	0.211
STORY8	2	COMB1 MIN	0	-0.18	0	0	0	-0.211
STORY8	3	COMB1 MAX	0	0	0	0	0	0
STORY8	3	COMB1 MIN	0	0	0	0	0	0
STORY8	4	COMB1 MAX	0	0	0	0	0	0
STORY8	4	COMB1 MIN	0	0	0	0	0	0
STORY8	5	COMB1 MAX	0	0	0	0	0	0
STORY8	5	COMB1 MIN	0	0	0	0	0	0
STORY7	1	COMB1 MAX	0	0.17	0	0	0	0.204
STORY7	1	COMB1 MIN	0	-0.17	0	0	0	-0.204
STORY7	2	COMB1 MAX	0	0.17	0	0	0	0.204
STORY7	2	COMB1 MIN	0	-0.17	0	0	0	-0.204
STORY7	3	COMB1 MAX	0	0	0	0	0	0
STORY7	3	COMB1 MIN	0	0	0	0	0	0
STORY7	4	COMB1 MAX	0	0	0	0	0	0
STORY7	4	COMB1 MIN	0	0	0	0	0	0
STORY7	5	COMB1 MAX	0	0	0	0	0	0
STORY7	5	COMB1 MIN	0	0	0	0	0	0
STORY6	1	COMB1 MAX	0	0.18	0	0	0	0.207
STORY6	1	COMB1 MIN	0	-0.18	0	0	0	-0.207
STORY6	2	COMB1 MAX	0	0.18	0	0	0	0.207
STORY6	2	COMB1 MIN	0	-0.18	0	0	0	-0.207
STORY6	3	COMB1 MAX	0	0	0	0	0	0
STORY6	3	COMB1 MIN	0	0	0	0	0	0
STORY6	4	COMB1 MAX	0	0	0	0	0	0
STORY6	4	COMB1 MIN	0	0	0	0	0	0
STORY6	5	COMB1 MAX	0	0	0	0	0	0
STORY6	5	COMB1 MIN	0	0	0	0	0	0
STORY5	1	COMB1 MAX	0	0.18	0	0	0	0.215
STORY5	1	COMB1 MIN	0	-0.18	0	0	0	-0.215
STORY5	2	COMB1 MAX	0	0.18	0	0	0	0.215
STORY5	2	COMB1 MIN	0	-0.18	0	0	0	-0.215
STORY5	3	COMB1 MAX	0	0	0	0	0	0
STORY5	3	COMB1 MIN	0	0	0	0	0	0
STORY5	4	COMB1 MAX	0	0	0	0	0	0
STORY5	4	COMB1 MIN	0	0	0	0	0	0
STORY5	5	COMB1 MAX	0	0	0	0	0	0
STORY5	5	COMB1 MIN	0	0	0	0	0	0
STORY4	1	COMB1 MAX	0	0.19	0	0	0	0.221
STORY4	1	COMB1 MIN	0	-0.19	0	0	0	-0.221
STORY4	2	COMB1 MAX	0	0.19	0	0	0	0.221
STORY4	2	COMB1 MIN	0	-0.19	0	0	0	-0.221
STORY4	3	COMB1 MAX	0	0	0	0	0	0
STORY4	3	COMB1 MIN	0	0	0	0	0	0

STORY4	4	COMB1 MAX	0	0	0	0	0	0
STORY4	4	COMB1 MIN	0	0	0	0	0	0
STORY4	5	COMB1 MAX	0	0	0	0	0	0
STORY4	5	COMB1 MIN	0	0	0	0	0	0
STORY3	1	COMB1 MAX	0	0.19	0	0	0	0.221
STORY3	1	COMB1 MIN	0	-0.19	0	0	0	-0.221
STORY3	2	COMB1 MAX	0	0.19	0	0	0	0.221
STORY3	2	COMB1 MIN	0	-0.19	0	0	0	-0.221
STORY3	3	COMB1 MAX	0	0	0	0	0	0
STORY3	3	COMB1 MIN	0	0	0	0	0	0
STORY3	4	COMB1 MAX	0	0	0	0	0	0
STORY3	4	COMB1 MIN	0	0	0	0	0	0
STORY3	5	COMB1 MAX	0	0	0	0	0	0
STORY3	5	COMB1 MIN	0	0	0	0	0	0
STORY2	1	COMB1 MAX	0	0.19	0	0.002	0	0.218
STORY2	1	COMB1 MIN	0	-0.19	0	-0.002	0	-0.218
STORY2	2	COMB1 MAX	0	0.19	0	0.002	0	0.218
STORY2	2	COMB1 MIN	0	-0.19	0	-0.002	0	-0.218
STORY2	3	COMB1 MAX	0	0	0	0	0	0
STORY2	3	COMB1 MIN	0	0	0	0	0	0
STORY2	4	COMB1 MAX	0	0	0	0	0	0
STORY2	4	COMB1 MIN	0	0	0	0	0	0
STORY2	5	COMB1 MAX	0	0	0	0	0	0
STORY2	5	COMB1 MIN	0	0	0	0	0	0
STORY1	1	COMB1 MAX	0	0.19	0	0.001	0	0.2
STORY1	1	COMB1 MIN	0	-0.19	0	-0.001	0	-0.2
STORY1	2	COMB1 MAX	0	0.19	0	0.001	0	0.2
STORY1	2	COMB1 MIN	0	-0.19	0	-0.001	0	-0.2
STORY1	3	COMB1 MAX	0	0	0	0	0	0
STORY1	3	COMB1 MIN	0	0	0	0	0	0
STORY1	4	COMB1 MAX	0	0	0	0	0	0
STORY1	4	COMB1 MIN	0	0	0	0	0	0
STORY1	5	COMB1 MAX	0	0	0	0	0	0
STORY1	5	COMB1 MIN	0	0	0	0	0	0
BASE	1	COMB1 MAX	23.45	0.04	80.3	0.002	0.578	0.003
BASE	1	COMB1 MIN	-8.65	-0.04	-31.02	-0.002	-0.249	-0.003
BASE	2	COMB1 MAX	8.6	0.04	80.31	0.002	0.249	0.003
BASE	2	COMB1 MIN	-23.44	-0.04	-30.83	-0.002	-0.576	-0.003
BASE	3	COMB1 MAX	0.73	0	76.24	0	3.173	0
BASE	3	COMB1 MIN	-0.3	0	36.87	0	-2.408	0
BASE	4	COMB1 MAX	0.55	0	75.4	0	2.752	0
BASE	4	COMB1 MIN	-0.75	0	61.09	0	-3.214	0
BASE	5	COMB1 MAX	0.27	0	69.49	0	2.386	0
BASE	5	COMB1 MIN	-0.67	0	43.55	0	-3.119	0
BASE	6	COMB1 MAX	2.68	0.03	116.74	0.008	1.191	0.001
BASE	6	COMB1 MIN	-3.01	-0.03	-31.86	-0.008	-0.608	-0.001
BASE	7	COMB1 MAX	3.07	0.03	116.75	0.008	0.609	0.001
BASE	7	COMB1 MIN	-2.63	-0.03	-31.52	-0.008	-1.187	-0.001
BASE	8	COMB1 MAX	3.37	0.01	69.84	0.01	1.129	0

