ADVANCED MASTERS IN STRUCTURAL ANALYSIS
OF MONUMENTS AND HISTORICAL CONSTRUCTIONS

Master's Thesis

Sonia Guerra Pinto

Numerical modelling of the seismic behavior of timber-framed structures based on macro-elements

Universidade do Minho

UNIVERSITAT POLITÈCNICA DE CATALUNYA

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DECLARATION

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Supervisor(s): Elisa Poletti, Hugo Rodrigues.

Year: 2017.

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

I hereby declare that the MSc Consortium responsible for the Advanced Masters in Structural Analysis of Monuments and Historical Constructions is allowed to store and make available electronically the present MSc Dissertation.

University: Universidade do Minho

Date: 17 of June, 2017.

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Dedicado a mis padres.

Gracias por creer en mí y motivarme a ser un mejor profesional y sobre todo una mejor persona. Ustedes me han enseñado que con amor y perseverancia todo se puede lograr.

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ABSTRACT

Historical timber-framed structures can be found all over the world since ancient times, being able to observe a variety of procedures and construction systems which is adapted to each zone according to the materials and available knowledge. Recent earthquakes have highlighted the good anti-seismic behavior of this structural typology. Likewise, its antiquity has also evidenced a good structural capacity. The case of Pombalino Buildings are born from the need to build an anti-seismic constructive system after the earthquake of Lisbon 1755 which destroyed most part of the city. The present thesis seeks to complement the study of these buildings due to the uncertainty related to their seismic behavior since up to date there has not yet been an earthquake registered in Lisbon since 1755.

The work presented in this thesis seeks a better understanding of the mechanical behavior of Pombalino structures based on finite element modelling on OpenSees program. The experimental campaign of Gonçalves (2015) is used as reference and centered on the experimental results, the developed models were calibrated. A sensitive analysis was carried out in order to determine the variants that affected the behavior of the cyclic curve and also to elaborate an adequate calibration process. Finally a macro-model was elaborated from the floorplans of an existing building and using the properties of the calibrated model, the mechanical behavior and seismic performance of the building was reproduced.

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RESUMO

"Modelação numérica do comportamento sísmico de estruturas de madeira com base em macro-elementos"

Estruturas históricas de madeira podem ser encontradas em todo o mundo, podendo ser observada uma variedade de procedimentos e sistemas construtivos adaptados à cada zona segundo os materiais e o conhecimento disponível.

Sismos recentes destacaram o bom comportamento anti-sísmico de tipologia estrutural, embora ESTA sua antiguidade têm evidenciado que é bom partilha estrutural. Os recentes sismos têm destacado o bom comportamento anti-sísmico desta tipologia estrutural. Além disso, sua antiguidade também evidenciou um bom comportamento estrutural. O caso dos edifícios Pombalinos nasce da necessidade de reconstruir adotando um sistema construtivo antisísmico após o terramoto de Lisboa de 1755, que destruiu grande parte da cidade. A presente dissertação pretende complementar o estudo destes edifícios devido à incerteza relacionada com seu comportamento sísmico já que até a data ainda não se teve um terramoto registado em Lisboa desde 1755. Este assunto tem sido estudado na última decada por diferentes autores e várias campanhas experimentais e numéricas de forma a reproduzir e compreender o comportamento sísmico desta tipologia de estruturas.

O trabalho apresentado nesta tese procura um melhor entendimento do comportamento mecânico das estruturas Pombalinas baseando-se em elementos finitos. A campanha experimental de Gonçalves (2015) foi utilizada como referência, em particular os resultados experimentais pelos quais os modelos numéricos foram calibrados. Uma análise de sensibilidade foi feita de modo de avaliar as variantes que afectam o comportamento da curva cíclica e também calibrar o modelo. Finalmente um macro-modelo foi aplicado num edifício existente com base nas propriedades dos modelos já calibrados, os comportamentos mecânico e sísmico do edifício foram reproduzidos.

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RESUMEN

"Modelación numérica del comportamiento sísmico de estructuras de madera basado en macro-elementos"

Estructuras históricas en madera pueden ser reconocidas alrededor de todo el mundo, pudiendo observar una variedad de procedimientos y sistemas constructivos adaptados a cada zona según los materiales y conocimiento disponible. Terremotos recientes han resaltado el buen comportamiento antisísmico de esta tipología estructural. Asimismo su antigüedad también ha evidenciado un buen compartamiento estructural. El caso de los edificios Pombalino nace de la necesidad de construir un sistema constructivo antisísmico después del terremoto de Lisboa de 1755, que destruyó gran parte de la ciudad. La presente tesis pretende complementar el estudio de estos edificios debido a la incertidumbre relacionada con su comportamiento sísmico ya que hasta la fecha todavía no se ha habido un terremoto registrado en Lisboa desde 1755. Este asunto ha sido estudiado desde hace un par de años por investigadores y campañas experimentales que se han realizado buscando reproducir y comprender el comportamiento sísmico de estas estructuras.

El trabajo presentado en esta tesis busca un mejor entendimiento del comportamiento mecánico de las estructuras Pombalino basándose en elementos numéricos finitos. La campaña experimental de Gonçalves (2015) se utiliza como referencia y centrándose en los resultados experimentales, modelos numéricos fueron calibrados. Un exhaustivo análisis sensitivo fue llevado a cabo de modo de determinar las variantes que afectan el comportamiento de la curva cíclica y también calibrar el modelo. Finalmente un macro-modelo fue elaborado desde la planimetría de un edificio existente y usando las propiedades de los modelos ya calibrados, el comportamiento mecánico y comportamiento sísmico del edificio fue reproducido.

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1. INTRODUCTION

1.1 Introduction

Timber Structures have been built worldwide having an antiquity that dates 14.500 BP [1] and it is being used until nowadays. Timber Structures have proven to have excellent seismic performance, as testified by the fact that in seismic regions houses and other structures are built in timber. It is interesting to see the diversity of constructive processes throughout the globe, every country adapts the timber structures according to their knowledge and construction types of materials available, and this also includes different infill types which are mostly composed of masonry or earth.

Timber structures, being unique in every region also have an important heritage value worth preserving. Even though the antiquity of these structures has very old data the studies regarding the seismic behavior is still recent if compared to the amount of studies regarding masonry. Seeking to fill this gap, several authors such as Quinn, D'Ayala & Descamps (2015) [2], Aktas Y. (2017) [3], Ceccotti, Faccio, Nart, Sandhass & Simeone (2006) [4] have performed studies of timber framed structures in different parts of the globe in which we can have an understanding of their differences regarding materials and behavior. Although the skeleton may be the same material, the composition, infills, geometry and measures can vary deeply the behavior of one structure against another.

As mentioned before, since old times timber has been adopted as a seismic resistant material, such as the case of Pombalino Buildings which were erected after the 1755 earthquake of Lisbon which left most of the city on the floor. Pombalino buildings were seeking to encompass the need of having a constructive system that would be able to resist future earthquakes. Notwithstanding the small amount information regarding the seismic performance of these buildings, has led in the last couple of years to perform experimental campaigns that seek to reproduce the seismic performance of these structures keeping in mind that there is an imminent earthquake return period and it is important to foresee the mechanical behavior of these buildings.

The present thesis starts from previous experimental and numerical studies in this field, and uses the experimental campaign performed by Goncalves [5] as a basis in order to calibrate a macro-model in OpenSees program through a non-linear finite element analysis, and then evolves to the numerical modelling of a real case Pombalino Building. OpenSees is a computational program that can perform complex analysis with small amount of computational resources, it's difficulty is that as it is based on codes, the analyst has to have an advanced knowledge on the performance of these codes, but currently certain visualizers (OpenSeesNavigator for MATLAB and OSLite) that can make this task rather easier.

The first numerical model will use the properties considered in the experimental campaign done by Goncalves [5] for calibration purposes and later on this information will be used in order to elaborate an existing building and to seek an understanding of its mechanical parameters and seismic behavior.

1.2. Research Objectives and methodology

The objectives of this research are to seek answers to the following questions:

- Based on experimental results, can a simplified macro-model be used to simulate the global wall behaviour?
- Which are the limitations and advantages of OpenSees in the elaboration of a timber frame numerical macro-model?
- Can the developed macro-model be applied to the analysis of an existing building?

The exposed objectives are established throughout the finite element method in OpenSees Program, a software framework for simulating the seismic response of structural systems analyzing the nonlinear response of systems using a wide range of material models, elements, and solution algorithms.

1.3. Thesis Outline

In order to complete the above tasks, the present work is organized into the following chapters:

Chapter 2 provides a literature review of the existing timber structures with the different types of infill and constructive systems, also a brief explanation of the mechanical properties and behavior is explained. An overview of existing numerical modelling is given, emphasizing on the results, in order to evaluate if the model was accurate or not and if it is worth considering.

Chapter 3 focuses on the elaboration of the numerical model based on the experimental campaign of Goncalves (2015) [5] giving a small summary of the material properties and results in order to develop the model and proceed to the calibration process, a discussion of this process is given including a sensitivity analysis.

Chapter 4 illustrates the development of an existing building, which will be modelled considering the calibrated parameters in the previous chapter. The results will be exposed and discussed.

Chapter 5 presents conclusions from this thesis and recommendations for future works.

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2. LITERATURE REVIEW

2.1. Introduction

The present chapter will firstly give an overview of the mixed timber framed constructive systems available for different geographic locations, to afterwards indicate and explain the differences between each other. It will also give a description of the materials that are most commonly used and the basic constructive system that includes the dimensions and unions between timber elements, and also explaining briefly the floor system. Recent studies show that timber framed structures behave very well under seismic loads, a general idea of the results of several experimental campaigns done by researches will be given, focusing mainly on the failure types. Although timber framed structures have very good mechanical properties, they are prone to suffer biological and weathering decay, so a brief overview will be presented regarding this issue. Finally an overview of some previous numerical simulations done in the past will be given, in which basic parameters for model elaboration will be explained and afterwards considerations for the non-linear analysis to finalize with seismic parameters that must be taken into account.

2.2. Overview of Timber-Framed Structures

In Central and South America timber has been used since prehistoric times, there is data from the year 16.500 B.C. in Monte Verde, Chile [6]. European archaeological excavations in the buried settlements after the eruption of Vesuvius in 79 A.C. brought into light timber frame walls in many noble buildings mainly of Herculaneum and secondarily of Pompeii [7]. Although there is a large amount of information regarding timber structures throughout history, the present literature review will focus on historic timber framed structures which are dated since the 17th Century in Europe (Spain) [8] and since the 16th Century in South America, specifically in Peru [2]. This type of framing is assigned different names which is associated to a specific constructive system that varies according to the region in which it has been built, for example in territories from Southern Central Anatolia to the Ottoman Balkans including Black Sea Coasts of Romania, Crimea, Bulgaria, FYR Macedonia and Bosnia Herzegovina to Greece in the West we can find 'hımıs' [9] ; [10], In Spain the timber-framed construction system was called 'entramado o telar' [11], 'Borbone' Constructive system is found in the Calabrian Region of Italy, 'Dahjji Construction' in Pakistan [12], 'Pombalino' Constructions in Lisbon (Figure 2) –Portugal and in South America we can find 'Quincha' Buildings in the coastal area of Perú [2], 'Adobillo' Structures in the Central Zone of Chile [13] and ´Gingerbread Houses´ and 'Kay Peyi' in Haiti [14].

Name of the System	Geographical Area	Ground Floor (Structural Material)	Upper Storey Exterior Wall (Structural Material)	Type of Infill (Upper Storeys)
Himis	Anatolia to the Balkans, Europe			Bagdadi, Masonry or Adobe
Pombalino	Lisbon, Portugal	Masonry Bricks	Masonry	Masonry Ceramic Debris
Entramado	Madrid, Spain	Masonry or Timber		Stone Rubble, Unfired bricks, Broken Bricks.
Quincha	Coastal Area of Peru	Adobe or Fired Brick		Weave of canes covered with mud
Adobillo	Central Zone, Chile	Timber	Timber	Adobillo: Bricks of Earth and Straw
Borbone	Calabrian Region, Italy			Calci lutite Masonry
Dahjji	Pakistan	Timber	Timber	Stone and Masonry
Gingerbread Houses	Haiti	Masonry Bearing Walls, Brick Infill	Same as Ground Floor	Braced Timber, colombage[1] or masonry bearing wall.
Dolomites	Northern Italy	Masonry	Timber	lime mortar and roughly-crushed stones

Table 1. summary of the studied timber framed structures of SEISMIC prone areas

In Valparaiso – Chile the adobillo timber frame constructive system is a constructive technique of timber and infill of bricks composed of earth, the timber framed structure is arranged from its first storey on top of stone foundations (See Figure 1). Dhajji constructions (which is a constructive system in use till nowadays, particularly for reconstruction purposes) can be built from one storey and can also be built with timber structure from the ground level, also in entramado walls between the 18th and 20th Century (although it was not recommended) timbered walls were built on top of ground floors; in these cases it is important to consider a very well done foundation system in order to avoid dampness [8] [12]. In most regions, the timber framed constructive system which considers the exterior façade and interior partition are arranged on the upper-storeys of a ground storey built in another material as shown on

1 Colombage: Braced Timber with Masonry Infill

Table 1; in this table it is also possible to see the different types of infill used.

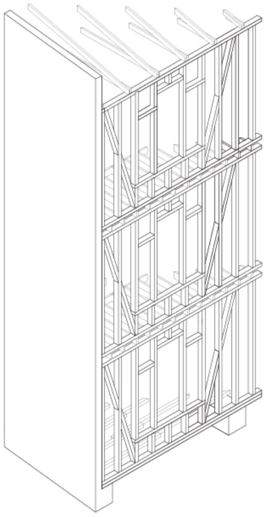


Figure 1. detail of timber-structure of adobillo façade wall [13]

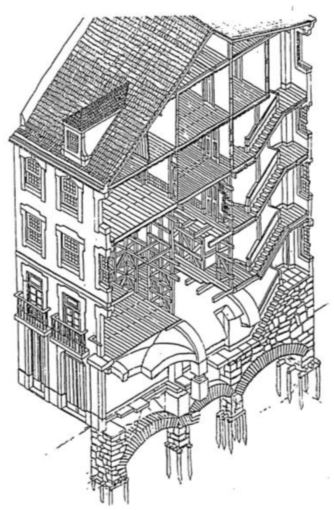


Figure 2. structural details of a "pombalino building" [15]

2.2.1. Connections and Infill of Timber Framed Structures

The connection between different timber members in himis frames, entramado and borbone are provided almost solely by nails; carpentry joints, even simple ones, are mostly further supported with nails [16], [8], in entramado structures different types of notches were made using different methods, and a rope, called tomiza, was placed around the timber and nails to help the materials work together [8]. Pombalino building connections show that the vertical and horizontal members are cut (grooved) at their mid-sections for them to be connected, one can see how two diagonal elements are attached together; these are also grooved at half their thickness to be attached to each other (Kouris, Meireles, Bento, & Kappos, 2014) [17] as shown in Figure 3. Unions between elements for quincha structures can be shown in Figure 4 .

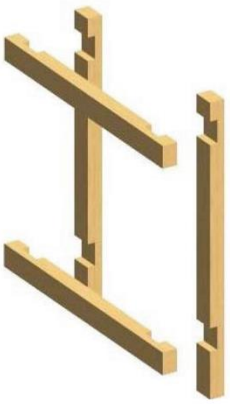


Figure 3. Detail of Cross Halving Joint for pombalino buildings [18]

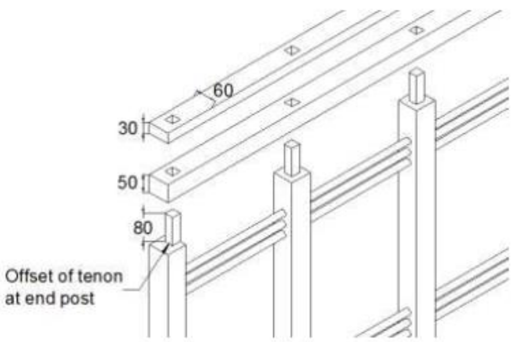


Figure 4. quincha mortice and tenon detail [19]

The bagdadi infill in himis walls are wooden laths nailed onto the timber frame with around 1 cm gap in between so that the later applied plaster will hold on the surface more easily, also the infills for himis frames can be composed by masonry or adobe blocks with mortar unions composed by sand-lime-water in the case of masonry and sand-water-straw in the case of adobe blocks. [20]. The infill for quincha consists of 25mm diameter horizontal canes passing through holes in the vertical posts. The canes are usually inserted through the posts in pairs, with four or five pairs evenly spaced vertically up the posts. Another set of tightly packed canes weaves vertically through them. A layer of mud mixed with straw is applied to the canes and covered with lime plaster [2], when choosing the mud for the adobe you must consider that it must not contain any vegetable earth, that it has no particles bigger than 1/16" (2mm) [12].

Adobillo infill is similar to adobe bricks, the construction system based on earth is formed basically by the rigging of units of sun-dried earth and agglutinated with clay, which acts as a mortar. The basic units of these elements are manufactured and / or molded in various formats [21] adobillo bricks are typically 0,50 X 0,10 X 0,15 mt blocks but it can also have different sizes according to the dimensions of the timber [22] . In Figure 5 it is possible to notice how the adobillo block is fit into the voids of the timber framed structure. In entramado walls, this was first made up of a mixture of stone rubble and plaster from the previously demolished house, unfired bricks, and broken bricks; in later buildings it was made of fired bricks with lime or mud mortar, with a pattern depending on the thickness of the frame [8].

In Gingerbread houses, the colombage building technique utilizes the braced timber frame with the distinction that the spaces between timber members are infilled with masonry. The masonry infill for the Gingerbread Houses is composed of either rubble stone laid in clay mortar or brick laid in lime mortar. In many examples, brick infill was used on main facades and stone infill was used on the secondary elevations. Where rubble stone infill was used, it was often reinforced with barbed wire laid haphazardly within the space to be filled, and nail fastened to the wood members on both sides of that space [14].

Pombalino structure infill consists of masonry ceramic debris and lime-sand-mortar for ancient mortars [18]. It is important to emphasize that when using stone or masonry infill the use of round stones should be avoided, as they will fall out quickly, [12] indicates that the mortar layers should be around ½" thick and the proportion should not exceed one quarter of mortar for three quarters of stones. After the infill and after the structure is finished usually a layer of plaster is then applied, hiding the timber frames [18]. These different types of infill have important influence on the thermal and acoustic insulation performance and the fire resistance of a timber framed structure and also contributes to the conservation the structural system of the wall [23].

It can also be observed that timber structures in non-seismic areas have infills built of wattle-and-daub as shown in Figure 6 [24]. Wattles (or withies) were usually made from cleft oak, hazel or willow, though other timber species were sometimes used. Hazel and willow wattles might ether be split or used round. The wattles were woven around staves of cleft oak then daubed with clay. This type of panel relied on shelter from the eaves of the roof and regular lime-washing to prevent deterioration. Generally, staves were set vertically and spanned the shorter dimension of a rectangular panel, but sometimes they were set horizontally, with the wattles woven vertically. The staves were usually set some 12–15 inches (300–375 mm) apart by springing them into a groove cut into the top face of the lower timber, and holes or rough mortices cut into the underside of the upper horizontal timber. To support the ends of the wattles, staves were set close to each vertical component of the frame [24]

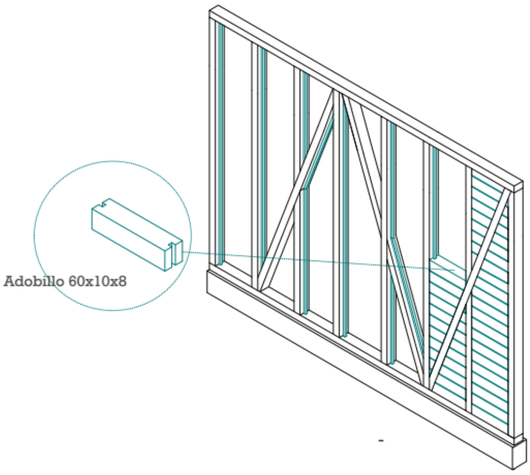


Figure 5. diagram of adobillo constructive system mounting [13]

Figure 6. Wattle and Daub Infill Panels

2.2.2. General Disposition and Components of Timber Framed Structures

Regarding the general disposition and distribution, himis frame structures outer boundaries are defined by a wall plate, a foot plate, and two main posts, and the frame interior is divided into smaller compartments by means of horizontal/vertical inner elements, usually but not always thinner than the other members, as well as diagonal members, which also help increase in-plane lateral load-bearing capacity [3]. Regarding the main dimensions of the timber frame parts himis buildings usually have a cross-section of 10x10, 5x10 cm. In spaces with larger spans, elements with larger cross-sections (15x20, 20x20 cm) may be used which in any case do not exceed maximum 1 or 2 girders in a building [25].
In party walls of madrilean-entramado structures (Figure 7), studs were spaced at an equal distance of about five to seven feet and the space left between them was divided into three equal parts to avoid buckling, the other walls were raised according to openings, doorways, windows and balconies, with no fixed characteristics. The timber elements used in building on walls, floors and roofs have been named according to

their length, width and height. They are based on a module known as the Castilla foot, and their dimensions change in increments of one quarter-foot. The frames were the following: media vara (1½f×1¼f), pie y cuarto (1¼f×1f), tercia(1f×¾f), cuarta (¾f×¾f) and sesma (¾f×½f). The most common wooden frames were media vara and pie y cuarto on ground floors, tercia for main and second floors, and sesma for third and fourth floors [11].

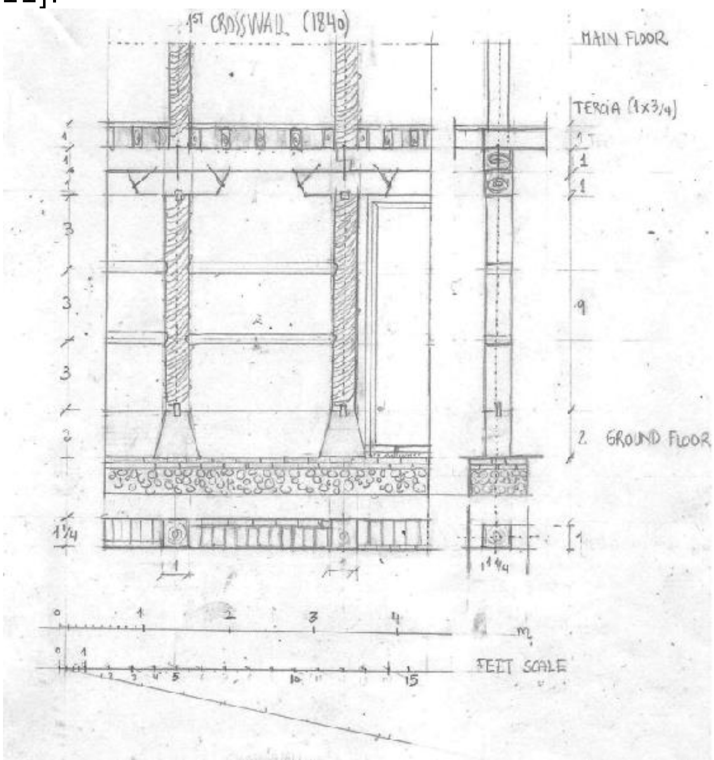


Figure 7. detail of a pie y quarto timber framed wall built in the ground floor for entramado building [11]

In a typical quincha frame, the vertical timber posts are spaced between 0.5 and 1.0m, and joined at the top and bottom to horizontal timber elements by cylindrical mortice and tenon joints. In addition to the mud and cane infill, the frame also contains an additional lateral bracing, which can be in the form of short diagonal wooden struts known as citara in between posts, or a single diagonal bracing member extending the whole height of the frame and crossing several posts. The first frame (Figure 8) found on the second storey directly supported on the adobe wall, uses short diagonal struts to brace the lower portion of the frame. Adobe blocks, or in some cases, small fired bricks, are placed between these struts to provide a modest increase in stiffness and add mass. This is the most common arrangement found in Lima. The second frame (Figure 9) is less common and found on the third storey and does not contain the struts or bricks, but has a diagonal bracing member extending across three or four bays [19]. It is also important to point out that floors in quincha structures were also built with timber [26].

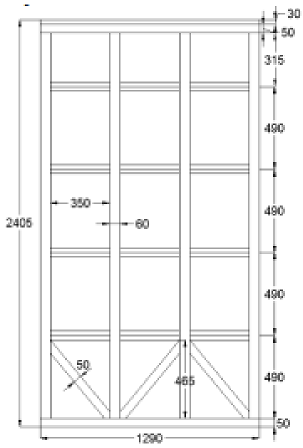


Figure 8. Quincha 1st Frame Typology

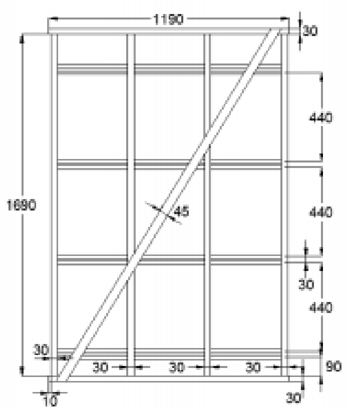


Figure 9. Quincha 2nd frame typology [27]

According to [13], adobillo structures are composed by a balloon frame system. Pizzi (2003) indicates that balloon frame houses are based on a closely spaced two inch boards of varying widths, two by two, two by four, two by six, or two by twelve, joined only by nails. Corner posts and principal horizontal members are made of boards nailed together. The principal supporting members are closely spaced two by four or two by six vertical studs of both the exterior and key interior walls. The main principle of the balloon framing system is the substitution of thin plates and studs, running the entire height of the building and held together by nails, like putting together a box [28]. Gingerbread house braced timber frame construction is composed of vertical wood members—principally sized at four inches square—that are mortised into wood sills and top plates of each story, and mechanically connected with wooden pegs. Diagonal timbers are placed at corners and other locations to brace the frame assembly (Figure 10). Later timber-frame assemblies adopted the use of nails rather than mortise and tenon connections with wooden pegs, but the overall composition is similar [14].

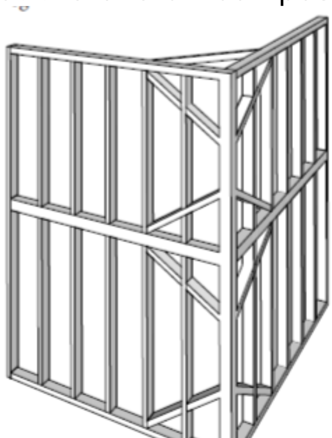


Figure 10. Detail of a gingerbread house braced Frame structure [14]

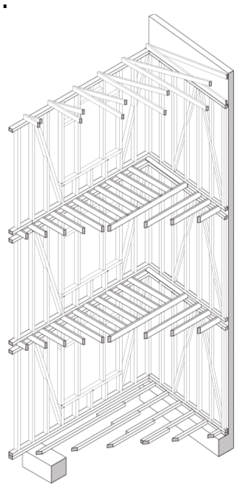


Figure 11. 3D section of an adobillo structure house in valparaiso [13]

The Pombalino building system starts by the foundations which consist in a system of wooden piles over alluvium layers [17]. The piles are similar and repetitive, on average 15 cm in diameter and 1.5m in length. These form two parallel rows in the direction of the main walls, which were linked at he top by horizontal cross-members attached by thick iron nails. The construction between the ground and first floors consisted of solid walls and piers linked by a system of arches. In more elaborate cases, thick-groined vaults spanned between the arches, which protected the upper floors from the spread of any fire that might start at ground floor level. From the first floor up this building system has the aforementioned three-dimensional timber gaiola structure, thought to be an improved system based on prior traditional wooden houses. Gaiola is composed of traditional timber floors and new mixed timber frame masonry panels (“frontal” walls) that would support not only the vertical loads but also horizontal seismic loading. These Timber Frame walls are one of the key characteristics of these buildings, and a paradigm of the above-mentioned Timber Frame masonry structures. They are made up of a wooden truss system with X-type diagonal braces, filled with a weak mortar masonry in the empty spaces. It is important to also point out that, based on recent studies, these walls would have a beneficial effect on the out-of-plane failure of the façade walls since they were connected to them through the floor [17]. The other interior walls (partition walls) are wooden panels without structural functions. Façades are made of masonry columns and beams without the gaiola structure. The wall’s average thickness is 0.8 m for masonry exterior walls, 0.18m for the interior walls of gaiola and 0.12 m for the other interior walls [29]. The different types of wood which are used in each case are associated to the availability of the region. Studies done by [3] show that this material selection does not have major influence on the seismic behavior of the structure though.

Traditionally, the floor system of timber framed buildings is formed by main beams, secondary beams and bracing. These structural elements are commonly disposed orthogonally to each other. They tend to show a regular geometry and a regular relative distance. Generally, the timber beam elements are supported by the vertical structural elements such as stone masonry walls or exterior tabique walls, in their ends. On the other hand, the timber secondary beam elements are supported by the timber beams (Figure 12). The secondary beams support the flooring boards and also brace the beams in order to avoid possible lateral bending instability phenomena. A timber bracing system is also applied and acts transversally on the secondary beams or on the beams. The main beams are supported on the ground floor and on this stone masonry/adobe wall, a peripheral timber beam is placed in between. All the mentioned timber elements are connected to each other by nails [30].

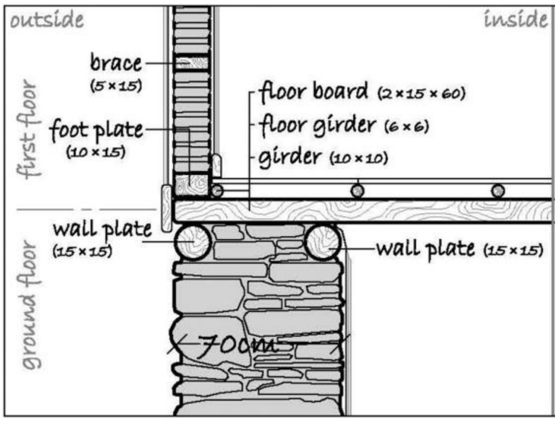


Figure 12. Schematic drawing of the detailing between masonry ground floor and timber-frame upper floor on an case study structure from Birgi, Turkey [3]

The structural roof solution of timber frame buildings is a commonly traditional timber structural system solution, made of trusses, purling, boards and rafters. Generally, the trusses are similar in terms of geometry and size, and they are placed regularly (i.e. having the same distance in between them). They also tend to be a symmetric system themselves. They are directly supported by the stone masonry or by the exterior timber frame walls, at their ends [23].

2.3. Pombalino Case Study

Pombalino construction was standardized to be used for the reconstruction of Lisbon after the 1755 earthquake, but its use was not limited to Lisbon. Mass production of building components, a basic principle of Pombaline architecture in Portugal was also used in Vila Real de Santo Antonio, and in many other Portuguese cities. The form construction of these buildings was very similar to that of Lisbon, the party and exterior walls being in stone, while inside there were timber framed partition walls with St. Andrew crosses incorporated to them. Arches in bricks were used to tie the foundations together and for some walls [31].

The plan of Santo Antonio, as in Lisbon, consisted of a rectangle, with one of the long sides facing the river, to the east. The rectangle was cut by 5 streets in a North-South direction and orthogonally in an East-West direction. All the streets were the same width and they contained 43 blocks; 32 of which were identical in size, being 240 palms by 100. In Vila Real, there are four quite distinct architectural types: the river front buildings (Figure 13), the buildings in the square (Figure 14), the single storey houses with towers and the single storey houses without towers (Figure 15): [31]. The walls of the residential floor had an anti-seismic wooden structure incorporated into them, similar to that seen in the Pombalino quarter in Lisbon. The roof structure was very simple and repetitive, covered by wooden boards on which the tiles were laid [31].

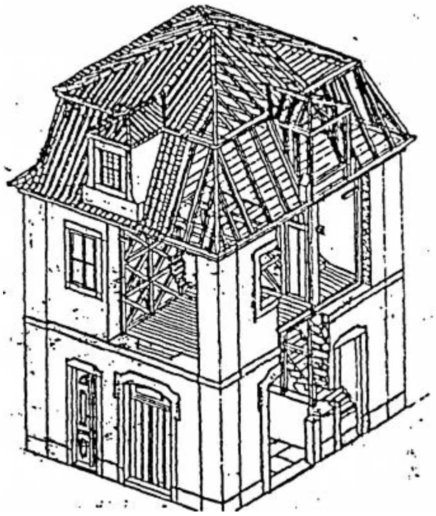
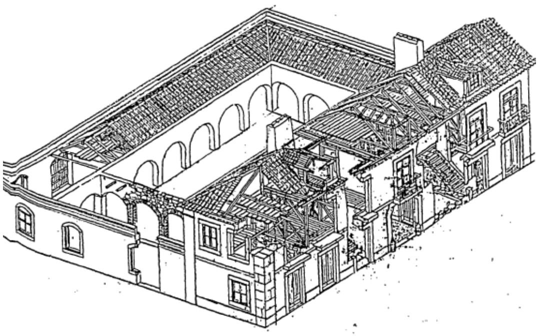


Figure 13. isometric of typical river front construction [15]



. Figure 14. isometric showing typical corner house in the square [15]

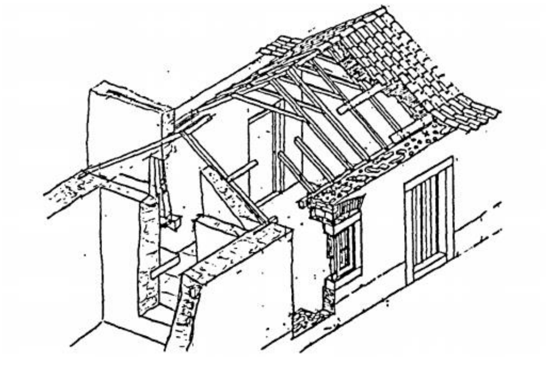


Figure 15. isometric showing one storey construction [31]

2.4. Behavior of Timber framed Structures under Seismic Loads

2.4.1. Generalities

Studies show that timber structures behave very well under seismic loads, the 2010 the Haiti earthquake has revealed that traditional construction techniques have value in resisting to earthquakes [14]. Ambraseys & Jackson [32] state that after the 1509 Istanbul Earthquake, the Ottoman authorities prohibited masonry and enforced the construction of timber-frame houses, claiming that masonry was responsible for most of the casualties produced by the earthquake. By the end of the century the city was almost entirely built in wood. For a set of earthquakes between the beginning of the 20th century and 1980 in Turkey and Greece, it is stated that that “the number of people killed per 100 houses destroyed by earthquakes of magnitude equal to or greater than 5,0 is only around 1 for timber constructions. In Peru the Quincha technique reached its peak after the 1687 earthquake, when a law was passed ruling that quincha must be used for the upper storeys of any building greater than a single storey in height [33]. Today a number of these buildings survive, most dating from the 18th and 19th centuries, with quincha in the upper storeys, and the first storey in adobe or fired brick [2]. In the Calabrian region of Italy after the 1783 earthquake the government ruled by Borbone dynasty enacted what is considered the first European anti-seismic code; called “Sistema costruttivo borbonico” that amongst other measures enforced the presence in the new constructions or repair of damaged buildings, of a timber skeleton as an essential requirement to ensure safety [34], In Portugal the Pombalino buildings were introduced after the 1755 catastrophic earthquake as a structural solution that would provide the required seismic resistance. These were built in quarters, each block comprising an average of 10 buildings, it was arguably the first case in history of an entire town built with the purpose of providing seismic resistance to its buildings [17].

2.4.2. Timber Elements Behavior

Some studies have also been done focusing mainly on the timber framed elements. [3] shows that the damage mechanism is the same regardless of the timber type used for their construction, frame size/geometry and infill/cladding type: at each loading cycle nails at the opposite side of the loading are partially pulled out and, when the lateral loading changes direction, they are driven back. It is pointed out that nailed connections in timber frames are the main source for high energy dissipation and ductility within a frame because first there is compression and crushing of wood grain with the formation of a cavity due to the presence of nails and also because of the inelastic deformation of the iron nails [34]. Because of this it is important for the timber frames to be suitably connected to each other’s, to the ground and to the floors, in order to behave as a box-like unit [35]. Research conducted on traditional houses in Japan and the strengthening proposals comprise some similar details. The use of nails instead of metal clamps, screws or joints in timber buildings particularly increases the flexibility of the structure [36]. Beside from the connections, it is shown that the diagonal and vertical elements also produce the failures in the structure, the diagonal element can fail after the nails work loose and also when the compressed diagonal is crushed or unstable leading to flexural rupture. Test show that only the compressed diagonal absorbs internal forces while the tensioned diagonal works loose. There is a stiffness degradation mainly caused by the unclasping of the tensioned diagonal and by the lateral instability of the compressed one due to the midpoint halved section [18]. Partition walls also have an important contribution to the stability of the building because they allow a connection of the main structural elements [23]. Experiments done by [29] on Pombalino Cells reveal that they actually behave like a lattice, leaving the infill unsolicited, infill and hence the type of infill exert no impact on the lateral load capacity, but only on the initial stiffness due to the very lattice-like behavior exhibited by the elementary cell, which in turn reveals that infill offers a low lateral load capacity.

2.4.3. Masonry

Cardoso, Lopes & Bento (2005) [37] show that masonry damaged elements are mainly located at the top of the building. The obtained damage patterns identify the expected collapse mechanism, corresponding to the fall out-of-plane of the front façade at the top floor. This mechanism is one of the typical collapse mechanisms of masonry buildings which was observed in buildings that collapsed during recent earthquakes in Europe. Regarding the properties of this material, Kouris, Meireles, Bento & Kappos (2014) [17] define masonry as a non-homogenous, anisotropic and discontinuous (as soon as it cracks) quasi-brittle material, which does not actually present a yielding behavior such as that implied by the plasticity theory. However, if masonry is treated macroscopically, a plastic-like behavior can be determined with yielding, hardening, and finally failure, accounting for all cracks observed at a meso-scale.