BASE	8	COMB1 MIN	-1.11	-0.01	16.52	-0.01	-0.873	0
BASE	9	COMB1 MAX	1.16	0.01	69.73	0.01	0.878	0
BASE	9	COMB1 MIN	-3.3	-0.01	16.77	-0.01	-1.123	0

Support reactions at each point per floor for the third model:

STORY	POINT	LOAD	FX	FY	FZ	MX	MY	MZ
STORY14	1	COMB1 MAX	0	0.15	0	0.025	0	0.095
STORY14	1	COMB1 MIN	0	-0.15	0	-0.025	0	-0.095
STORY14	2	COMB1 MAX	0	0.15	0	0.025	0	0.095
STORY14	2	COMB1 MIN	0	-0.15	0	-0.025	0	-0.095
STORY14	3	COMB1 MAX	0	0	0	0	0	0
STORY14	3	COMB1 MIN	0	0	0	0	0	0
STORY14	4	COMB1 MAX	0	0	0	0	0	0
STORY14	4	COMB1 MIN	0	0	0	0	0	0
STORY14	5	COMB1 MAX	0	0	0	0	0	0
STORY14	5	COMB1 MIN	0	0	0	0	0	0
STORY13	1	COMB1 MAX	0	0.18	0	0.004	0	0.14
STORY13	1	COMB1 MIN	0	-0.18	0	-0.004	0	-0.14
STORY13	2	COMB1 MAX	0	0.18	0	0.004	0	0.14
STORY13	2	COMB1 MIN	0	-0.18	0	-0.004	0	-0.14
STORY13	3	COMB1 MAX	0	0	0	0	0	0
STORY13	3	COMB1 MIN	0	0	0	0	0	0
STORY13	4	COMB1 MAX	0	0	0	0	0	0
STORY13	4	COMB1 MIN	0	0	0	0	0	0
STORY13	5	COMB1 MAX	0	0	0	0	0	0
STORY13	5	COMB1 MIN	0	0	0	0	0	0
STORY12	1	COMB1 MAX	0	0.2	0	0.002	0	0.139
STORY12	1	COMB1 MIN	0	-0.2	0	-0.002	0	-0.139
STORY12	2	COMB1 MAX	0	0.2	0	0.002	0	0.139
STORY12	2	COMB1 MIN	0	-0.2	0	-0.002	0	-0.139
STORY12	3	COMB1 MAX	0	0	0	0	0	0
STORY12	3	COMB1 MIN	0	0	0	0	0	0
STORY12	4	COMB1 MAX	0	0	0	0	0	0
STORY12	4	COMB1 MIN	0	0	0	0	0	0
STORY12	5	COMB1 MAX	0	0	0	0	0	0
STORY12	5	COMB1 MIN	0	0	0	0	0	0
STORY11	1	COMB1 MAX	0	0.2	0	0.001	0	0.143
STORY11	1	COMB1 MIN	0	-0.2	0	-0.001	0	-0.143
STORY11	2	COMB1 MAX	0	0.2	0	0.001	0	0.143
STORY11	2	COMB1 MIN	0	-0.2	0	-0.001	0	-0.143
STORY11	3	COMB1 MAX	0	0	0	0	0	0
STORY11	3	COMB1 MIN	0	0	0	0	0	0
STORY11	4	COMB1 MAX	0	0	0	0	0	0
STORY11	4	COMB1 MIN	0	0	0	0	0	0
STORY11	5	COMB1 MAX	0	0	0	0	0	0
STORY11	5	COMB1 MIN	0	0	0	0	0	0

STORY10	1	COMB1 MAX	0	0.21	0	0.001	0	0.147
STORY10	1	COMB1 MIN	0	-0.21	0	-0.001	0	-0.147
STORY10	2	COMB1 MAX	0	0.21	0	0.001	0	0.147
STORY10	2	COMB1 MIN	0	-0.21	0	-0.001	0	-0.147
STORY10	3	COMB1 MAX	0	0	0	0	0	0
STORY10	3	COMB1 MIN	0	0	0	0	0	0
STORY10	4	COMB1 MAX	0	0	0	0	0	0
STORY10	4	COMB1 MIN	0	0	0	0	0	0
STORY10	5	COMB1 MAX	0	0	0	0	0	0
STORY10	5	COMB1 MIN	0	0	0	0	0	0
STORY9	1	COMB1 MAX	0	0.21	0	0.001	0	0.148
STORY9	1	COMB1 MIN	0	-0.21	0	-0.001	0	-0.148
STORY9	2	COMB1 MAX	0	0.21	0	0.001	0	0.148
STORY9	2	COMB1 MIN	0	-0.21	0	-0.001	0	-0.148
STORY9	3	COMB1 MAX	0	0	0	0	0	0
STORY9	3	COMB1 MIN	0	0	0	0	0	0
STORY9	4	COMB1 MAX	0	0	0	0	0	0
STORY9	4	COMB1 MIN	0	0	0	0	0	0
STORY9	5	COMB1 MAX	0	0	0	0	0	0
STORY9	5	COMB1 MIN	0	0	0	0	0	0
STORY8	1	COMB1 MAX	0	0.21	0	0.001	0	0.148
STORY8	1	COMB1 MIN	0	-0.21	0	-0.001	0	-0.148
STORY8	2	COMB1 MAX	0	0.21	0	0.001	0	0.148
STORY8	2	COMB1 MIN	0	-0.21	0	-0.001	0	-0.148
STORY8	3	COMB1 MAX	0	0	0	0	0	0
STORY8	3	COMB1 MIN	0	0	0	0	0	0
STORY8	4	COMB1 MAX	0	0	0	0	0	0
STORY8	4	COMB1 MIN	0	0	0	0	0	0
STORY8	5	COMB1 MAX	0	0	0	0	0	0
STORY8	5	COMB1 MIN	0	0	0	0	0	0
STORY7	1	COMB1 MAX	0	0.21	0	0.001	0	0.149
STORY7	1	COMB1 MIN	0	-0.21	0	-0.001	0	-0.149
STORY7	2	COMB1 MAX	0	0.21	0	0.001	0	0.149
STORY7	2	COMB1 MIN	0	-0.21	0	-0.001	0	-0.149
STORY7	3	COMB1 MAX	0	0	0	0	0	0
STORY7	3	COMB1 MIN	0	0	0	0	0	0
STORY7	4	COMB1 MAX	0	0	0	0	0	0
STORY7	4	COMB1 MIN	0	0	0	0	0	0
STORY7	5	COMB1 MAX	0	0	0	0	0	0
STORY7	5	COMB1 MIN	0	0	0	0	0	0
STORY6	1	COMB1 MAX	0	0.21	0	0.001	0	0.15
STORY6	1	COMB1 MIN	0	-0.21	0	-0.001	0	-0.15
STORY6	2	COMB1 MAX	0	0.21	0	0.001	0	0.15
STORY6	2	COMB1 MIN	0	-0.21	0	-0.001	0	-0.15
STORY6	3	COMB1 MAX	0	0	0	0	0	0
STORY6	3	COMB1 MIN	0	0	0	0	0	0
STORY6	4	COMB1 MAX	0	0	0	0	0	0
STORY6	4	COMB1 MIN	0	0	0	0	0	0
STORY6	5	COMB1 MAX	0	0	0	0	0	0

STORY6	5	COMB1 MIN	0	0	0	0	0	0
STORY5	1	COMB1 MAX	0	0.22	0	0.001	0	0.153
STORY5	1	COMB1 MIN	0	-0.22	0	-0.001	0	-0.153
STORY5	2	COMB1 MAX	0	0.22	0	0.001	0	0.153
STORY5	2	COMB1 MIN	0	-0.22	0	-0.001	0	-0.153
STORY5	3	COMB1 MAX	0	0	0	0	0	0
STORY5	3	COMB1 MIN	0	0	0	0	0	0
STORY5	4	COMB1 MAX	0	0	0	0	0	0
STORY5	4	COMB1 MIN	0	0	0	0	0	0
STORY5	5	COMB1 MAX	0	0	0	0	0	0
STORY5	5	COMB1 MIN	0	0	0	0	0	0
STORY4	1	COMB1 MAX	0	0.22	0	0.002	0	0.155
STORY4	1	COMB1 MIN	0	-0.22	0	-0.002	0	-0.155
STORY4	2	COMB1 MAX	0	0.22	0	0.002	0	0.155
STORY4	2	COMB1 MIN	0	-0.22	0	-0.002	0	-0.155
STORY4	3	COMB1 MAX	0	0	0	0	0	0
STORY4	3	COMB1 MIN	0	0	0	0	0	0
STORY4	4	COMB1 MAX	0	0	0	0	0	0
STORY4	4	COMB1 MIN	0	0	0	0	0	0
STORY4	5	COMB1 MAX	0	0	0	0	0	0
STORY4	5	COMB1 MIN	0	0	0	0	0	0
STORY3	1	COMB1 MAX	0	0.23	0	0.002	0	0.155
STORY3	1	COMB1 MIN	0	-0.23	0	-0.002	0	-0.155
STORY3	2	COMB1 MAX	0	0.23	0	0.002	0	0.155
STORY3	2	COMB1 MIN	0	-0.23	0	-0.002	0	-0.155
STORY3	3	COMB1 MAX	0	0	0	0	0	0
STORY3	3	COMB1 MIN	0	0	0	0	0	0
STORY3	4	COMB1 MAX	0	0	0	0	0	0
STORY3	4	COMB1 MIN	0	0	0	0	0	0
STORY3	5	COMB1 MAX	0	0	0	0	0	0
STORY3	5	COMB1 MIN	0	0	0	0	0	0
STORY2	1	COMB1 MAX	0	0.22	0	0.003	0	0.145
STORY2	1	COMB1 MIN	0	-0.22	0	-0.003	0	-0.145
STORY2	2	COMB1 MAX	0	0.22	0	0.003	0	0.145
STORY2	2	COMB1 MIN	0	-0.22	0	-0.003	0	-0.145
STORY2	3	COMB1 MAX	0	0	0	0	0	0
STORY2	3	COMB1 MIN	0	0	0	0	0	0
STORY2	4	COMB1 MAX	0	0	0	0	0	0
STORY2	4	COMB1 MIN	0	0	0	0	0	0
STORY2	5	COMB1 MAX	0	0	0	0	0	0
STORY2	5	COMB1 MIN	0	0	0	0	0	0
STORY1	1	COMB1 MAX	0	0.17	0	0.008	0	0.115
STORY1	1	COMB1 MIN	0	-0.17	0	-0.008	0	-0.115
STORY1	2	COMB1 MAX	0	0.17	0	0.008	0	0.115
STORY1	2	COMB1 MIN	0	-0.17	0	-0.008	0	-0.115
STORY1	3	COMB1 MAX	0	0	0	0	0	0
STORY1	3	COMB1 MIN	0	0	0	0	0	0
STORY1	4	COMB1 MAX	0	0	0	0	0	0
STORY1	4	COMB1 MIN	0	0	0	0	0	0