2.4.4. Infill Behavior

It is also important to analyze the behavior of the structure focusing on the performance of infill. According to N.Ruggieri, G. Tampone and R.Zinno (2015) [34] the frame stiffness under in-plane horizontal actions is mainly given by the infill. The lateral load strength of a timber frame increases with infill/cladding on average by 88%, and the secant stiffness values also increased about 200% on average, the secant stiffness (or effective stiffness) is defined as the ratio of the strength, VB, to the maximum displacement ΔD [38]. On the other hand, infill/cladding also results in a weight increase and changes the natural vibration period of the structure. The increased ratio in weight is always higher than the increase in lateral load strength, the exception of bagdadi cladding [20]. According to Y.Aktas (2017) [3] the increase in strength and stiffness with infill/cladding is always less than the increase in weight. In order to prevent failure types, it may be recommended to use lightweight infill materials such as pumice stone, perlite blocks, or autoclaved aerated concrete. Another possibility for improved safety is to remove the heavy old infill material and convert walls to bagdadi-type cladding for multistory timber houses. Experiments show that, in infilled frames, the energy dissipation depends mostly on friction and small ruptures in the masonry and J.G. Ferreira, M. J. Teixeira, A. Dutu and A.M. Goncalvez (2014) [18] state that the presence of masonry could be important when the timber-framed walls are subjected to high vertical loads [26]. Other experiments point out that the initial inelastic phase of the model was brief and its end was marked by un-nailing of the diagonals from the surrounding frame; after detachment of the tension diagonal, the panel undergoes large deformations. In this regard masonry infills serve essentially as lateral support for the timber elements and prevent out-of-plane buckling of the diagonals in compression [39]. As the horizontal displacement of the panel increases, the gap between the tensioned diagonal and the frame becomes larger and masonry infills are no more able to deform, hence crush and eventually collapse out-of-plane of the masonry. This is followed by visible buckling (and crushing) of the diagonals which leads to collapse. Haitian Colombage construction, which incorporates the braced frame, behaves in a similar fashion to braced frame construction, however, the masonry infill panels (of either fired brick or rubble stone) in many cases became loosened or completely fell outward. This should not be considered a failure of the colombage technique as the masonry behaved as an energy absorber and protected the building frame as a whole by absorbing the lateral movements in a sacrificial manner, While the earthquake caused a number of the infill panels to fall out of the frames, the integrity of the overall timber structures did not appear in any case to be dependent on the presence of the masonry infill [14]. Maybe because of these failures several type of inappropriate repairs and alterations implemented prior to earthquake contributes to seismic damage has been made, such as the use of cement to repair/replace rubble stone infill (for example) [14],it is also seen that people remove the infill leaving the timber frames bare; Y. D. Aktas, U. Akyüz, A.Türer, B.Erdil and N.S. Güchan (2014) [20] indicate that it is not recommended for non-experts to alter the original structure.

FIGURE 16. DETAIL OF INFILL LOSS AFTER AN EARTHQUAKE [25]

2.4.5. Multi-Scale Behavior

Also several experimental studies have been made showing general behavior of timber framed structures various wall components under seismic loads. Vieux Champagne (2017) [40] did an experiment regarding a whole timber framed structure and 2 structural modifications which consisted in type 1: a punched steep strip surrounding the wooden part as a a steel-wood nailed joint and type 2: the joint between the middle of the post, the bracings and the noggin resulting from successive seismic tests. The first model results indicate that there is a significant reduction in both the natural frequency and amplitude, while the viscous damping ratio increased. The same model was repaired and put again under seismic loads, and we can see that the energy dissipation reached a maximum value due to damage of the previously repaired connections. After amplifying the seismic level in the same model, a portion of the filling collapsed which significantly reduced the weight of the transverse walls. Despite the increase in overall structural damage, the normalized equivalent lateral stiffness remained constant while the acceleration amplitude and viscous damping ratio decreased. After each signal, the natural period of the building is in fact modified due to the damage sustained. We can also observe that the transverse wall deformation is much greater than that of the shear wall. This outcome can easily be explained by the absence of a stiff horizontal bracing structure to prevent this strong deformation and moreover by the fact that the connections between wall and roof are quite flexible [40]. Ferreira (2014) [18] indicates that masonry infill models can confer higher deformation capacity than bare timber framed structures. Experiments done [19] in quincha structures indicate that the hysteresis loops for the infilled frames are quite wide, which means that it is dissipating a large amount of energy through small cracking in the mud and friction between mud and frame. There is also prevalent shear deformation of the panel as a whole rather than the flexural deformation, the infilled frame behaves more like a rigid body, rocking (out-of-plane behavior) as the external posts lift up, rather than deforming in flexure like the bare frame. Also the contribution of the racking stiffness of the infill to the stiffness is greater than the contribution of the diagonal. [34] did a campaign on cyclic actions in Borbone frames, which show a non-linear behavior related to “pinching”. This phenomenon could be attributed to the detachment of the masonry infill from the frame and the generation of a gap during the reversed cyclic load increase. Experiments done by Cebbotti, Faccio, Nart, Sandhass & Simoene [4] where several models with different infills were submitted to an increasing load showed that regardless of the expected failure type (expulsion of the filling). Being confined by the diagonal panels and by the main members of their timber frame, the brickwork masonry parts did not collapse at failure, they simply became cracked. Instead, failure loads determined the collapse of the stones of the other model. This difference in behavior can be explained by the typically random arrangement of the stones in the triangular portion of the quadrants.

2.5. Damages by Biological Decay

Güchan [25] indicates that some damages in timber structures produced by earthquakes are due to biological degradation. Most of the significant earthquake damage to these structures was often related to pre-existing damage caused by termites, and in some instances other forms of wood rot [14]. It is determined that that the natural timber degradation causes damping ratios to increase and secant stiffness to decrease, leading to higher periods when submitted to seismic loads. The roof and the ground floor are identified as the main susceptible deterioration focuses, due to the water infiltrations [23]. Because of this it is important to consider a maintenance plan, as the one elaborated in Madrid since 1997, and revised in 2011 for entramado structures which is explained by [8] and states that that owners are required to commission an inspection every ten years, on penalty of a fine, and this policy is the key to effective conservation. [41] indicates a series of advantages of quincha structures but is also aware of the deterioration vulnerability, it is because of this that he proposes a maintenance plan to protect the structure from insects and the effect of water. For the Portuguese context, July, August and September are the most reliable months to perform this task because they correspond to the dry season [23]

2.6. Previous Numerical Simulations.

2.6.1. Model Development

Timber frame elements are usually simulated with linear elastic beam elements with axial and flexural stiffness corresponding to their actual geometry. Ferreira, Teixeira, Dutu & Goncalves [18] consider that the connections between vertical and horizontal elements should be considered to be fully rigid. Tests showed that only the compressed diagonal absorbs internal forces while the tensioned diagonal soon works loose. In order to consider this fact but still maintaining the linear elastic property of the model, both diagonals were considered, but with only half of their geometric stiffness. The connection between the two diagonals was assumed to be fully rigid. The beams and columns were assumed to be infinitely rigid connected with rotational springs in the corners [4] the assumptions for the model are shown in Figure 17. The mass of the frames was concentrated as a lumped mass in the two upper joints of the frame. This means, all structural behavior of the model was depending exclusively on the stiffness values of the rotational springs having the beams infinitely stiff. The floors were modelled by [4] as truss bars with free rotations at the connections to the walls, simulating flexible diaphragms and restraining out-of-plane relative displacements of parallel walls.

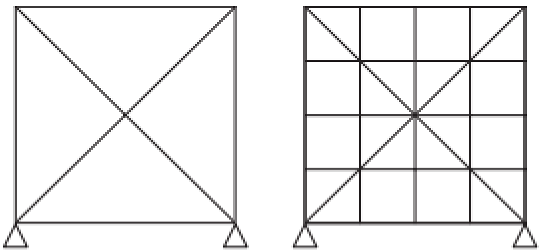
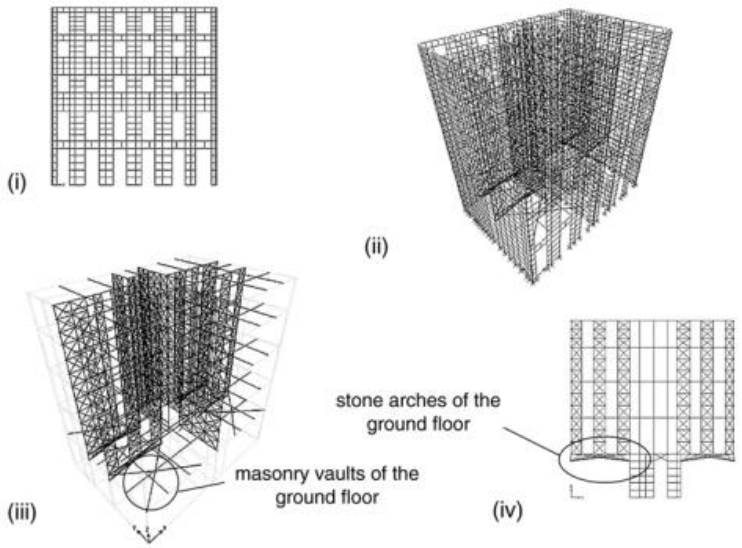


Figure 17. numerical models elements for timber frames (left) and masonry walls (right) [18]

The infill of the masonry wall elements was simulated with linear elastic square and triangular plane shell elements, the square and triangular plane shell elements were rigidly connected to the timber elements at their nodes. For structural design purposes the mesh used may be less refined, leading to lower computational effort and a more simple analysis of results [18]. Considerations for the Numerical model by Cardoso, Lopes & Bento (2005) [37] indicate that masonry exterior walls shall be simulated by a thin bi-dimensional shell element considering only bending deformation in and out of plane (Figure 18), It was concluded that it was not worth refining the mesh for masonry elements, bearing in mind that the level of accuracy does not need to go beyond the accuracy in the evaluation of the material properties as input. Cardoso, Lopes & Bento (2005) [37] indicate that the connections between timber elements and perpendicular masonry walls were simulated considering short bars that only resist axial forces, intending to simulate the strength of the connection. No iron elements were considered in the evaluation of the strength of the connections due to the uncertainties about their real existence in the buildings the roof structure was not included in the model. Its self-weight was assigned to the nodes at the top of the building.



(i) Shell elements of masonry walls of front façade;
(ii) Complete three-dimensional structure with shell elements and bars (detailed in (iii));
(iii) 3D 'gaiola' interior walls, floors bars, vaults (crosses) and stone arches at ground floor;
(iv) 'Gaiola' interior walls and stone arches parallel to front façade.

Figure 18. numerical model of a building [37]

According to Kouris, Meireles, Bento & Keppos (2014) [17] diagonals are usually unable to provide any noticeable resistance to tension; hence, in a model any such resistance is neglected while compression forces are accounted for by friction connection between the brace and the surrounding Timber Frame. As a sensitivity analysis, five different friction coefficients were considered, varying from zero up to full connection, see Figure 22 for results. In the Timber Frame wall that was analyzed, masonry infills are not substantially loaded; in fact, they remain almost intact. The main stress path of the compressive stresses resulting from horizontal loading is obviously through the diagonals. In a Timber Frame wall with two diagonal braces early separation of the diagonal in tension occurs, as well as relative sliding of the masonry infills with respect to the Timber Frame. This behavior can be more accurately simulated by introducing discontinuities, whereas the assumption of full contact does not reflect the actual response. Another interesting feature is the degree of penetration of the diagonals braces into the surrounding frame, a feature that can only be captured by sophisticated analysis. Kouris & Kappos (2014) [39] indicate that after the pushover analysis was done, we can observe that high stresses develop in only the compressed diagonal as shown in Figure 19 and its edges develop plastic deformation, masonry infills develop low stresses which should not come as a surprise due to their initial detachment from the bounding timber elements. Only shear stresses are induced in masonry infills while they slide (with friction) along timber elements. On the contrary for the stiff spring the maximum displacement becomes smaller when there is no vertical loading as the stiffness of the spring is very high and becomes the centre of rotation which leads to excessive deformation of the respective elements and rather early termination of the analysis.

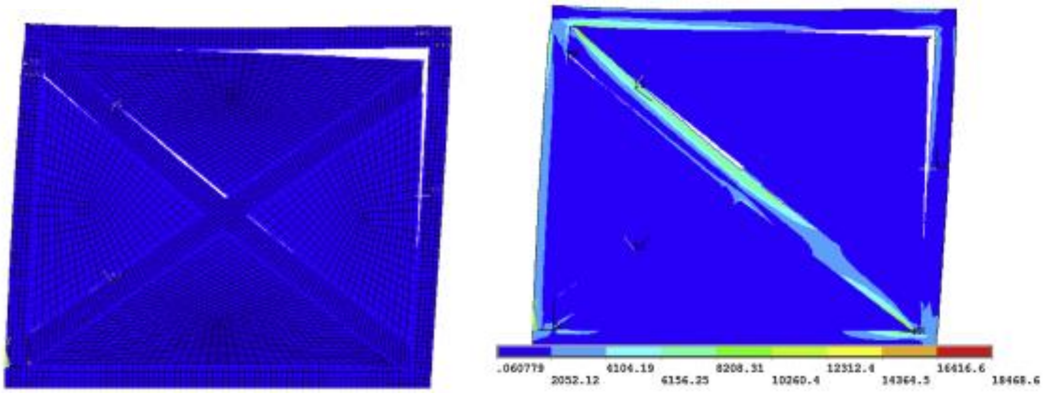


Figure 19. horizontally loaded timber frame walls (left) deformed shaped and (right) stresses in Kpa inmediately prior to the final stp of the pushover analysis [39].

2.6.2. Non Linear Behavior Considerations

Several authors propose that the Non-Linear considerations must be taken into account in the spring elements, A model proposed by Kouris & Kappos (2014) [39] takes into account the masonry infill indirectly through the rotational springs that simulate the pinching effect during the reversal of the load direction. The joint formed by a beam and a post deforms as a frame joint, an elastic spring connects the nodes of the beam and the respective post of the inner nodes of the joints which is indicated by a spline. To study this feature, the parametric analysis considers a horizontal gap (with no initial width) between the beams and the posts as shown in Figure 20. Connection flexibility has a non-negligible effect on ultimate displacement. This procedure is implemented through the following steps: 1) Discretization of the building into individual Timber Frame elements. 2) The equivalent vertical load is calculated in each Timber Frame panel. 3) The empirical formulas are applied to define the constitutive load of each panel in terms of horizontal shear vs. displacement. 4) The elastic stiffness of the diagonals is corrected. This proposition of macro-model permits estimation of the lateral load capacity of traditional Timber Frame buildings not only with relatively limited computational effort, but also with limited knowledge about the properties of the structure.

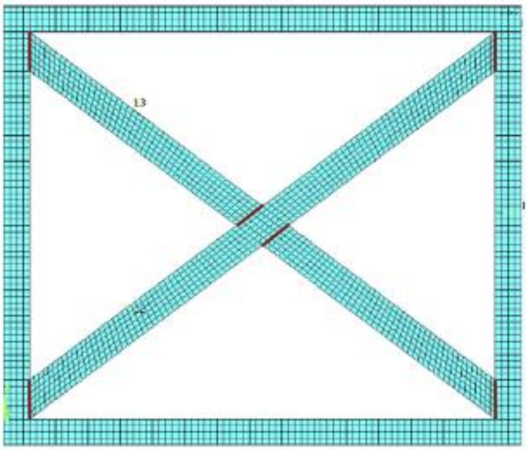


Figure 20. discontinuties of the frame regarding the diagonal element [39]

Lukic (2016) [42] proposes a model developed composed of elastic beamcolumn elements for the perimeter frame and for the internal struts with single point constraints at the base (See Figure 21). The four struts are connected at the central node joined by a two-node link element with a single hysteretic spring applied in the transversal direction. All nonlinear behaviour is concentrated at the central node and it was decided to use SAWS uniaxial material model to describe the nonlinear behaviour. The calibration of the macro-model was performed by both cyclic and pushover analyses under a vertical pre-compression loading using displacement increments used in experimental campaign of Gonzalves (2015) [5] which was calibrated by previous experimental campaign performed by Poletti (2013) [43] SAWS parameters from the detailed model calibration were used as reference and adjusted iteratively. Adjustments were made to the spring element strength (F0) and to the initial stiffness of the shear wall spring element (S0) to capture the overall load capacity. Additional adjustments were made to the stiffness degradation parameter (alpha) and to the stiffness ratio of the pinching branch (P4).

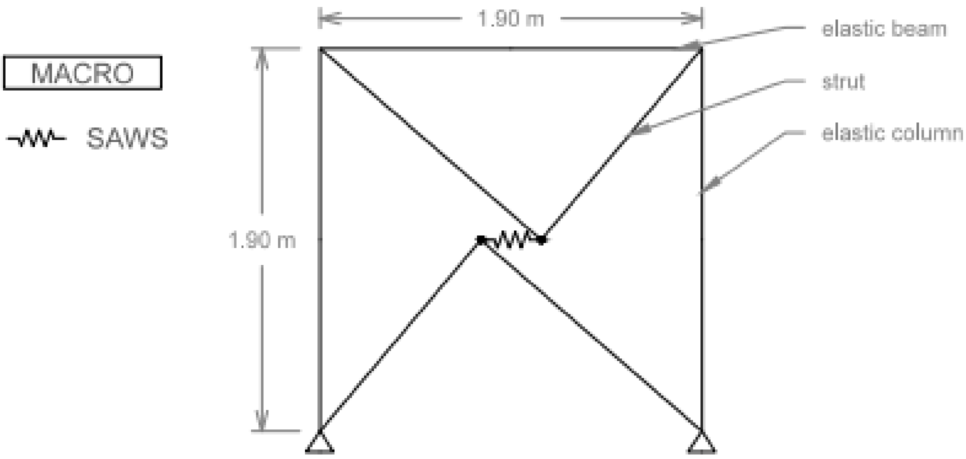


Figure 21. developed masonry infill-macro model [42]

Kouris, H. Meireles, R. Bento y A. J. Kappos (2014) [17] proposed a procedure for modelling a Timber Frame Wall which consisted in obtaining preliminarily by the elastic analysis the axial stresses of the timber post due to gravity loading, afterwards there is a discretization process of the Timber Frame structure and finally the processing of the model with a Non Linear Pushover analysis. The curves obtained will be transformed into a simple bilinear one in order to define the yield and failure point as shown in Figure 22. Afterwards, the axial stiffness must be modified of the diagonals to take into account their expected sliding.