STORY1	5	COMB1 MAX	0	0	0	0	0	0
STORY1	5	COMB1 MIN	0	0	0	0	0	0
BASE	1	COMB1 MAX	16.99	0.01	102.49	0.005	1.731	0.002
BASE	1	COMB1 MIN	-5.69	-0.01	-37.33	-0.005	-0.906	-0.002
BASE	2	COMB1 MAX	5.67	0.01	102.46	0.005	0.905	0.002
BASE	2	COMB1 MIN	-16.94	-0.01	-37.06	-0.005	-1.728	-0.002
BASE	3	COMB1 MAX	0.77	0	77.04	0	3.449	0
BASE	3	COMB1 MIN	-0.34	0	36.3	0	-2.672	0
BASE	4	COMB1 MAX	0.6	0	75.67	0	3.042	0
BASE	4	COMB1 MIN	-0.81	0	61.07	0	-3.515	0
BASE	5	COMB1 MAX	0.31	0	70.05	0	2.657	0
BASE	5	COMB1 MIN	-0.71	0	43.02	0	-3.396	0
BASE	18	COMB1 MAX	4.3	0.03	113.07	0.037	1.441	0.001
BASE	18	COMB1 MIN	0.14	-0.03	4.22	-0.037	-1.099	-0.001
BASE	19	COMB1 MAX	-0.08	0.03	112.9	0.037	1.103	0.001
BASE	19	COMB1 MIN	-4.21	-0.03	4.62	-0.037	-1.433	-0.001

Pier forces of the wall for the second model:

STORY	PIER	LOAD	Loc	P	V2	V3	T	M2	M3
STORY14	P1	COMB1 MAX	Top	-1.79	2.88	0	0	0.024	14.572
STORY14	P1	COMB1 MAX	Bottom	-15.46	2.88	0	0	0.02	22.767
STORY14	P1	COMB1 MIN	Top	-1.8	-3.01	0	0	-0.024	-14.1
STORY14	P1	COMB1 MIN	Bottom	-15.48	-3.01	0	0	-0.02	-22.687
STORY13	P1	COMB1 MAX	Top	-17.18	4.07	0.01	0	0.017	39.095
STORY13	P1	COMB1 MAX	Bottom	-30.86	4.07	0.01	0	0.002	30.092
STORY13	P1	COMB1 MIN	Top	-17.32	-4.26	-0.01	0	-0.017	-38.365
STORY13	P1	COMB1 MIN	Bottom	-30.99	-4.26	-0.01	0	-0.002	-29.935
STORY12	P1	COMB1 MAX	Top	-32.59	8.06	0	0	0.004	46.077
STORY12	P1	COMB1 MAX	Bottom	-46.26	8.06	0	0	0.003	28.647
STORY12	P1	COMB1 MIN	Top	-32.84	-8.19	0	0	-0.004	-45.324
STORY12	P1	COMB1 MIN	Bottom	-46.51	-8.19	0	0	-0.003	-28.274
STORY11	P1	COMB1 MAX	Top	-47.99	11.55	0	0	0.003	43.031
STORY11	P1	COMB1 MAX	Bottom	-61.66	11.55	0	0	0.004	26.829
STORY11	P1	COMB1 MIN	Top	-48.35	-11.68	0	0	-0.003	-42.077
STORY11	P1	COMB1 MIN	Bottom	-62.02	-11.68	0	0	-0.004	-26.273
STORY10	P1	COMB1 MAX	Top	-63.39	14.64	0	0	0.004	34.456
STORY10	P1	COMB1 MAX	Bottom	-77.06	14.64	0	0	0.005	39.378
STORY10	P1	COMB1 MIN	Top	-63.85	-14.77	0	0	-0.004	-33.351
STORY10	P1	COMB1 MIN	Bottom	-77.52	-14.77	0	0	-0.005	-38.647
STORY9	P1	COMB1 MAX	Top	-78.8	17.38	0	0	0.005	33.432
STORY9	P1	COMB1 MAX	Bottom	-92.47	17.38	0	0	0.006	67.643
STORY9	P1	COMB1 MIN	Top	-79.34	-17.5	0	0	-0.005	-32.188
STORY9	P1	COMB1 MIN	Bottom	-93.01	-17.5	0	0	-0.006	-66.743
STORY8	P1	COMB1 MAX	Top	-94.21	19.82	0	0	0.006	54.578
STORY8	P1	COMB1 MAX	Bottom	-107.88	19.82	0	0	0.006	106.181

STORY8	P1	COMB1 MIN	Top	-94.82	-19.93	0	0	-0.006	-53.211
STORY8	P1	COMB1 MIN	Bottom	-108.49	-19.93	0	0	-0.006	-105.128
STORY7	P1	COMB1 MAX	Top	-109.61	22	0	0	0.006	91.289
STORY7	P1	COMB1 MAX	Bottom	-123.29	22	0	0	0.006	152.691
STORY7	P1	COMB1 MIN	Top	-110.29	-22.08	0	0	-0.006	-89.821
STORY7	P1	COMB1 MIN	Bottom	-123.96	-22.08	0	0	-0.006	-151.471
STORY6	P1	COMB1 MAX	Top	-125.03	24.09	0	0	0.006	137.717
STORY6	P1	COMB1 MAX	Bottom	-138.7	24.09	0	0	0.005	206.65
STORY6	P1	COMB1 MIN	Top	-125.75	-24.17	0	0	-0.006	-136.15
STORY6	P1	COMB1 MIN	Bottom	-139.42	-24.17	0	0	-0.005	-205.346
STORY5	P1	COMB1 MAX	Top	-140.43	25.12	0	0	0.005	192.316
STORY5	P1	COMB1 MAX	Bottom	-154.1	25.12	0	0	0.005	264.974
STORY5	P1	COMB1 MIN	Top	-141.19	-25.18	0	0	-0.005	-190.705
STORY5	P1	COMB1 MIN	Bottom	-154.86	-25.18	0	0	-0.005	-263.538
STORY4	P1	COMB1 MAX	Top	-155.84	27.14	0	0	0.005	251.901
STORY4	P1	COMB1 MAX	Bottom	-169.51	27.14	0	0	0.005	331.036
STORY4	P1	COMB1 MIN	Top	-156.65	-27.21	0	0	-0.005	-250.196
STORY4	P1	COMB1 MIN	Bottom	-170.32	-27.21	0	0	-0.005	-329.537
STORY3	P1	COMB1 MAX	Top	-171.27	28.61	0	0	0.005	319.925
STORY3	P1	COMB1 MAX	Bottom	-184.94	28.61	0	0	0.007	403.801
STORY3	P1	COMB1 MIN	Top	-172.12	-28.64	0	0	-0.005	-318.221
STORY3	P1	COMB1 MIN	Bottom	-185.79	-28.64	0	0	-0.007	-402.185
STORY2	P1	COMB1 MAX	Top	-186.72	30.01	0.01	0	0.011	395.206
STORY2	P1	COMB1 MAX	Bottom	-200.4	30.01	0.01	0	0.017	483.625
STORY2	P1	COMB1 MIN	Top	-187.6	-29.96	-0.01	0	-0.011	-393.453
STORY2	P1	COMB1 MIN	Bottom	-201.27	-29.96	-0.01	0	-0.017	-481.742
STORY1	P1	COMB1 MAX	Top	-202.2	30.61	0.01	0	0.018	478.06
STORY1	P1	COMB1 MAX	Bottom	-220.42	30.61	0.01	0	0.033	598.956
STORY1	P1	COMB1 MIN	Top	-203.08	-30.79	-0.01	0	-0.018	-476.131
STORY1	P1	COMB1 MIN	Bottom	-221.31	-30.79	-0.01	0	-0.033	-597.735

Pier forces of the wall for the third model:

STORY	PIER	LOAD	Loc	P	V2	V3	T	M2	M3
STORY14	P1	COMB1 MAX	Top	-1.76	3.07	0.03	0	0.050	13.844
STORY14	P1	COMB1 MAX	Bottom	-12.78	3.07	0.03	0	0.028	22.705
STORY14	P1	COMB1 MIN	Top	-1.77	-3.21	-0.03	0	-0.050	-13.405
STORY14	P1	COMB1 MIN	Bottom	-12.8	-3.21	-0.03	0	-0.028	-22.687
STORY13	P1	COMB1 MAX	Top	-14.48	3.08	0.00	0	0.020	38.732
STORY13	P1	COMB1 MAX	Bottom	-25.51	3.08	0.00	0	0.029	32.586
STORY13	P1	COMB1 MIN	Top	-14.62	-3.28	0.00	0	-0.020	-38.088
STORY13	P1	COMB1 MIN	Bottom	-25.65	-3.28	0.00	0	-0.029	-32.538
STORY12	P1	COMB1 MAX	Top	-27.21	6.32	0.00	0	0.027	48.584
STORY12	P1	COMB1 MAX	Bottom	-38.24	6.32	0.00	0	0.030	34.274
STORY12	P1	COMB1 MIN	Top	-27.47	-6.46	0.00	0	-0.027	-47.963
STORY12	P1	COMB1 MIN	Bottom	-38.49	-6.46	0.00	0	-0.030	-34.053
STORY11	P1	COMB1 MAX	Top	-39.95	9.17	0.00	0	0.029	49.795