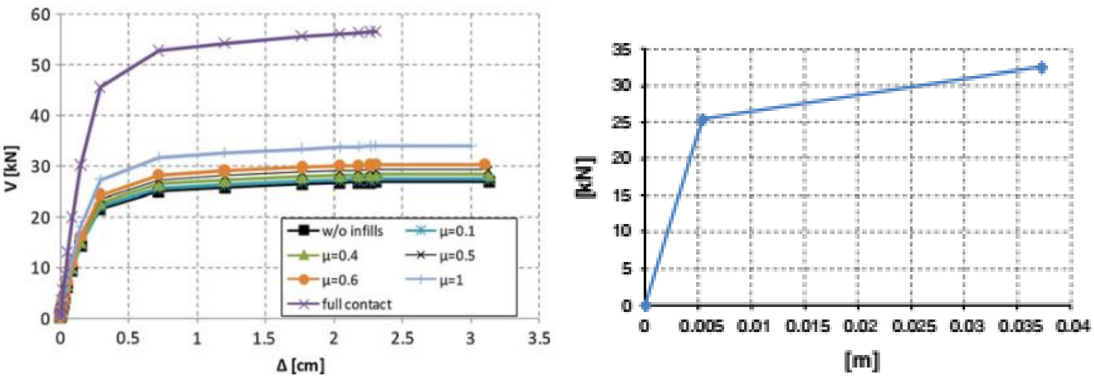


Figure 22. (left) pushover curves of timber frame walls with various friction coefficients. (right) bilinear pushover curve [17]

Ceccotti & Sandhass [44] propose timber type models that can be represented by spring models with lumped masses where rigid members are representing the framing and rotational springs are representing the global behavior of the panel as shown in Figure 23. The rotational springs are calibrated on cyclic test results; only these springs represent the behavior under lateral loading. Springs can reproduce the nonlinear pinching hysteresis loops of typical semi-rigid joints in timber constructions. With the insertion of stiffness the spring model is able to model the pinching behavior but not the strength impairment. Effects such as friction are implicitly included in the springs. Another parameter apart from the springs that influences the mechanical behavior of such wall models in a dynamic analysis is the equivalent viscous damping. Values must be attributed for damping in order to undertake a non-linear dynamic analysis. The calibration procedure for the models is iterative and the calibration parameters are maximum force, maximum displacement and amount of dissipated energy. The correct representation of the envelope curve is prerequisite for proper modelling.

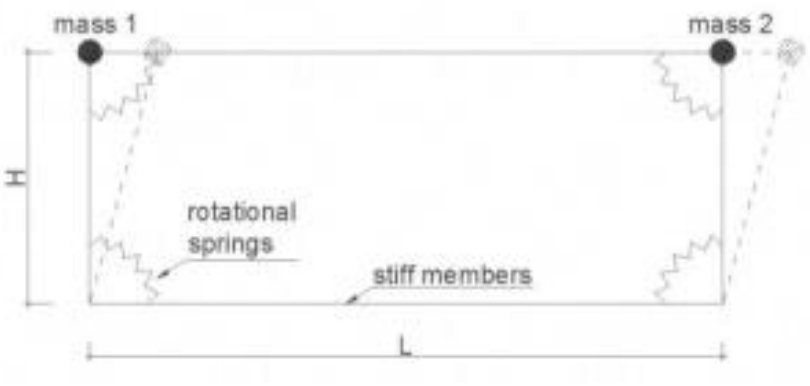


Figure 23. model of platform frame or timber-frame panel [44]

Certain key assumptions have been made for modelling by Kouris (2012) [7]: The residual strength and the maximum strain of each spring that connects the diagonals with the exterior frame are determined from the maximum capacity and the corresponding strain assuming reasonable ratios between them. The connection between diagonals and frame is considered in the model as a simple contact between the timber members, capable of transferring only compressive loads and, to some extent, shear stress; this type of connection is incapable of carrying tensile stress. Contact problems are highly non-linear and the estimation of the areas in contact depends on the external loading and the boundary conditions of the problem at each step.

Another approximation explained by Kouris, Meireles, Bento & Kappos (2014) [17] consists in determining the non-linear behavior of a Timber Frame is using envelope curves, one is modelled using exponential function and one linear function. The exponential function defines the ascending branch (exponential envelope) and the linear function the descending branch (linear envelope). The envelope curve is defined by six identifiable parameters that were fitted to experimental data. The parameters, illustrated in Figure 24 are F0, K0, r1, r2, δu and δmax. The exponential function used to describe the ascending branch was first proposed by Foschi (1974) [45] and later by used by Folz & Filiatraut (2001) [46] to model the response of wood shear walls. Beyond the displacement δu, which corresponds to the ultimate load Fu, the load-carrying capacity is reduced. Failure of the wall under monotonic loading occurs at displacement δmax.

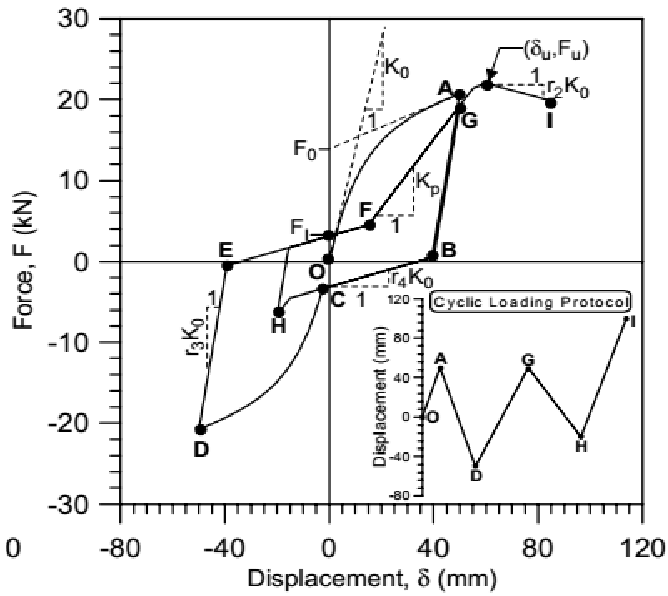


Figure 24. envolope curve parametres [46]

There are several considerations that Kouris & Kappos (2014) [39] take into account in the parametric non-linear analysis of the structure such as aspect ratio, thickness, depth and vertical loading: regarding the panel area, a harmonious combination of wood and masonry contributes to maximizing its displacement ductility (i.e. the ratio of failure to yield displacement), while a heavily or poorly reinforced (with timber elements) wall lead to lower ductility. We must consider also that no negative slopes are allowed in the pushover analysis; In what respects the timber section depth the 'yield' point of the bilinear curve does not in principle represent the real on set of the Non Linear response but it is always located beyond this point. The smoother the pushover curve the larger is the distance between the yield point and the real on set of yielding. Although elastic stiffness increases with increasing d values the curvature of the pushover curve near the yielding area also increases and this results to practically constant values of K_{el}; Regarding the analysis for the timber strength: The shears V_y and V_u are linearly correlated to $f_{c,t}$ with correlation coefficient exceeding 90%. Also linear is the variation of lateral stiffness Kel and Kinel. Timber strength does not affect displacements dy and du, which remain almost constant; for the vertical loading, both V_y and Vu slightly decrease with increasing vertical load, elastic lateral stiffness seems to be substantially influenced by the vertical load N. Regarding the influence of the vertical load N on yield displacement d_y it remains almost constant. On the contrary, maximum displacement du is strongly influenced by the vertical load N. In what respects the behavior of the structure at yield the main parameter affecting the shear at yield V_y, is the compressive strength fc,t of wood that defines the strength of the diagonal strut (Figure 25 (Right)). Yield displacement dy is mainly affected by the area of the panel, dy is a correction coefficient that takes into account the aspect ratio of the panel as shown in Figure 25 (Left).

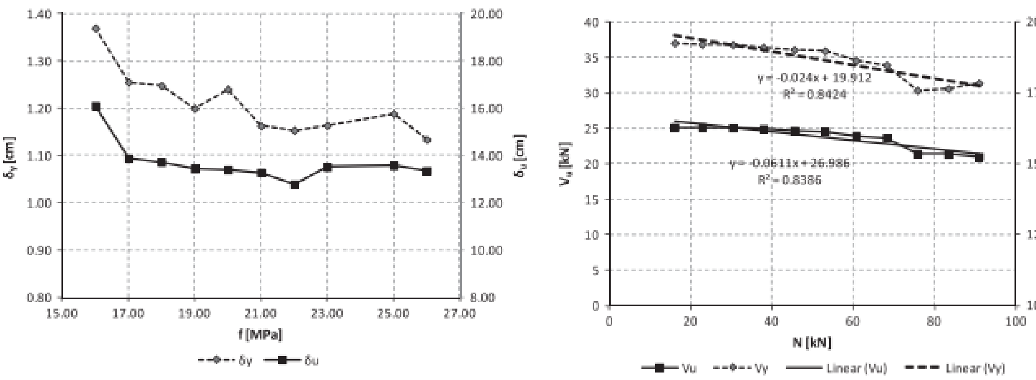


Figure 25. (left) variation of displacements dy and du with timber strength fc,t. (right) variation with n of shear strength

2.6.3. Seismic Considerations

The purpose of the analysis [37] was to obtain the value of γsis that defines the intensity of the seismic action corresponding to the collapse of the structure, quantifying, in this manner, its seismic resistance according to (Equation **1**. R. Bento, M. Lopes and R. Cardoso (2005) [27] indicate that this equation defines the design action effects (internal forces) in structural elements (F_{Sd}) where F_{Perm} are the effects of vertical permanent loads and FE are the effects of the code prescribed seismic action.

$$F_{Sd} = F_{Perm} \pm \gamma_{sis} F_E \qquad \textbf{(Equation 1)}$$

By an iterative (step-by-step) procedure the value of γsis obtained at the end of each analysis called γsis max was obtained in order to simulate, in an approximate manner, the non-linear behavior of the structure. In fact, by introducing a number of changes in structural configuration, it is possible to simulate the main sources of non-linear behavior: (i) cracking of the masonry elements and (ii) failure of the connections between the timber elements and masonry walls.

The global stiffness of the structure, K , was obtained with (Equation **2** considering the effects of the seismic action obtained in the analyses, the global base shear reactions, F, and the average of the displacements of all the nodes of the top of the building, d, for both horizontal directions [37].

$$K = \frac{F}{d} \qquad \textbf{(Equation 2)}$$

Ferreira, Teixeira, Dutu & Goncalves (2014) [18] indicate that the numerical model must reproduce not only the initial stiffness but also the stiffness of the segment of the load-displacement diagrams after the initial decay, where it approximately shows linear behavior. This modification consisted of reducing the geometric stiffness of the diagonals by a factor that makes the overall model stiffness the same as the experimental target value. The experimental target value is the average of the Timber Frame models stiffness values, each given by the slope of the linear regression line,

The way that Cecotti & Sandhass (2010) [44] quantifies q values for timber buildings, is simply that the peak ground acceleration (PGA) of different earthquakes at which near-collapse status of the building was reached is divided by the design PGA with which the building was designed elastically, according to the code in use, where PGAnear-collapse = PGA at near-collapse state, PGAdesign = design PGA with q=1. Another method to determine the behavior factor q is to approach the issue from the reaction side and not from the action side. Strictly speaking q-factor can also be defined by the ratio in (EQUATION 4 where $R_{elastic}$ = seismic base shear assuming linear-elastic behavior, Rplastic = seismic base shear real accounting for real non-linear behavior. The chosen near-collapse criterion for Timber Frame is inter-storey drift although the collapse is usually defined as the deformation at 80% of the maximum load-bearing capacity [4]. The chosen values for the collapse displacement were the “elbow values” at the sharp bend of the envelope curves of the cyclic test data (Figure 24). The dynamic seismic actions are transferred into horizontal static forces. These forces depend above all on the mass of the building and the expected peak ground acceleration for this region. the reaction a building shows towards a seismic action is also depending on its capacity to dissipate energy, on its ductility. Therefore, an action reduction factor, the so-called behavior factor q, is introduced in most seismic codes. Furthermore, in order to generalize the behavior factor q, a large variety of earthquakes must be selected. In some way this definition is code independent, i.e. it represents a “real” q-value, instead of a “conventional” design-code based q-value. The higher the q-factor, the lower the seismic base shear. In other words, the more energy a structure is dissipating, the higher the q-factor. Plastic deformation capability and hence energy dissipation are very important concepts for earthquake design. Friction is also a powerful contribution to energy dissipation but it’s nearly impossible to determine as well.

$$q=\frac{PGA_{near-collapse}}{PGA_{design}} \qquad \textbf{(Equation 3)}$$

$$q=\frac{R_{elastic}}{R_{plastic}} \qquad \textbf{(Equation 4)}$$

The proposed procedure by [44] is a simple and straight forward approach to determine the behavior factor q which consists in the following steps: Global cyclic test data on shear walls are fitted to hysteretic models which are able to reproduce pinching behavior. The fitting parameters are envelope curve and energy dissipation, the term “envelope curve” of a cyclic test is denominating the curve wrapping, “enveloping”, the loops as if it would be a monotonic test curve (which in fact should also be carried out when undertaking cyclic testing) as shown in Figure 26. Hence this simple curve is representing the initial

elastic stiffness of a system, its ultimate load-carrying capacity and its ultimate slip [4].
The hysteretic models are basically non-linear springs; The calibrated non-linear hysteretic models, the springs, are used to represent the behavior of a shear wall without the need of explicit modelling of shear wall components; The cyclic test data is analysed and the lateral stiffness, maximum load-carrying capacity and a near-collapse criterion are established; A building is designed elastically with q=1 and a certain PGAdesign according to the current seismic standards and the elastic seismic shear forces are identified; The shear wall models are used to model 2D or 3D buildings whose behavior is hence completely governed by the hysteretic springs; all other components are considered as rigid. Assumptions must be taken on the rigidity of roofs and floors (in 3D models). The wall lengths are adjusted that they just resist the elastic seismic forces; The building models are subjected to accelerograms of various earthquakes covering a wide range of frequencies. The earthquakes' PGA values are increased until the near-collapse state is reached; The ratio of PGAdesign over PGAnear-collapse returns the behavior factor q [4].

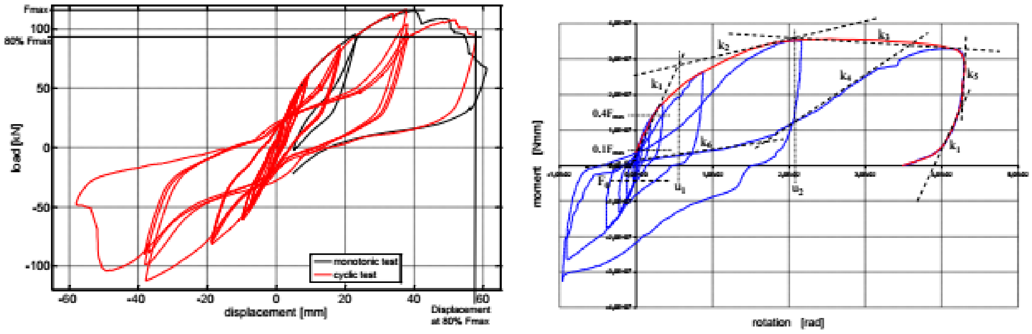


Figure 26. (left) cyclic Test on X-lam Panel [44]. (right) determination of spring model values

2.7. Final Remarks

Kouris & Kappos [39] investigated the contribution of masonry infills (using the detailed finite element model) and found to be barely influential; hence they were neglected in the proposed macro-model. Moreover, the degree of the connection effectiveness between beams and post was investigated and found to affect substantially only the ultimate displacement of the panel was investigated and found to affect substantially only the ultimate displacement of the panel. The reliability of the proposed empirical model was validated finding reasonably good match of the envelopes of the experimental loops for the test series; the macro-model was able to capture the salient features of the response (strength, stiffness, ultimate deformation) within an accuracy that is deemed appropriate for practical analysis, especially if the significant uncertainties in the mechanical characteristics of this interesting, still complex, type of traditional structural system are considered.

Kouris, Meireles, Bento & Kappos [17] indicate that the analyzed micro-model was found to compare well with the experimental results, offering good predictions in terms of both base shear and displacement. The model can also provide predictions of other, local, quantities, like penetration of one member into another, or relative sliding between members. Nevertheless, the main advantage of this rather complex model is its versatility, i.e. that it can be applied to virtually any Timber Frame wall configuration, since it does not include parameters that are calibrated on the basis of test results. Ferreira, Teixeira, Dutu & Goncalvez [18] indicate that the tests results show that the stiffening effect of the masonry infill is lower than expected, the importance of the diagonal element in the overall behavior of Timber Frame is also emphasized. For design purposes, the contribution of the tensioned diagonal should be discarded while the stiffness of the compressed one should be reduced by a specific factor. Cardoso, Lopez & Bento [37] conclude that in each iteration, damage in the structural elements or connections between elements due to collapse (brittle behavior) or yielding (ductile behavior) are identified and the structural system changes accordingly. The fact that each iteration only comprises a linear analysis allows the use of the method in current design practice. This method also allows the identification of the weakest links and connections in the structure and the identification of its expected collapse mechanism, which are relevant information to the design of seismic strengthening solutions. Ceccotti & Sandhass [44] indicate that the proposal for a standard procedure to establish the behavior factor q is a simple and straightforward method which leads to computationally efficient numerical models. The proposed standard procedure is easy to apply and reliable. The problem with the concept of static ductility ratio is avoided; energy dissipation and pinching behavior of semi-rigid joints in timber structures can be taken into account.

3. MACRO-MODEL CALIBRATION

In the present chapter the assumptions and considerations for the elaboration of the macro-model will be explained and discussed. In the first section a small presentation of the OpenSees program will show the basics of the program and the general element considerations for the preparation of the model, afterwards a brief summary of the experimental survey will be exposed in order to obtain the main parameters and materials characteristics. The next subchapter will explain how the considerations of the experimental survey are applied in the model and also some results of the experimental survey will be shown in order to see which parameters will be taken into account in order to perform the calibration process.
In order to study the non-linearities of the present model, some considerations must be done, this leads to a calibration process where graphs will be elaborated to show the results and validation process and this chapter will finalize with a sensitivity analysis.

3.1. OpenSees

Open System for Earthquake Engineering Simulation (OpenSees), was initially developed by F. McKenna and G. L. Fenves with many other contributors at the NSF sponsored Pacific Earthquake Engineering (PEER) centre, is an object-oriented framework for simulating applications in earthquake engineering using finite element analysis [47]. It has the capability to perform many types of analysis including static push-over, static reversed-cyclic, dynamic time-series, and

uniform or multi-supported excitations for inelastic time-history analysis for both structural and geotechnical systems [48].
It is based in fully based on the Tcl/Tk scripting language. It is comprised of a set of four modules that perform the finite element analysis as depicted in Figure 27. The model builder that performs the finite element model; the analysis module specifies the analysis procedure; the domain selects quantities to be monitored during the analysis; and the recorder records the output [48]. The OpenSees platform originally does not contain a graphical user interface and can therefore be challenging for users unfamiliar with the Tcl/Tk scripting language. Although there are several plugins such as "OpenSeesNavigator" for Matlab and "OSLite V0.35" that allow us to visualize the current model, also allowing us to visualize it's stresses and modal shapes. GID program can be used in order to generate the coordinates, nodes and elements of the model that shall be developed.