STORY11	P1	COMB1 MAX	Bottom	-50.97	9.17	0.00	0	0.03	30.991
STORY11	P1	COMB1 MIN	Top	-40.31	-9.31	0.00	0	-0.029	-49.016
STORY11	P1	COMB1 MIN	Bottom	-51.34	-9.31	0.00	0	-0.03	-30.631
STORY10	P1	COMB1 MAX	Top	-52.68	11.70	0.00	0	0.03	44.381
STORY10	P1	COMB1 MAX	Bottom	-63.71	11.70	0.00	0	0.031	29.203
STORY10	P1	COMB1 MIN	Top	-53.15	-11.83	0.00	0	-0.03	-43.491
STORY10	P1	COMB1 MIN	Bottom	-64.17	-11.83	0.00	0	-0.031	-28.706
STORY9	P1	COMB1 MAX	Top	-65.42	13.96	0.00	0	0.03	35.763
STORY9	P1	COMB1 MAX	Bottom	-76.45	13.96	0.00	0	0.029	38.91
STORY9	P1	COMB1 MIN	Top	-65.97	-14.08	0.00	0	-0.03	-34.773
STORY9	P1	COMB1 MIN	Bottom	-77.00	-14.08	0.00	0	-0.029	-38.281
STORY8	P1	COMB1 MAX	Top	-78.16	16.00	0.00	0	0.029	33.191
STORY8	P1	COMB1 MAX	Bottom	-89.19	16.00	0.00	0	0.03	61.484
STORY8	P1	COMB1 MIN	Top	-78.79	-16.11	0.00	0	-0.029	-32.113
STORY8	P1	COMB1 MIN	Bottom	-89.81	-16.11	0.00	0	-0.03	-60.737
STORY7	P1	COMB1 MAX	Top	-90.91	17.85	0.00	0	0.029	48.335
STORY7	P1	COMB1 MAX	Bottom	-101.94	17.85	0.00	0	0.03	93.039
STORY7	P1	COMB1 MIN	Top	-91.59	-17.94	0.00	0	-0.029	-47.188
STORY7	P1	COMB1 MIN	Bottom	-102.62	-17.94	0.00	0	-0.03	-92.154
STORY6	P1	COMB1 MAX	Top	-103.66	19.72	0.00	0	0.03	77.899
STORY6	P1	COMB1 MAX	Bottom	-114.68	19.72	0.00	0	0.031	132.115
STORY6	P1	COMB1 MIN	Top	-104.39	-19.81	0.00	0	-0.03	-76.681
STORY6	P1	COMB1 MIN	Bottom	-115.41	-19.81	0.00	0	-0.031	-131.172
STORY5	P1	COMB1 MAX	Top	-116.40	20.52	0.00	0	0.031	116.963
STORY5	P1	COMB1 MAX	Bottom	-127.42	20.52	0.00	0	0.033	175.23
STORY5	P1	COMB1 MIN	Top	-117.17	-20.58	0.00	0	-0.031	-115.724
STORY5	P1	COMB1 MIN	Bottom	-128.20	-20.58	0.00	0	-0.033	-174.179
STORY4	P1	COMB1 MAX	Top	-129.15	22.44	0.01	0	0.032	161.122
STORY4	P1	COMB1 MAX	Bottom	-140.18	22.44	0.01	0	0.037	225.983
STORY4	P1	COMB1 MIN	Top	-129.97	-22.52	-0.01	0	-0.032	-159.811
STORY4	P1	COMB1 MIN	Bottom	-141.00	-22.52	-0.01	0	-0.037	-224.887
STORY3	P1	COMB1 MAX	Top	-141.93	23.87	0.01	0	0.037	213.829
STORY3	P1	COMB1 MAX	Bottom	-152.95	23.87	0.01	0	0.04	283.535
STORY3	P1	COMB1 MIN	Top	-142.78	-23.90	-0.01	0	-0.037	-212.536
STORY3	P1	COMB1 MIN	Bottom	-153.81	-23.90	-0.01	0	-0.04	-282.335
STORY2	P1	COMB1 MAX	Top	-154.73	25.30	0.01	0	0.04	274.048
STORY2	P1	COMB1 MAX	Bottom	-165.75	25.30	0.01	0	0.05	348.488
STORY2	P1	COMB1 MIN	Top	-155.61	-25.26	-0.01	0	-0.04	-272.717
STORY2	P1	COMB1 MIN	Bottom	-166.63	-25.26	-0.01	0	-0.05	-347.03
STORY1	P1	COMB1 MAX	Top	-167.55	26.04	0.04	0	0.065	342.331
STORY1	P1	COMB1 MAX	Bottom	-182.25	26.04	0.04	0	0.083	445.177
STORY1	P1	COMB1 MIN	Top	-168.43	-26.22	-0.04	0	-0.065	-340.83
STORY1	P1	COMB1 MIN	Bottom	-183.13	-26.22	-0.04	0	-0.083	-444.392

Story shears for the first model

Story	Load	Loc	P	VX	VY	T	MX	MY
STORY14	KII028	Top	0	2.91	0.05	0.345	0.068	0.00
STORY14	KII028	Bottom	0	2.91	0.05	0.345	0.070	8.740
STORY13	KII028	Top	0	7.10	0.02	0.135	0.027	8.740
STORY13	KII028	Bottom	0	7.10	0.02	0.135	0.039	30.017
STORY12	KII028	Top	0	10.72	0.02	0.150	0.033	30.017
STORY12	KII028	Bottom	0	10.72	0.02	0.150	0.031	62.103
STORY11	KII028	Top	0	13.87	0.01	0.074	0.017	62.103
STORY11	KII028	Bottom	0	13.87	0.01	0.074	0.018	103.495
STORY10	KII028	Top	0	16.60	0.01	0.096	0.020	103.495
STORY10	KII028	Bottom	0	16.60	0.01	0.096	0.020	152.896
STORY9	KII028	Top	0	18.98	0.01	0.041	0.011	152.896
STORY9	KII028	Bottom	0	18.98	0.01	0.041	0.010	209.175
STORY8	KII028	Top	0	21.05	0.01	0.073	0.015	209.175
STORY8	KII028	Bottom	0	21.05	0.01	0.073	0.015	271.337
STORY7	KII028	Top	0	22.82	0.00	0.023	0.008	271.337
STORY7	KII028	Bottom	0	22.82	0.00	0.023	0.006	338.494
STORY6	KII028	Top	0	24.32	0.01	0.061	0.012	338.494
STORY6	KII028	Bottom	0	24.32	0.01	0.061	0.013	409.828
STORY5	KII028	Top	0	25.61	0.00	0.021	0.008	409.828
STORY5	KII028	Bottom	0	25.61	0.00	0.021	0.005	484.730
STORY4	KII028	Top	0	26.67	0.01	0.061	0.012	484.730
STORY4	KII028	Bottom	0	26.67	0.01	0.061	0.013	562.560
STORY3	KII028	Top	0	27.41	0.01	0.054	0.013	562.560
STORY3	KII028	Bottom	0	27.41	0.01	0.054	0.010	642.543
STORY2	KII028	Top	0	27.85	0.02	0.150	0.009	642.543
STORY2	KII028	Bottom	0	27.85	0.02	0.150	0.055	723.952
STORY1	KII028	Top	0	28.07	0.07	0.518	0.122	723.952
STORY1	KII028	Bottom	0	28.07	0.07	0.518	0.155	833.726

Story shears for the second model.

Story	Load	Loc	P	VX	VY	T	MX	MY
STORY14	COMB1 MAX	Top	5.51	3.32	0.00	0.011	0.024	-59.719
STORY14	COMB1 MAX	Bottom	27.12	3.32	0.00	0.011	0.020	-244.893
STORY14	COMB1 MIN	Top	5.51	-3.32	0.00	-0.011	-0.024	-59.719
STORY14	COMB1 MIN	Bottom	27.12	-3.32	0.00	-0.011	-0.020	-264.829
STORY13	COMB1 MAX	Top	32.63	8.21	0.01	0.038	0.017	-304.612
STORY13	COMB1 MAX	Bottom	54.24	8.21	0.01	0.038	0.002	-475.143
STORY13	COMB1 MIN	Top	32.63	-8.21	-0.01	-0.038	-0.017	-324.548
STORY13	COMB1 MIN	Bottom	54.24	-8.21	-0.01	-0.038	-0.002	-544.302
STORY12	COMB1 MAX	Top	59.76	12.46	0.00	0.004	0.004	-534.862
STORY12	COMB1 MAX	Bottom	81.36	12.46	0.00	0.004	0.003	-692.710
STORY12	COMB1 MIN	Top	59.76	-12.46	0.00	-0.004	-0.004	-604.021
STORY12	COMB1 MIN	Bottom	81.36	-12.46	0.00	-0.004	-0.003	-836.457