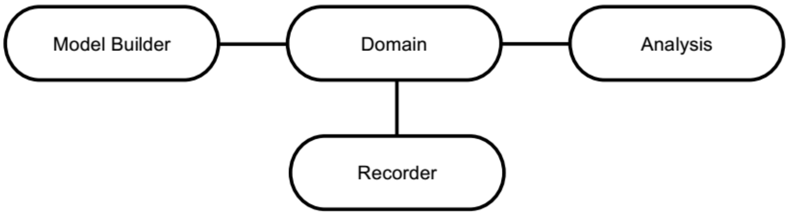


Figure 28. main modules in opensees for finite element analysis [47]

3.1.1. Model Builder

First it is important to establish the number of degrees of freedom and the dimension of the problem (1, 2 or 3) and afterwards consider the next steps:

3.1.1.1. Non-Linear Beam Column Elements

The model builder constructs as in any finite element analysis, the analyst's first step is to establish the nodes and it's coordinates, afterwards the column, beam, diagonal and girders are established as displacement beam column, truss element, linear beam column, plastic hinge, among others. In the case of the elaborated model Non-Linear Beam Column Elements were considered which is an object command based on the non-iterative or iterative force formulation and considers the spread of plasticity along the element. The integration along the element is based on Gauss-Lobatto quadrature rule (two integration points at the element ends). The element is prismatic meaning that the beam is represented by the section model identified at each integration point governing the response [47], in this step we must also assign the masses, in which for the present model will be considered as massnodes, although distributed mass nodes can also be considered throughout a different command.

3.1.1.2. Shell Element

This command is used to construct a plane 2D mesh object which can be represented as a Quadrilateral Element, Shell Element, Bbar Plane Strain Quadrilateral Element or Enhanced Strain Quadrilateral Element. In the case of the model elaboration Shell Element (ShellMITC4) is used, which uses a bilinear isoparametric formulation in combination with a modified shear interpolation to improve thin-plate bending performance, which will be considered in order to represent masonry surfaces. In this process the properties of the section are established as a PlateFiber and Elastic Isotropic, defining the young modulus, poisson's ratio and thickness.

3.1.1.3. Section Command

The elements of the studied model will be considered as an Elastic section. The general properties of each element such as young modulus, shear modulus, torsional moment of inertia, second moment of area about the local y-axis (Iy), second moment of area about the local z-axis (Iz) and Cross Section Area of the Section will be established.
The central elements of the diagonals will be considered as uniaxial materials, where the non-linear behavior will be concentrated as SAWS materials properties, which will be explained later on.

3.1.1.4. Linear Co-Ordinate Transformation

The linear co-ordinate transformation object command performs a linear geometric transformation of beam stiffness and resisting force from the basic local system to the global co-ordinate system [47]. In other words, this command will be established as linear and according to the movement of the model, it must be fixed at one axis and free in two axis (depending on the direction of the forces). For example in Figure 29 it is shown that according to the force application, the present model will be fixed in the z direction.

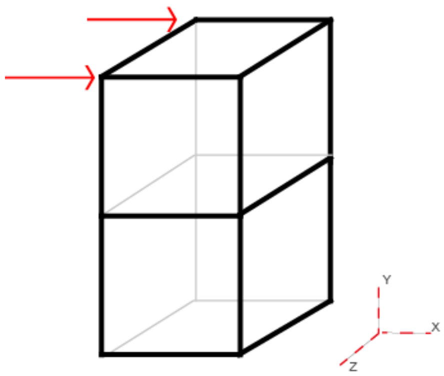


Figure 29. linear co-ordinate transformation representation

3.1.1.5. SAWS Uniaxial Material

SAWS provides the implementation of a one-dimensional hysteretic model developed as part of the CUREE Caltech wood frame project. The definition and material properties are shown in Figure 30. This force-deformation model is characterized by six physically identifiable parameters in developing the unloading and reloading paths. Degrading Stiffness (KP), Intercept strength of shear wall spring element (F0), Intercept strength for spring element pinching branch (FI), Spring element displacement at ult. Strength (DU), Initial stiffness of shear wall spring element (S0 or K0), Stiffness ratio of the asymptotic line (R1), Stiffness ratio of the descending branch (R2), Stiffness ratio of the unloading branch (R3), Stiffness ratio of the pinching branch (R4), Stiffness degradation parameter for the shear wall spring element (alpha), Stiffness degradation parameter for the spring element (beta) [49].

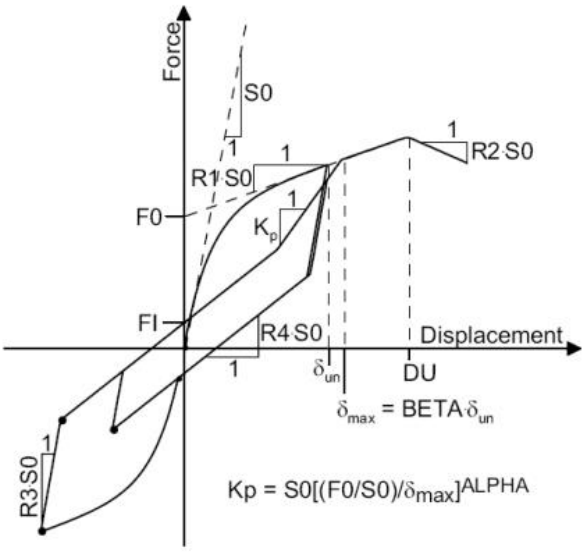


Figure 30. definition of saws uniaxial material model [47]

3.1.2. Domain, Recorder and Analysis

The Domain object is responsible for storing the objects created by the ModelBuilder as shown in Figure 31 and for providing the Analysis and Recorder objects access to these objects [47].

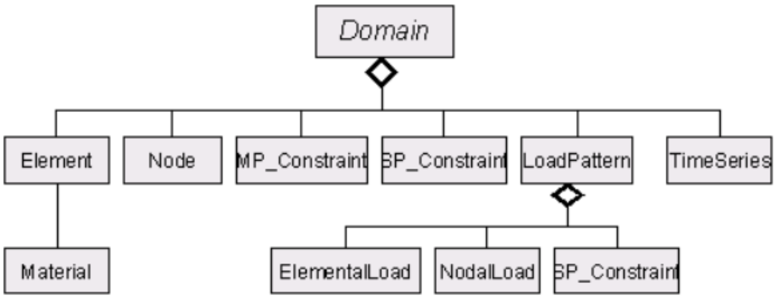


Figure 31. domain object [47]

The recorder object monitors user-defined parameters in the model during the analysis. This, for example, could be the displacement history at a node in a transient analysis, or the entire state of the model at each step of the solution procedure. Several Recorder objects are created by the analyst to monitor the analysis [47].

Each analysis in OpenSees consists of the following commands [47]:

- Dimension of the problem – 1, 2 or 3
- Constraints – handle the constraints defined on the domains
- Numberer – numbers the degrees-of-freedom in the domain.
- System – constructs the solving objects to store and solve the system of equations.
- Test – establish the convergence test to ensure the convergence can be achieved at the an end of iteration step.
- Algorithm – iterate from the last step to the current.
- Integrator – determines the next step for an analysis.
- Analysis – defines what type of analysis is to be performed.

Command	Available Options						
Constraints	Plain		Transformation		Lagrange Multipliers		Penalty
Numberer	Plain		RCM		AMD		
System	Band General	Band SPD	Profile SPD	UmfPack	Sparse SPD	Sparse General	
Test	Norm Unbalance	Rel. Norm Unbalance	Norm Displacement Increment	Rel. Energy Increment	Energy Increment	Rel. Norm Displacement Increment	
Algorithm	Linear	Newton	Modified Newton	Newton with Line Search	Krylov Newton	Broyden	BFGS
Integrator	Load Control	ArcLength Control	Min. Unbalanced Disp. Norm	Displacement Control	Central Difference	Hilber-Hughes-Taylor	Newmark
Analysis	Static		Transient		Variable Transient		

Table 2. list of options for analysis commands in opensees [48]

The analysis and the recorder will be established according to the expected results, these will be given in a *.*txt file and must be plotted separately, for the present study excel was used to plot the obtained results.

3.2. EXPERIMENTAL SURVEY

The thesis elaborated by Goncalves [5] aimed at evaluating the seismic vulnerability of the Pombalino buildings throughout an extensive experimental campaign consisting of a series of cyclic and dynamic tests. The experimental program consisted in developing a prototype, representative of the current characteristic Frontal wall, which was subsequently used for the construction of full-scale experimental models. From the results obtained from this survey, the material characteristics and general geometry of the model will be taken and analyzed.

3.2.2. Geometric and Material Characteristics

Starting with the definition of the front wall models, they reproduce the behavior of walls with two floors, with a total height of 6 m, length of 3m and a distance between walls of 2.7 m. Each wall has two 3x3 m2 panels that are connected on the first floor through half-wood connections and nails. The thickness of the wall is 12 cm. The diagonals have a section of 8x12 cm2. The middle beam is 22x12 cm2 and at the top 20x12 cm2. The floors are formed by 9 bars of 10x12 cm2, spaced apart 15 cm, on which a 16 mm thick plywood ply is laid to the bars.

The density of the mass in volume for masonry will be considered as 1800 Kg/m3 and the wood as 590 Kg/m3. As the thickness of the wall is of 0.12m, a superficial density of 216 Kg/m2 will be taken into account and timber’s thickness will vary according to the properties mentioned in the paragraph above. The Elasticity Modulus for masonry according to experiments done by [5] are between 421 and 450 MPa, for the purposes of this analysis we will use an average of both 435 Mpa and the elastic modulus for timber (pinheiro bravo NP 4305, 1995) is considered as 8000 Mpa. The shear Modulus (G) for timber is 0.69 Gpa and for Masonry is 0,63 Gpa [50].

3.3. NUMERICAL MODEL CONSIDERATIONS

The current model was elaborated on the basis of numerical model performed by Lukic [48] and modified according to experimental survey completed by Goncalves [5] in OpenSees Program. All of the floor-beams were represented in the girders of the model (z direction), while the diagonals, columns and beams are represented in the top, bottom and middle elements as shown in Figure 32 (right). The mass distribution will be considered in the exterior nodes (See Figure 34) as massnode in the x axis, it is important to consider the mass application in the same direction as the analysis will be performes (x and/or z axis). The Elasticity and Shear modulus of the elements will be considered as a composite material and will be calculated as shown in (Equation 5 as a Material with Composite Behavior where Et and Em is the Elastic Modulus of Timber and Masonry respectively and At and Am is the Area of Timber and Masonry, the same criterion will he considered for the Shear Modulus of the Elements, this procedure is referenced from Lourenco (1996) [51]

$$E_S = E_T A_T + E_M A_M \qquad \text{(EQUATION 5)}$$

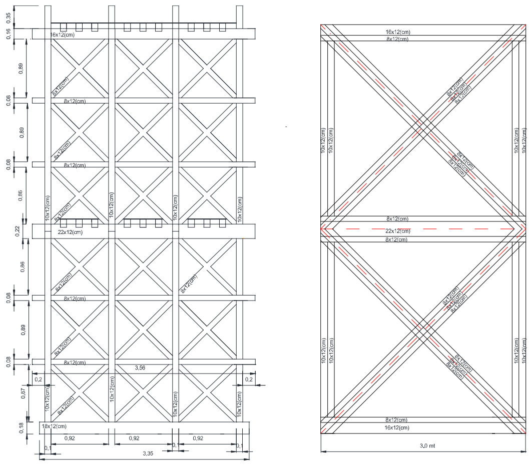


Figure 32 (left) experimental model. (right) representation of model in opensees program

		Timber (Ton)	Masonry (Ton)	Total (Ton)
Top	Floor Beam (z) Diagonal Columns Beam (x)	0,145	0,48	0,62
Middle	Floor Beam (Z) Diagonal Columns Beam	0,182	0,97	1,17

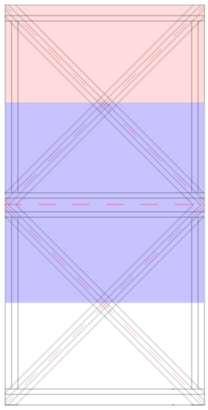


Figure 33 (left) summary of mass distribution. (right) sheme of mass distribution

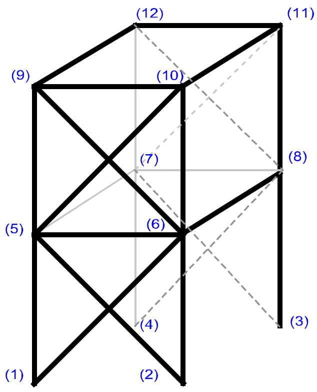


Figure 34. (right) representation of 3d model elaborated labeled with exterior nodes

The model will also consider two central nodes in the middle intersection of the diagonals as shown in Figure 40 (Right) between these two elements a dispBeamColumn element will be created, in which the Non-Linear behavior is considered throughout Seismic Analysis of Woodframe Structures (SAWS) properties. These parametres will be taken from experimental survey done by Goncalves [5] as shown in Figure 35 and . These parameters are explained in previous chapter, considering the slopes of the envelope curves, in this case it is important to point out that the Stiffness ratio of the descending branch (R2) is zero as there is no softening in the analysis. The values of alpha (a) and beta (b) will be calculated according to Mazzoni, McKenna, Scott & Fenves (2006) [47] by (Equation 6 and 7, where Dmax (dmax) corresponds to the maximum displacement of the envelope curve and Du (du) is the ultimate displacement (in this case, after the maximum displacement the curve has a plastic behavior).

$$D_{max} = BETA\ (b) * D_u \qquad \textbf{(Equation 6)}$$

$$KP = K0\ [(F0/K0)/D_{max}]^{ALPHA} \qquad \textbf{(Equation 7)}$$

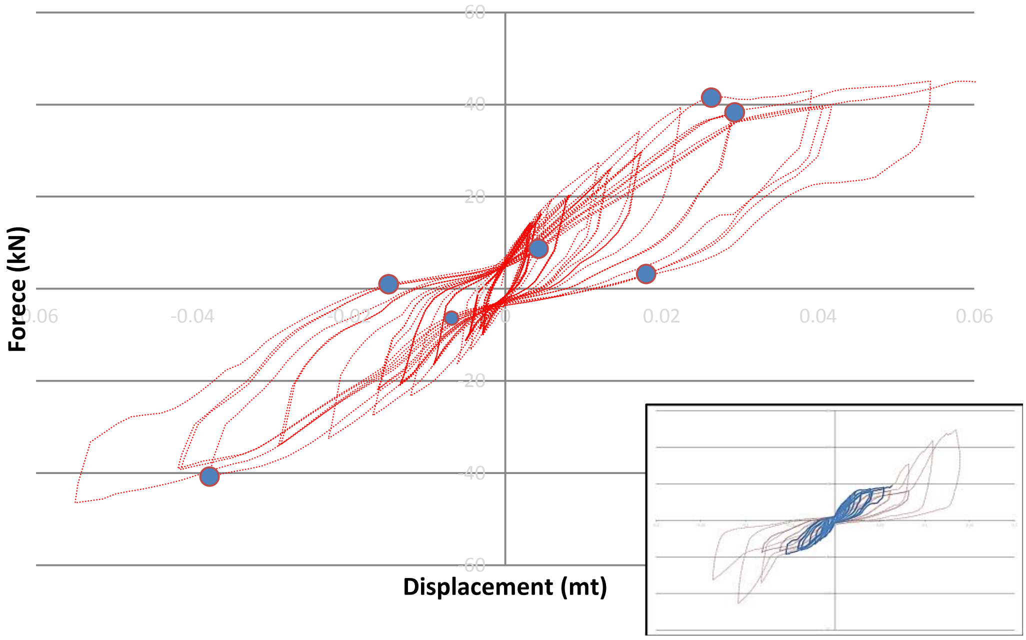


Figure 35. saws properties calculations and slopes for test 1

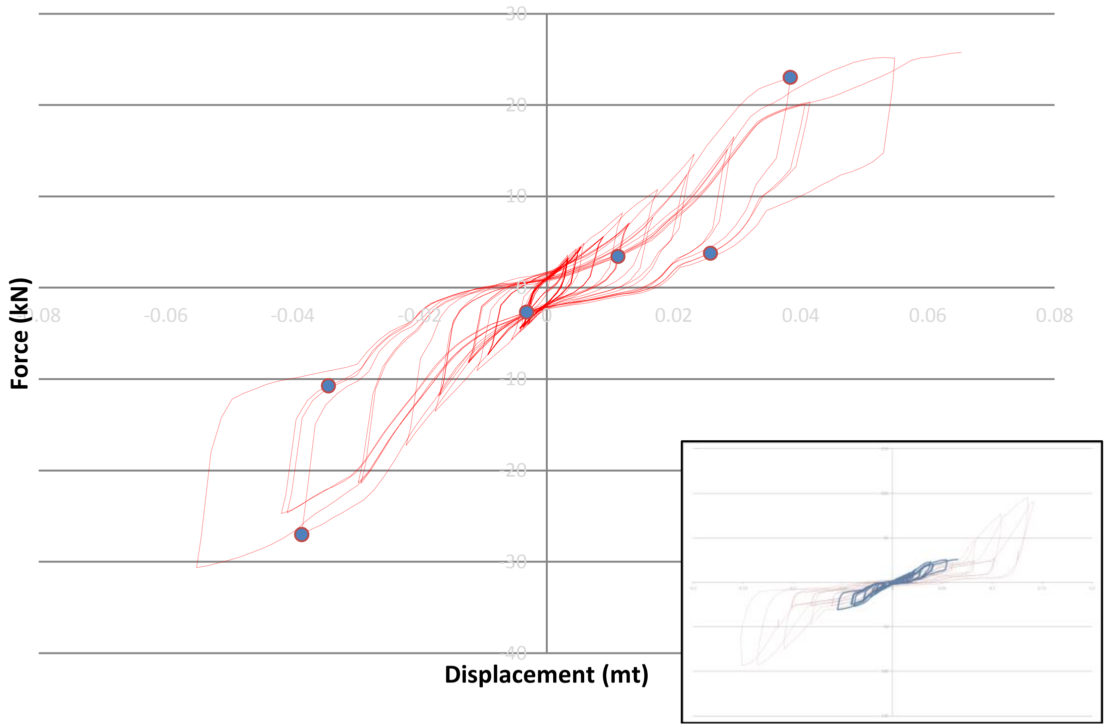


Figure 36. saws properties calculations and slopes for test 2

Parameter	Test 1	Test 2
Degrading Stiffness, KP	1195.00	1121
Intercept strength of shear wall spring element, F0	13 kN	15
Intercept strength for spring element pinching branch, FI (F1)	6.9 kN	4.40
Spring element displacement at ult. strength, DU	0.02 mt	0.03
Initial stiffness of shear wall spring element, S0 (K0)	3750 kN/mt	3970
Stiffness ratio of the asymptotic line, R1	0.33	0.28
Stiffness ratio of the descending branch, R2	--	---
Stiffness ratio of the unloading branch,R3	0.49	0.49
Stiffness ratio of the pinching branch, R4	0.10	0.07
Stiffness degradation parameter for the shear wall spring element, alpha	1.3	1.7
Stiffness degradation parameter for the spring element, beta	1.2	1.2

Table 3. saws properties results from experimentalsurvey done by [5].

The results of model 1-1 proposed by Goncalves [5] will be used, this model is compounded by the properties mentioned in the previous subchapter. Six identification tests where done, designated "Modal 1" to "Modal 6" and five vibration modes where identified from 2 Hz to 19 Hz as shown in Figure 37 (Right). For the present calibration process we will use Modal 1 in Modes 1° to 4° as shown in Figure 39. The modal shape of the corner identified in Figure 40 (Left) which in our model corresponds to node 9 will be analyzed.

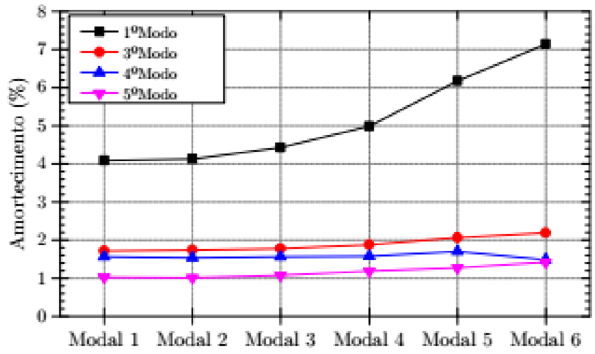


FIGURE 37. DAMPING RESULTS [5]

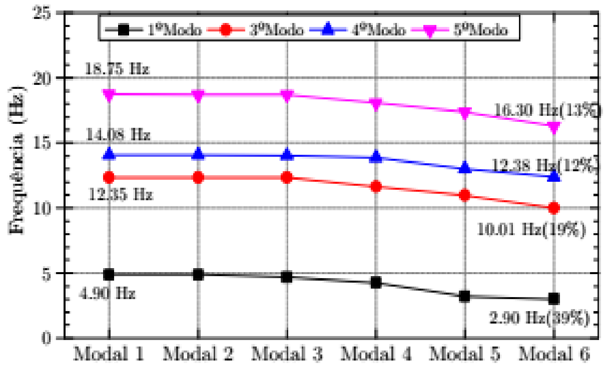


Figure 38. modal Frequency results. [5]

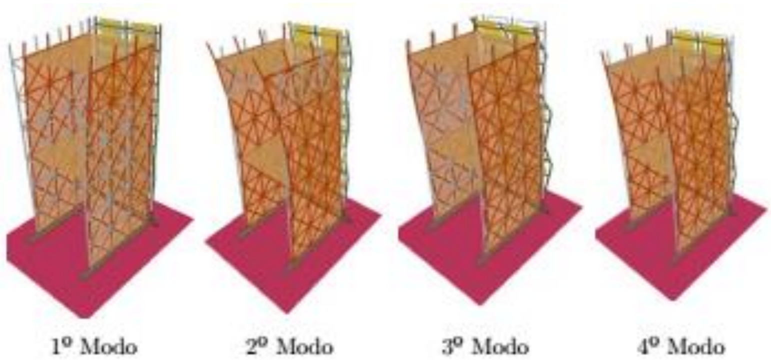


Figure 39. mode configuration for modal 1 (model 1-1) test [5]

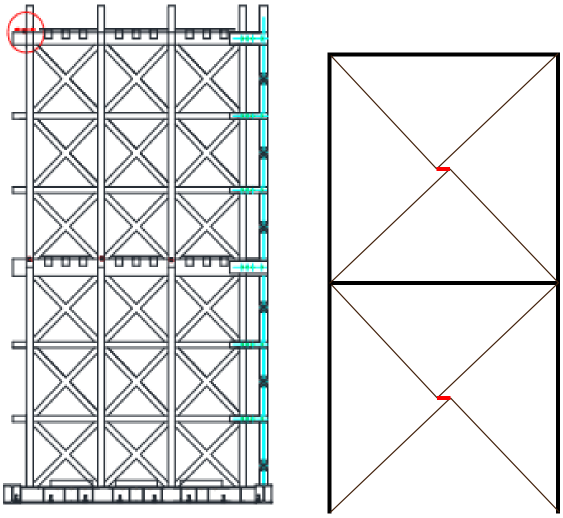


Figure 40. (left) position of the node in which the model is analyzed. (right) central element shown in red

Turning to the displacement domain, the horizontal relative displacements in the West wall on the Southern and Northern sides obtained by the optical transducers are shown in Figure 41. It is shown that the displacement increases with signal intensity but it is not linear [5].

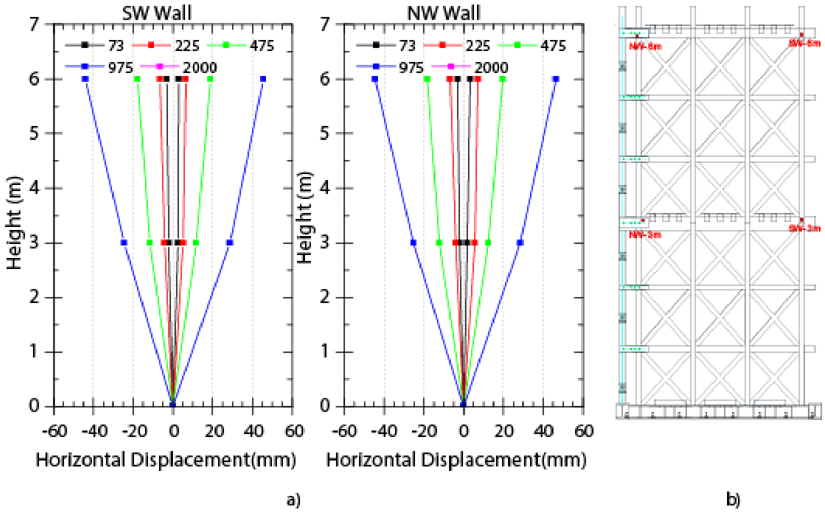


Figure 41. (a) relative horizontal displacement. (b) target localization. [5]

3.4. Calibration Macroelement

The properties explained previously are summarized in Table 4, but the initial stiffness will be modified dividing it by eight (8) having a final value S0 of 468,75 kN, this was done in order to obtain a similar pushover curve as the one given in the experimental survey.

The frequencies of the model will be very similar to the ones obtained from the experimental survey as shown in Table 5. Although the experimental curve has significant differences (Figure 42.)

General Properties	Total Young Modulus (kN/m)	6.606.000
	Total Shear Modulus (kN/m)	645.300
Column Properties	Area (m2)	0.024
	Iy (m3)	0.00049
	Iz (m3)	0.00027
Top Beam	Area (m2)	0.024
	Iy (m3)	0.00049
	Iz (m3)	0.00027
Middle Beam	Area (m2)	0.045
	Iy (m3)	0.00049
	Iz (m3)	0.00027
Girder	Area (m2)	0.054
	Iy (m3)	0.00049
	Iz (m3)	0.00027
Diagonal	Area (m2)	0.0096
	Iy (m3)	0.00013
	Iz (m3)	0.000061
SAWS Properties	F0 (kN)	15
	DU (m)	0.03
	S0 (kN)	496

Table 4. summary of original material properties

	Mode 1	Mode 2	Mode 3	Mode 4
Experimental Results (MW1)	4.9	12.35	14.08	18.75
Numerical Model	5.06	11.92	12.68	17.56
Error	3,1%	3,4%	9.9%	6.34%

Table 5. comparison of frequencies for experimental vs. numerical results.

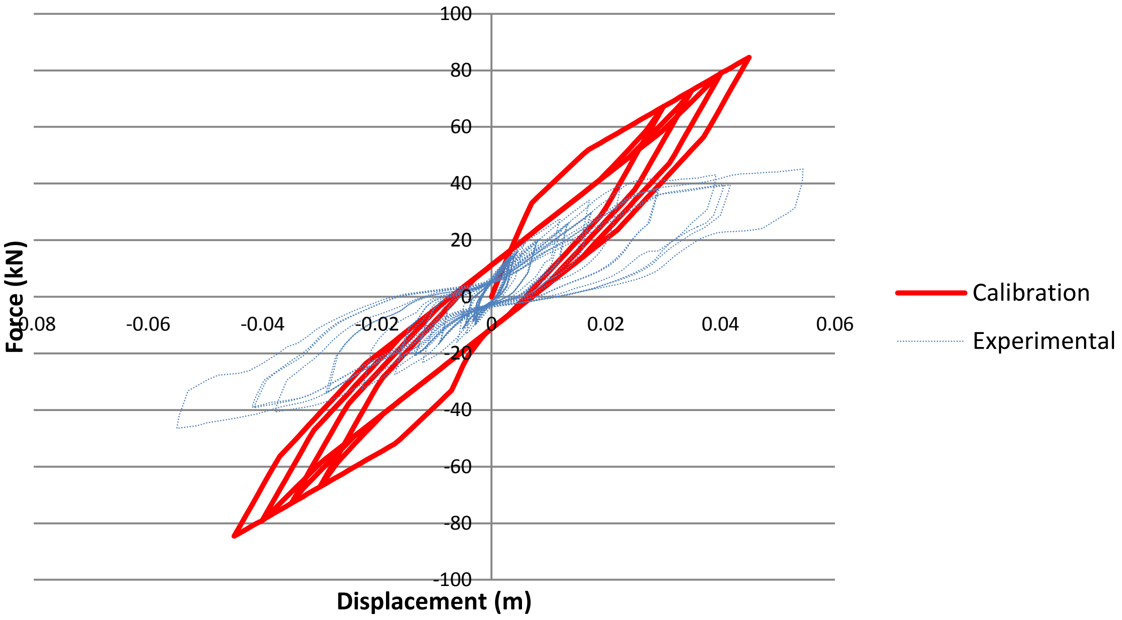


Figure 42. cyclic curve results using the materials original properties.

The calibration and the final model can be done based on the given experimental results, also considering the frequencies.

3.5. Sensitivity Analysis

The current model will consider the beam, gird, column and diagonal elements as trusses (See Figure 43 (Left)) because we want the nonlinearities and model dynamics concentrated on the central element shown in Figure 40. The model properties explained in the previous chapter (Table 4) will be modified, and iterations will be done in order to obtain similar envelope curve (Figure 35 and Figure 36) for the Cyclic Analysis. As explained previously the masses will be concentrated on the nodes (function: massnode), so this may lead to important differences in the calibration results, which will explained later on. The load pattern applied is shown in Figure 43 (Right) which will be represented on nodes 6 and 9. The properties exposed in Table 4 will be modified in order to consider the elements as trusses.

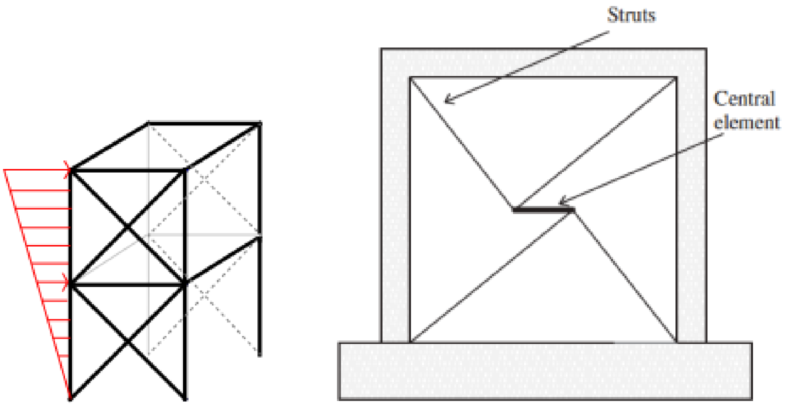


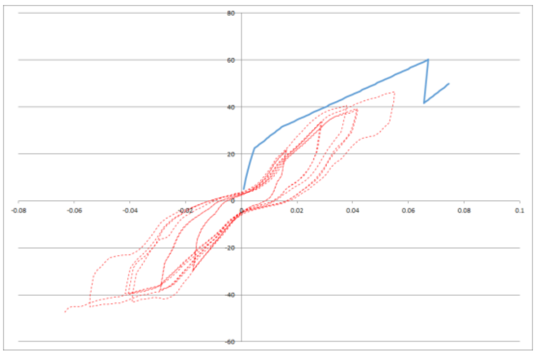
Figure 43 (left) load pattern distribution. (right) Equivalent bi-diagonal strut model [48]

General Properties	Total Young Modulus	6.606.000
	Total Shear Modulus (kN/m2)	645.300
Elements	Area (m2)	2E3
	I (m3)	0.0003
Diagonal Elements	Area (m2)	2E3
	Iy (m3)	0.00015
SAWS Properties	F0 (kN)	15
	DU (m)	0.03
	S0 (kN)	496

Table 6. summary of modification of properties

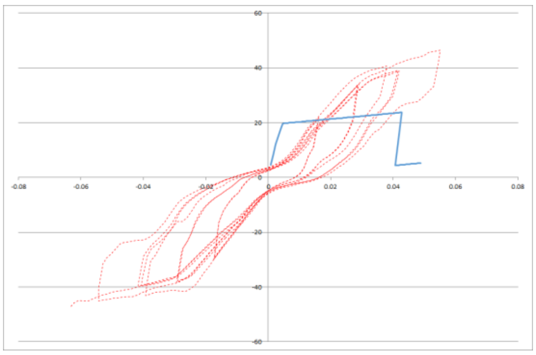
The pushover calibration will be done by a series of iterations as shown in Figure 44. After a series of modifications, it was proven that the parameters which meant the most important curve modifications where Inertia and Area. Case 3 and Case 8 will be used as the most adequate to start the iterations of the envelope curve. The cyclic envelope curve will be identified with three elements as shown in Figure 45: 1st slope, 2nd slope and the connection between both of them (which can be more round or sharp), the first slope represents the K0 (Stiffness), the second slope is related to the relationship force- displacement.

Pushover is a static-nonlinear analysis method where a structure is subjected to gravity loading and a monotonic displacement-controlled lateral load pattern which continuously increases through elastic and inelastic behavior until an ultimate condition is reached. Lateral load may represent the range of base shear induced by earthquake loading, and its configuration may be proportional to the distribution of mass along building height, mode shapes, or another practical means. Output generates a static-pushover curve which plots a strength-based parameter against deflection [52]



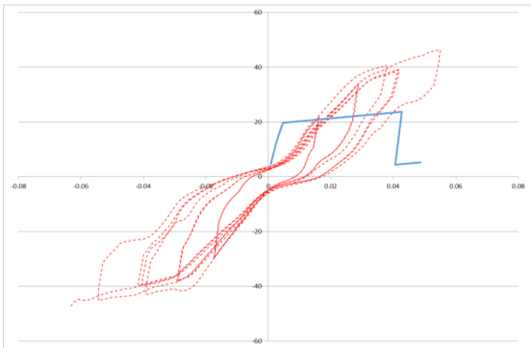
A) **CASE1**

Inercia: 0.0001
Area: 1*E10
DU: 0.30



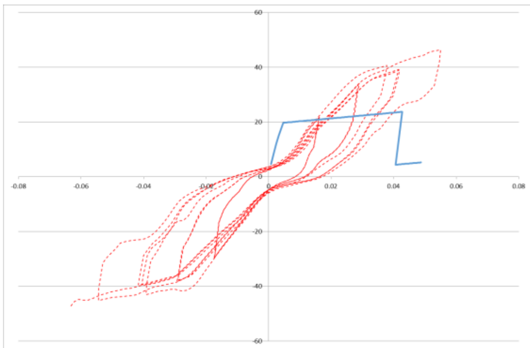
B) **CASE 2**

Inercia: 0.00001
Area: 1*E10
DU: 0.30



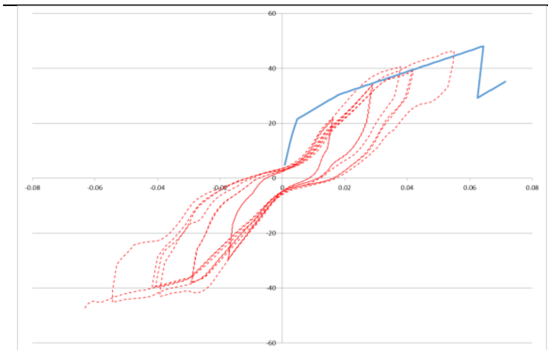
C) **CASE 3**

Inercia: 0.00001
Area: 1*E05
DU: 0.30



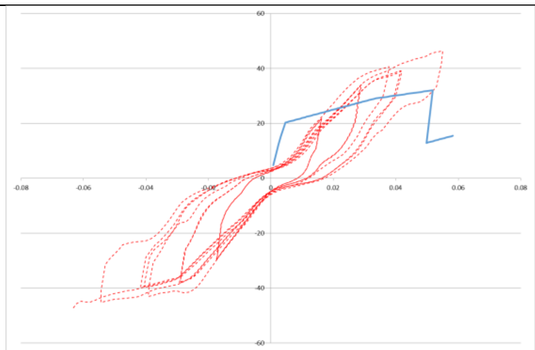
D) **CASE 4**

Inercia: 0.00001
Area: 1*E07
DU: 0.30



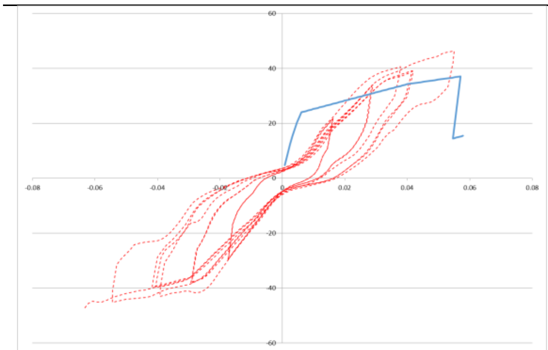
E) **CASE 5**

Inertia: 0.00007
Area: 1*E10
DU: 0.30



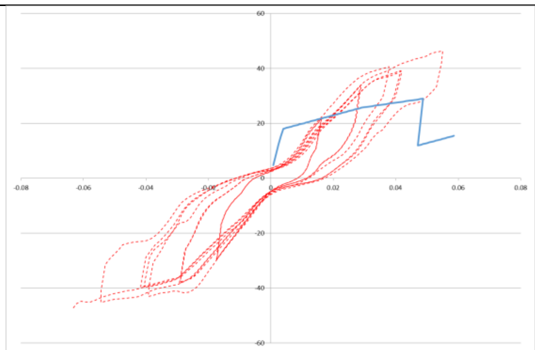
F) **CASE 6**

Inertia: 0.00003
Area: 1*E10
DU: 0.30



G) **CASE 7**

Inertia: 0.00003
Area: 1*E10
DU: 0.40



H) **CASE 8**

Inertia: 0.00003
Area: 1*E10
DU: 0.25

Figure 44. iteration of pushover curves

In the calibration procedure shown in Figure 46 it will be proven that the frequencies and the envelope curve cannot be calibrated simultaneously. This is explained because the correct representation of the mass should be concentrated on the element as a distributed mass, but at the moment of the model elaboration it was not possible to perform this, so simplifications were done and it was decided that the mass will be concentrated on the nodes. In order to calibrate the model the present study will focus on obtaining the correct representation of the envelope curve and assuming the error obtained in the frequency results.