STORY11	COMB1 MAX	Top	86.88	16.15	0.00	0.004	0.003	-752.429
STORY11	COMB1 MAX	Bottom	108.49	16.15	0.00	0.004	0.004	-899.336
STORY11	COMB1 MIN	Top	86.88	-16.15	0.00	-0.004	-0.003	-896.176
STORY11	COMB1 MIN	Bottom	108.49	-16.15	0.00	-0.004	-0.004	-1139.550
STORY10	COMB1 MAX	Top	114	19.35	0.00	0.004	0.004	-959.055
STORY10	COMB1 MAX	Bottom	135.61	19.35	0.00	0.004	0.005	-1096.549
STORY10	COMB1 MIN	Top	114	-19.35	0.00	-0.004	-0.004	-1199.273
STORY10	COMB1 MIN	Bottom	135.61	-19.35	0.00	-0.004	-0.005	-1452.063
STORY9	COMB1 MAX	Top	141.12	22.12	0.00	0.003	0.005	-1156.268
STORY9	COMB1 MAX	Bottom	162.73	22.12	0.00	0.003	0.006	-1285.698
STORY9	COMB1 MIN	Top	141.12	-22.12	0.00	-0.003	-0.005	-1511.782
STORY9	COMB1 MIN	Bottom	162.73	-22.12	0.00	-0.003	-0.006	-1772.637
STORY8	COMB1 MAX	Top	168.24	24.51	0.00	0.001	0.006	-1345.417
STORY8	COMB1 MAX	Bottom	189.85	24.51	0.00	0.001	0.006	-1467.988
STORY8	COMB1 MIN	Top	168.24	-24.51	0.00	-0.001	-0.006	-1832.356
STORY8	COMB1 MIN	Bottom	189.85	-24.51	0.00	-0.001	-0.006	-2100.07
STORY7	COMB1 MAX	Top	195.36	26.54	0.00	0.002	0.006	-1527.706
STORY7	COMB1 MAX	Bottom	216.97	26.54	0.00	0.002	0.006	-1644.506
STORY7	COMB1 MIN	Top	195.36	-26.54	0.00	-0.002	-0.006	-2159.789
STORY7	COMB1 MIN	Bottom	216.97	-26.54	0.00	-0.002	-0.006	-2433.274
STORY6	COMB1 MAX	Top	222.48	28.23	0.00	0.002	0.006	-1704.224
STORY6	COMB1 MAX	Bottom	244.09	28.23	0.00	0.002	0.005	-1816.253
STORY6	COMB1 MIN	Top	222.48	-28.23	0.00	-0.002	-0.006	-2492.993
STORY6	COMB1 MIN	Bottom	244.09	-28.23	0.00	-0.002	-0.005	-2771.25
STORY5	COMB1 MAX	Top	249.61	29.67	0.00	0.001	0.005	-1875.972
STORY5	COMB1 MAX	Bottom	274.08	29.67	0.00	0.001	0.005	-2017.440
STORY5	COMB1 MIN	Top	249.61	-29.67	0.00	-0.001	-0.005	-2830.968
STORY5	COMB1 MIN	Bottom	274.08	-29.67	0.00	-0.001	-0.005	-3146.670
STORY4	COMB1 MAX	Top	279.59	30.82	0.00	0.001	0.005	-2077.159
STORY4	COMB1 MAX	Bottom	304.07	30.82	0.00	0.001	0.005	-2215.405
STORY4	COMB1 MIN	Top	279.59	-30.82	0.00	-0.001	-0.005	-3206.389
STORY4	COMB1 MIN	Bottom	304.07	-30.82	0.00	-0.001	-0.005	-3525.313
STORY3	COMB1 MAX	Top	309.58	31.62	0.00	0.006	0.005	-2275.124
STORY3	COMB1 MAX	Bottom	334.06	31.62	0.00	0.006	0.007	-2411.042
STORY3	COMB1 MIN	Top	309.58	-31.62	0.00	-0.006	-0.005	-3585.031
STORY3	COMB1 MIN	Bottom	334.06	-31.62	0.00	-0.006	-0.007	-3906.283
STORY2	COMB1 MAX	Top	339.57	32.1	0.01	0.072	0.011	-2470.76
STORY2	COMB1 MAX	Bottom	364.05	32.1	0.01	0.072	0.017	-2605.162
STORY2	COMB1 MIN	Top	339.57	-32.1	-0.01	-0.072	-0.011	-3966.002
STORY2	COMB1 MIN	Bottom	364.05	-32.1	-0.01	-0.072	-0.017	-4288.770
STORY1	COMB1 MAX	Top	369.56	32.33	0.01	0.097	0.018	-2664.881
STORY1	COMB1 MAX	Bottom	402.19	32.33	0.01	0.097	0.033	-2842.798
STORY1	COMB1 MIN	Top	369.56	-32.33	-0.01	-0.097	-0.018	-4348.489
STORY1	COMB1 MIN	Bottom	402.19	-32.33	-0.01	-0.097	-0.033	-4780.132

Story shears for the third model.

Story	Load	Loc	P	VX	VY	T	MX	MY
STORY14	KII028	Top	0	2.9	0.03	0.194	0.05	0
STORY14	KII028	Bottom	0	2.9	0.03	0.194	0.028	8.7
STORY13	KII028	Top	0	7.07	0	0.032	0.02	8.7
STORY13	KII028	Bottom	0	7.07	0	0.032	0.029	29.887
STORY12	KII028	Top	0	10.67	0	0.033	0.027	29.887
STORY12	KII028	Bottom	0	10.67	0	0.033	0.03	61.827
STORY11	KII028	Top	0	13.8	0	0.022	0.029	61.827
STORY11	KII028	Bottom	0	13.8	0	0.022	0.03	103.006
STORY10	KII028	Top	0	16.51	0	0.026	0.03	103.006
STORY10	KII028	Bottom	0	16.51	0	0.026	0.031	152.122
STORY9	KII028	Top	0	18.87	0	0.019	0.03	152.122
STORY9	KII028	Bottom	0	18.87	0	0.019	0.029	208.053
STORY8	KII028	Top	0	20.91	0	0.031	0.029	208.053
STORY8	KII028	Bottom	0	20.91	0	0.031	0.03	269.812
STORY7	KII028	Top	0	22.67	0	0.019	0.029	269.812
STORY7	KII028	Bottom	0	22.67	0	0.019	0.03	336.516
STORY6	KII028	Top	0	24.16	0	0.034	0.03	336.516
STORY6	KII028	Bottom	0	24.16	0	0.034	0.031	407.36
STORY5	KII028	Top	0	25.44	0	0.036	0.031	407.36
STORY5	KII028	Bottom	0	25.44	0	0.036	0.033	481.744
STORY4	KII028	Top	0	26.49	0.01	0.041	0.032	481.744
STORY4	KII028	Bottom	0	26.49	0.01	0.041	0.037	559.039
STORY3	KII028	Top	0	27.24	0.01	0.057	0.037	559.039
STORY3	KII028	Bottom	0	27.24	0.01	0.057	0.04	638.477
STORY2	KII028	Top	0	27.68	0.01	0.057	0.04	638.477
STORY2	KII028	Bottom	0	27.68	0.01	0.057	0.05	719.344
STORY1	KII028	Top	0	27.89	0.04	0.277	0.065	719.344
STORY1	KII028	Bottom	0	27.89	0.04	0.277	0.083	828.404