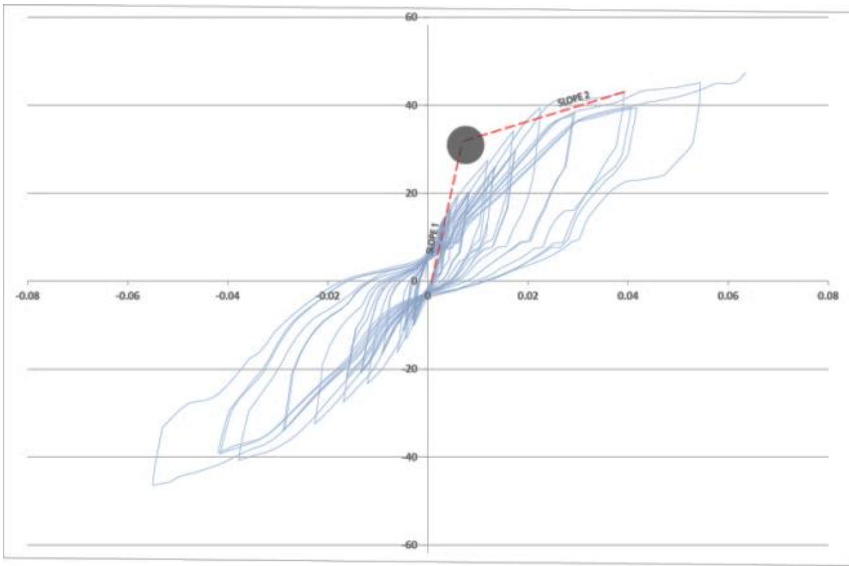


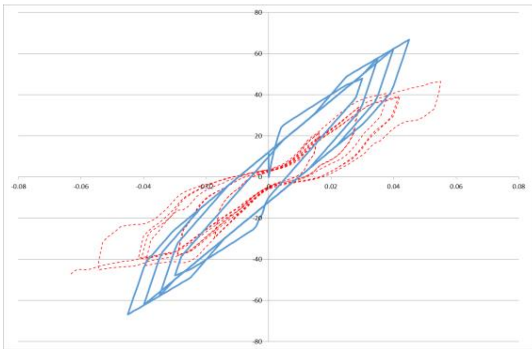
Figure 45. general bilinear representation of the Cyclic Envolope curve

The following study will consider a cyclic pushover analysis. This may be performed using either of two approaches, outlined as follows:

- Sequence of nonlinear-static load cases: Cyclic pushover analysis may be performed through a sequence of chained pushover analyses. Two key aspects of this approach include each pushover analysis would be pushing the structure in the direction opposite to that of the preceding pushover load case and each pushover load case, aside from the first, would use stiffness at the end of the previous pushover load case.

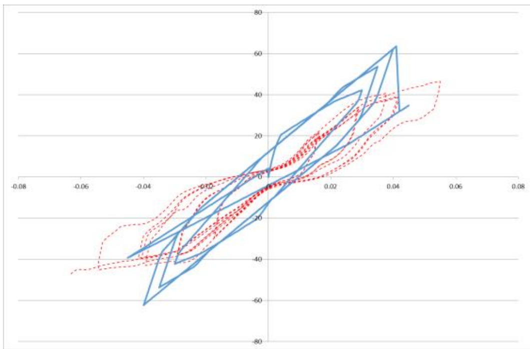
- Time-history load cases: An alternate approach is to use a single nonlinear time-history load case. Some special considerations are necessary when using a time-history load case to model applied loading, which can be: Load should be scaled up or down to achieve the monitored pushover displacement desired for each cycle; The time function should consist of linear segments which apply the loads in one direction and then the reverse, possibly with a constant segment to hold loads before their reverse; For each cycle in the sequence, the peak positive and negative time-function values must be found, starting with the first cycle of load application. [52]

For the present study cyclic sequence of nonlinear-static load cases will be considered.



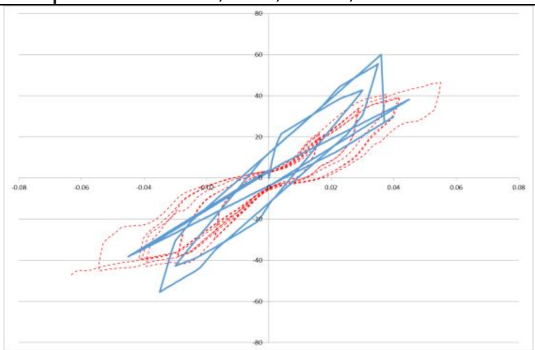
A) **CASE 1**

Inertia: 0.0001
F0: 15 kN
S0: 600
Frequencies: 6.3, 8.1, 15.2, 16.1



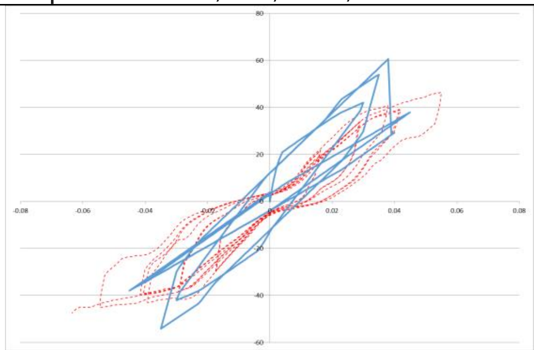
B) **CASE 2**

Inertia: 0.0001
F0: 10
S0: 600
Frequencies: 6.3, 8.1, 15.2,16.1



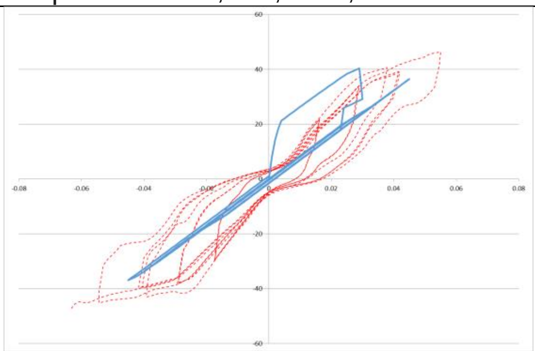
C) **CASE 3**

Inertia: 0.000095
F0: 10 kN
S0: 700
Frequencies: 6.7, 8.3, 16.3, 17.1



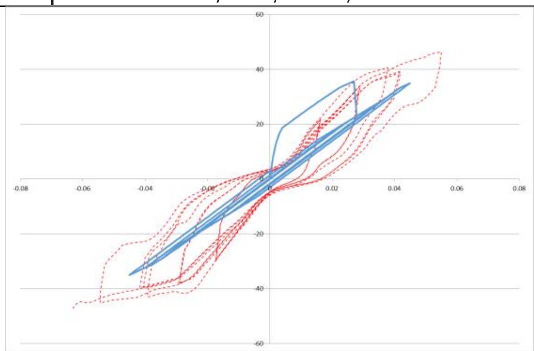
D) **CASE 4**

Inertia: 0.000095
F0: 10 kN
S0: 650
Frequencies: 6.5, 8.2, 15.8, 16.65



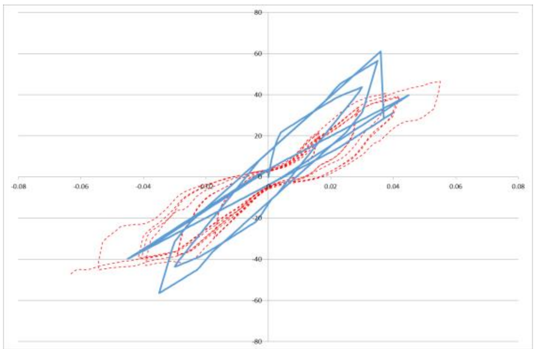
E) **CASE 5**

Inertia: 0.000085
F0: 10 kN
S0: 700
Frequencies: 6.7, 8.2, 16.3, 17.05



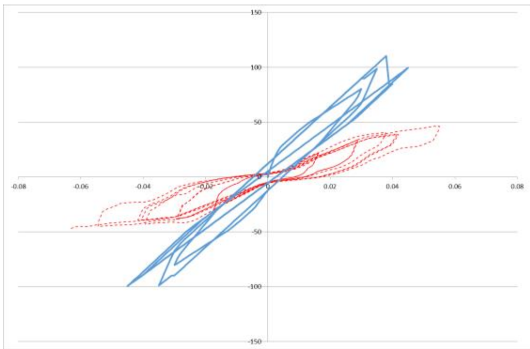
F) **CASE 6**

Inertia: 0.000085
F0: 8 kN
S0: 700
Frequencies: 5, 8, 15, 16



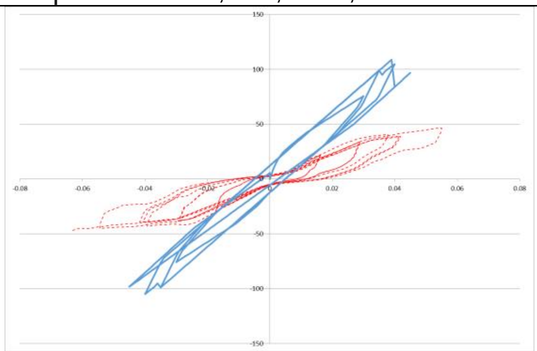
G) **CASE 7**

Inertia: 0.0001
F0: 10 kN
S0: 700
Frequencies: 6.7, 8.4, 16.4, 17.2



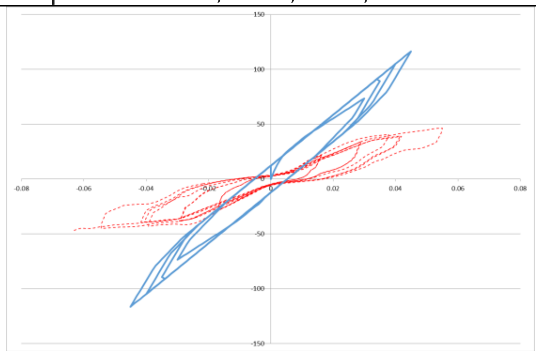
H) **CASE 8**

Inertia: 0.0003
F0: 10 kN
S0: 700
Frequencies: 7.2, 11.3, 17.4, 19.7



I) **CASE 9**

Inertia: 0.0003
F0: 8 kN
S0: 600
Frequencies: 6.7, 11.03, 16.43, 18.85



J) **CASE 10**

Inertia: 0.0003
F0: 8
S0: 450
Frequencies: 6.04, 10.5, 14.7, 17.3

Figure 46. cyclic analysis iterations and frequency results

Regarding the general properties of the macro-model, the results of the iterations show that Inertia and Area are overall factors that have a directly proportional relationship between the inclination of the second slope and the frequencies, this is assumed because higher inertia means more stiffness and this requires higher forces in order to displace the model. Inertia also modifies significantly the overall frequencies of the model (if the inertia is too small modes 1, 2 and 3,4 will have similar values). The area variation does not modify significantly the slope or the frequencies under the studied conditions. Another factor that is important in the modification of the second slope curve is the Elasticity Modulus because it modifies the inclination of the slope and also the frequencies, in inversely proportional way.
Regarding the SAWS material properties, the factors that modify significantly the inclination of the curve and the frequencies of the model are: K0 (Stiffness), which modifies the frequencies in a directly proportional way, it also modifies the response of the curve with a higher Fmax value (same slope, higher values); F0 modifies the initial pushover, it starts at lower F0 values so the pushover reaches lower Fmax and Ultimate Displacement (DU); DU will modify the length of the envelope curve according to the x axis and also the initial stiffness slope in a directly proportional way.

3.6. Final Numerical Model calibration

The analysis will focus in obtaining similarities in the cyclic envelope curve. We will calibrate the cycles shown in Figure 47. The final results for the cyclic curve analysis are shown in Figure 48 and the properties used for this analysis are exposed in Table 7. The first cycle that shows the initial stiffness (Figure 48) will not be considered in the present calibration process, in which cycles 0.018, 0.028 and 0.0398 are used.

General Properties	Total Young Modulus	1.000.000
	Total Shear Modulus	--
Elements	Area	2E4 m2
	I	0.00035
Diagonal Elements	Area	2E4 m2
	Iy	0.00035
SAWS Properties	F0	7
	DU	0.035
	S0	500

Table 7. summary of property modifications

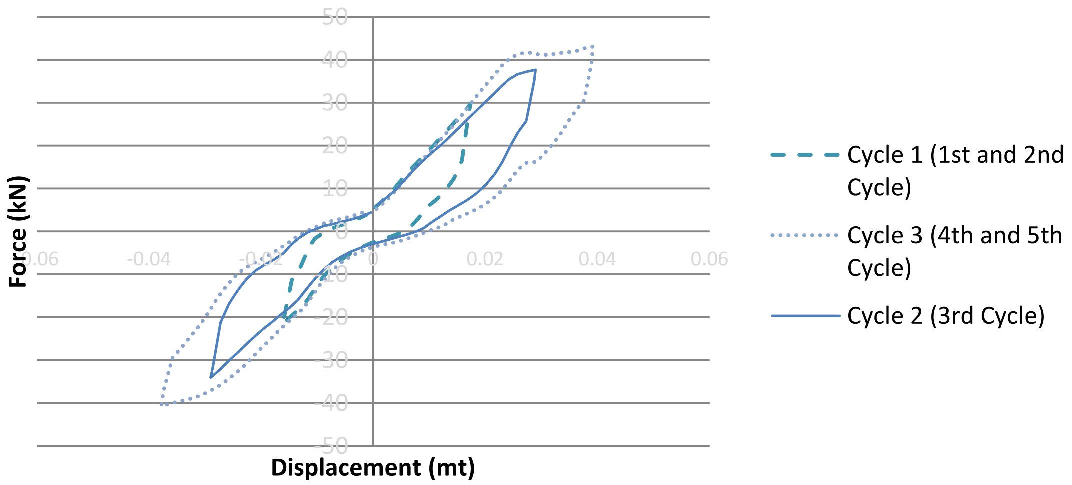


Figure 47. summary of cycles (experimental) that will be calibrated.

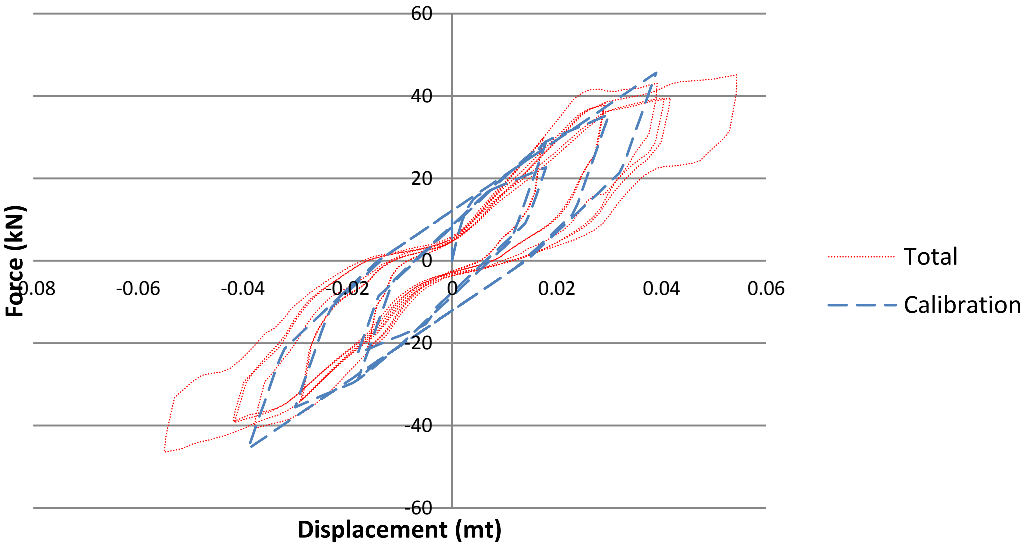
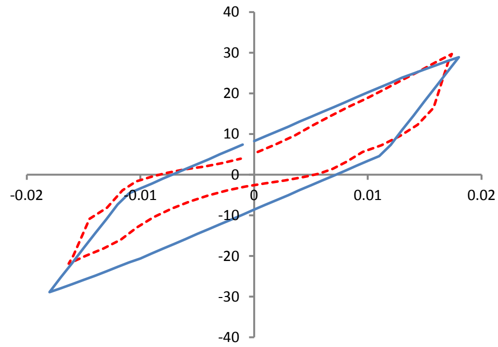
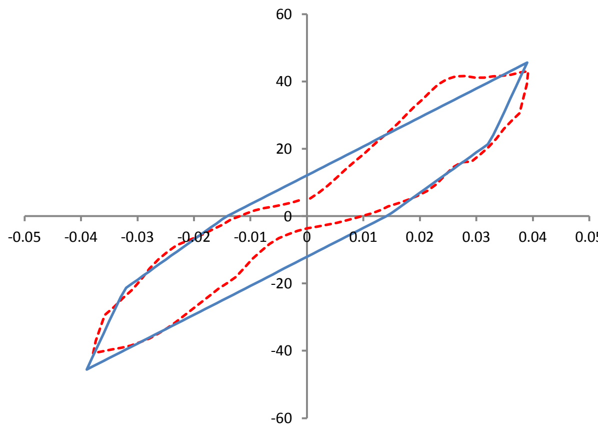


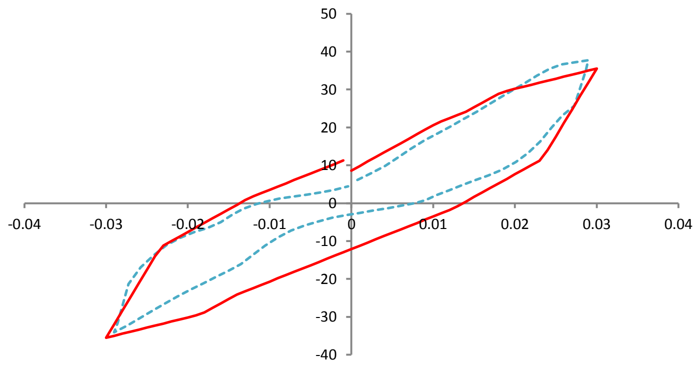
Figure 48. Cycle calibration experimental curve (blue), calibration curve (red).



(A)



(B)



(C)

Figure 49. cycle 1 calibration (a). cycle 2 calibration (b). Cycle 3 calibration (c).

The areas of each curve will be calculated in order to obtain the energy of each cycle and this value will be compared between numerical and experimental curves. As shown in Table 8 the error in the Cycles 1 and 2 is rather low, but Cycle 3 has a significantly larger error percentage. The dissipated and accumulative energy for both analysis as shown in Figure 50 and Figure 51 is rather alike, what will affirm the correct calibration of the model.

	Experimental Area	Numerical area	Error (%)
1st Cycle	0,8	0,9	10%
2nd cycle	2,2	1,94	12,9%
3rd cycle	0,88	1,26	30,15%

Table 8. summary of cyclic curve area calculations

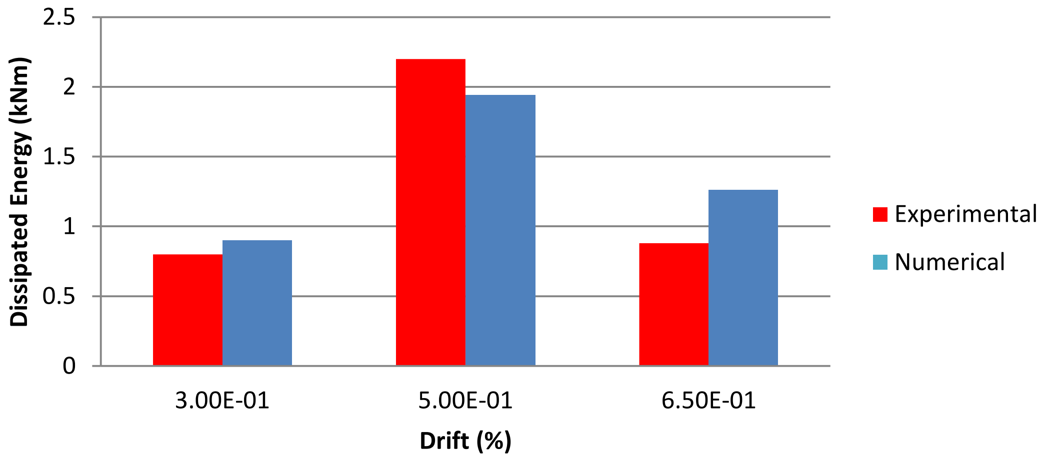


Figure 50. energy vs. drift results

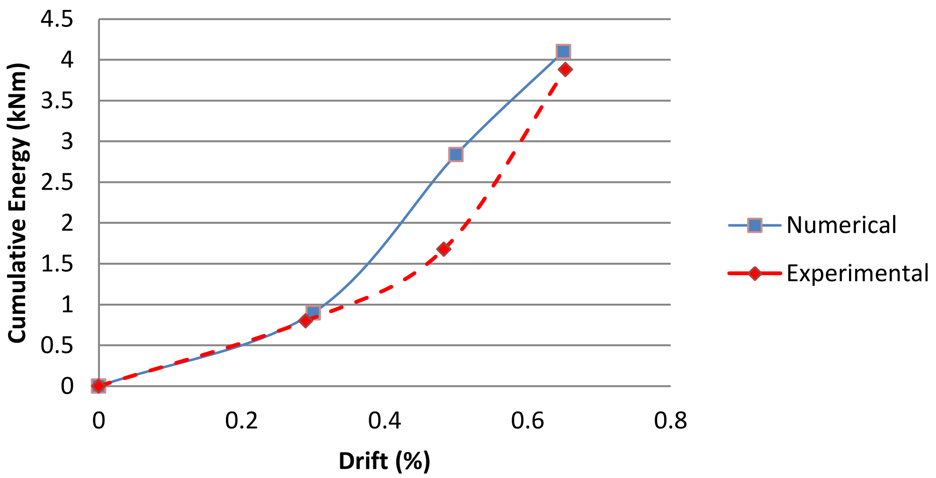


Figure 51. cummulative dissipated energy

Figure 52 shows the relative horizontal displacement graph and as explained in the Figure 41m the displacement on the 1st and 2nd floor is increasing, but the increment is not completely elastic, which could be explained because the present structure has floorbeams that modifies the behavior of the structure. Finally in Figure 53 to Figure 56 are presented the mode shapes for the calibrated model, it shoul be noted that the formed shapes cannot be compared with the experimental ones (see Figure 38), once in the experimental test the mass is distributed along the high of the frame and in the numerical model the mass was considered concentrated at the floor level.

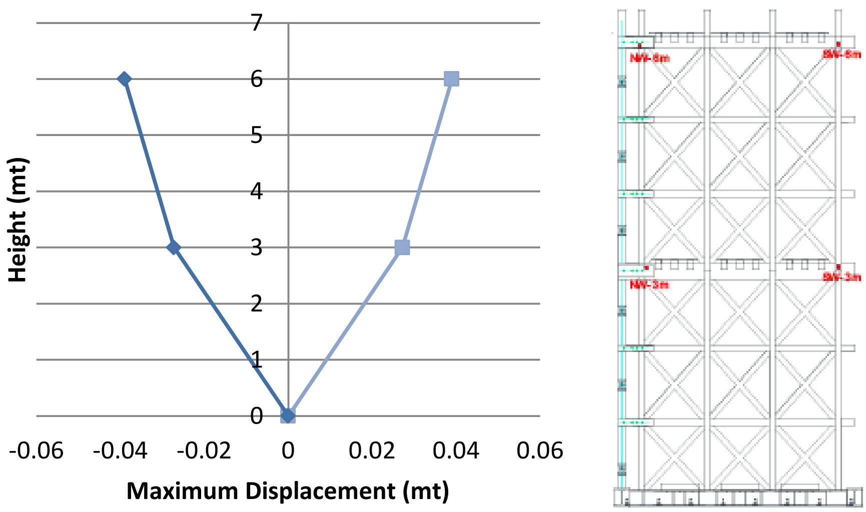


Figure 52. (left) (right) position of the recorders

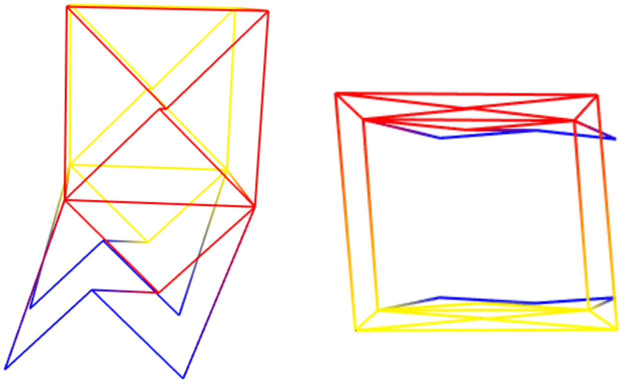


Figure 53. mode shape 1

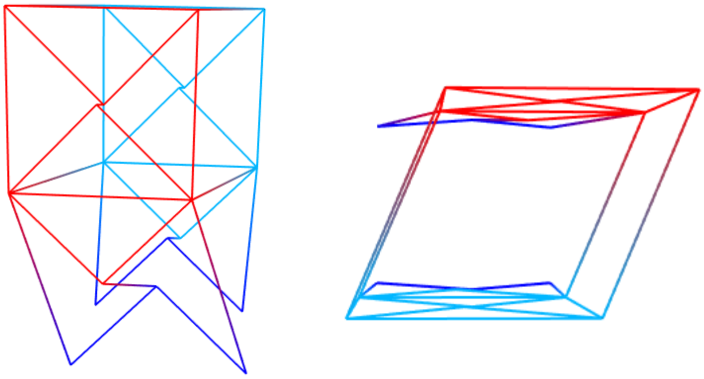


Figure 54. mode shape 2

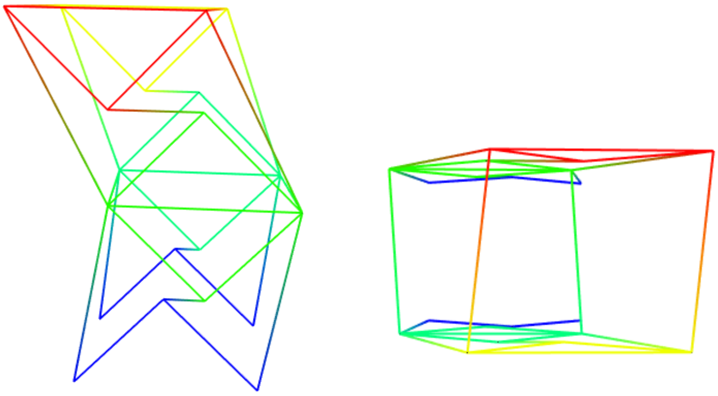


Figure 55. mode shape 3

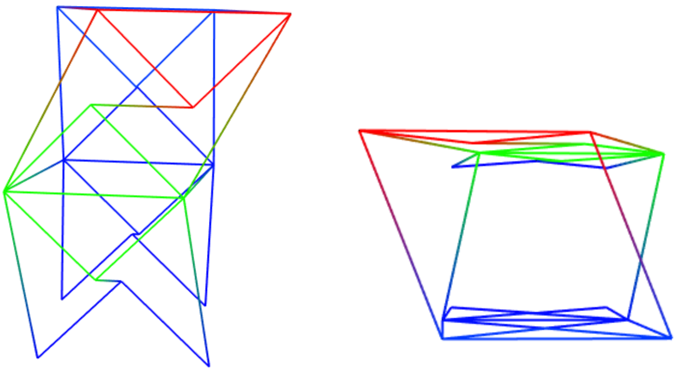


Figure 56. mode shape 4

3.7. Final Remarks

It is possible to calibrate a model based on experimental survey, although there are certain issues that still have to be worked on, such as the calibration of the envelope curve and frequencies simultaneously. The application of a distributed mass along the beams could resolve this issue, but this would have to be proven in a new numerical model.
Also, in the final model the beam, columns and girders were considered with large areas so they could work as trusses and concentrate the non-linear behavior in the central element, this factor will also influence the original behavior of the structure.
Overall, it is important to highlight that a numerical model can be done and calibrated from an experimental survey. These properties will be used later on to elaborate a real scale building and analyze it's dynamic properties.

3. REAL CASE STUDY

The properties of the macromodel calibrated in the previous chapter were used as a basis to elaborate a numerical model of a global pombalino building. A brief description of the structure's material and dimensions will be explained to finally proceed with the explanation of the real case model elaboration. This chapter will finalize with the results obtained from a pushover analysis both horizontal directions.

4.1. Case Study - Lots 210 to 220 of Rua (Street) da Prata.

The plan that created the downtown Pombalino was defined by a regular scheme of streets and squares. Each square was divided into lots of buildings with different front widths, but maintaining the same depth and height as shown in Figure 57, which also shows the studies building. The total area of the square was of 2.000 m2, varying the areas of the lots between one hundred and three hundred square meters. The studied lots have a very wide façade, In terms of the initial plan, the width of seventeen meters corresponds to six modules of facade, each having 2.8 meters. In the Floor Plan (Figure 58) there are two shops and the entrance of the building. The upper floors (2nd to 4th) are composed of a floor-plan type shown as shown in Figure 59, in which we can find: on the first floor, a row of rods and a commercial store; In the second, an office; In the third, housing; In the fourth, a house with a balcony; The fifth floor is composed of two attics (Figure 60). [53]

Figure 57. Facade of "Rua (street) de prata"

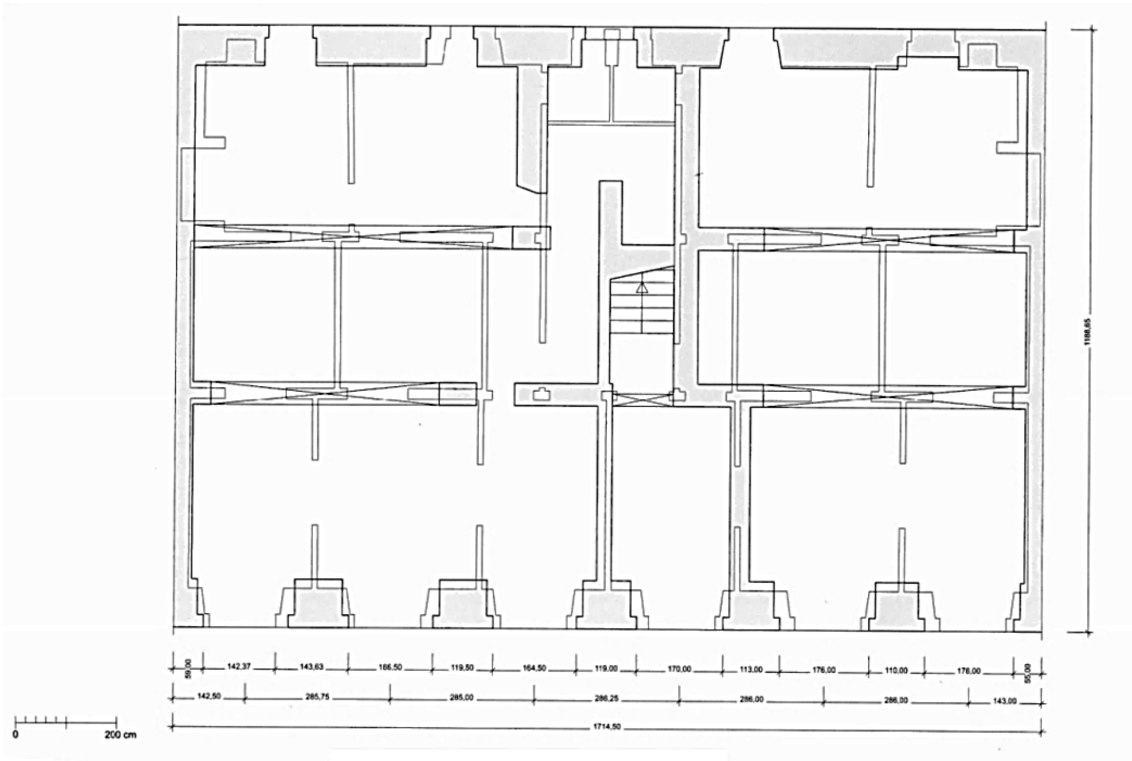


Figure 58. Floor plan (masonry ground storey)

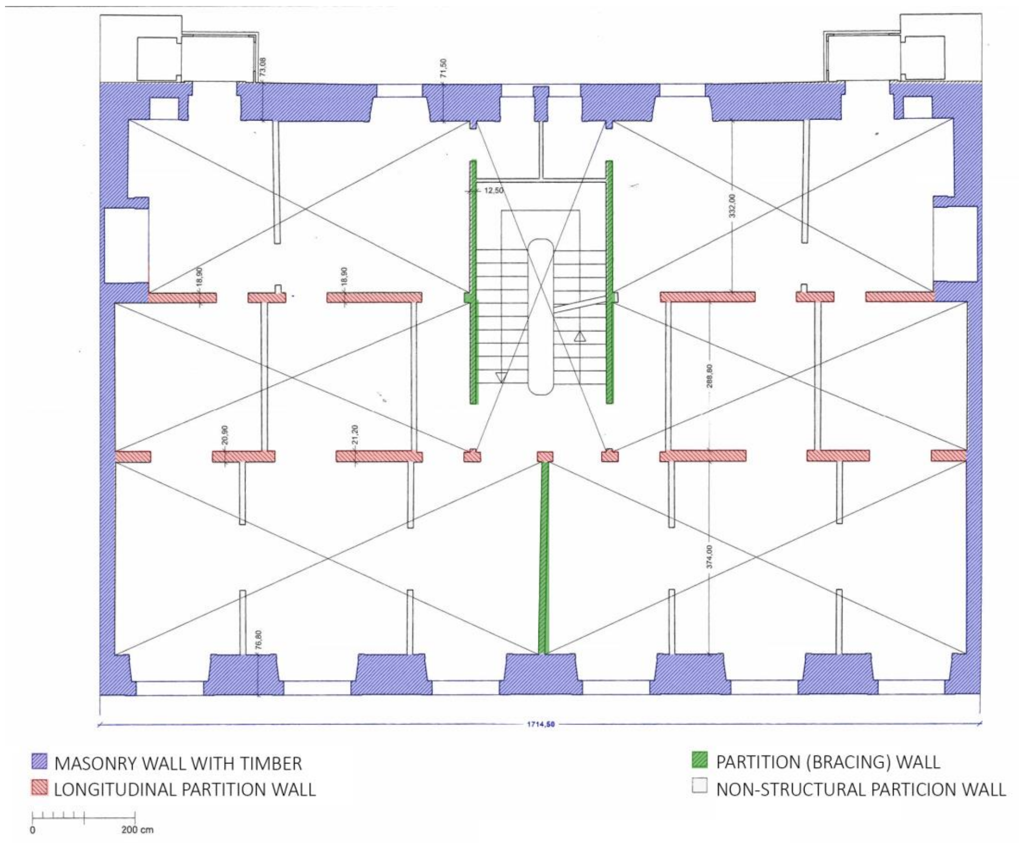


Figure 59. structural floor-type

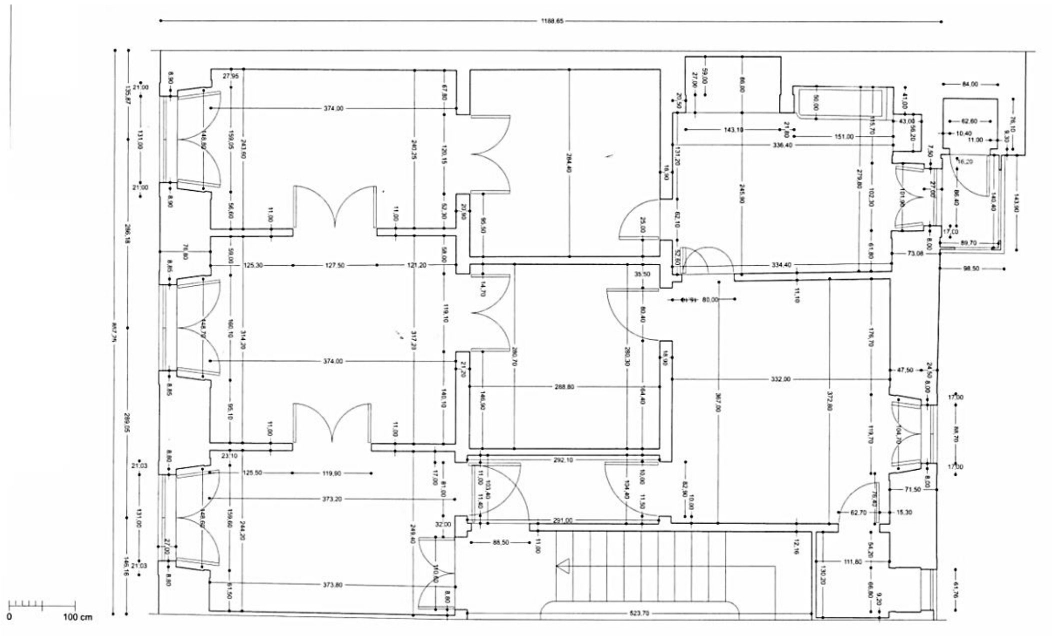
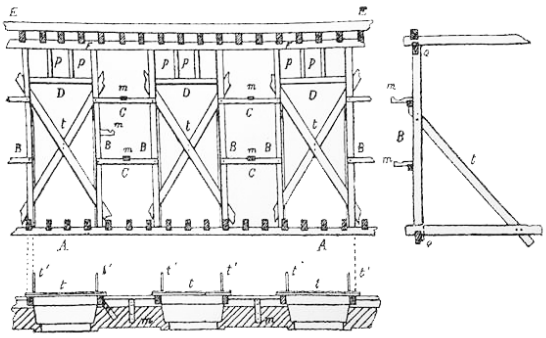


Figure 60. attic floor-plan

4.1.1. Description of Structure

A specific construction type with wooden structure (gaiola) was used in the Lisbon reconstruction, its origin is unknown (though similar construction was already present in Portugal and in Lisbon in particular and it behaved well during the earthquake), but considered at the time as being the most appropriate to resist earthquakes, like described in Chapter 2. Industrialized construction was adopted for Pombalino Buildings, which implied a continuous production of constructive elements with fixed dimensions outside the construction site. Gaiola can be described as a structure constituted by a skeleton of timber with infill of traditional masonry; in case of a seismic hazard and with the probable disintegration and collapse of the masonry, the wooden structure would remain standing. Until the beginning of the century, gaiola has continued to be used not only in the downtown area, but throughout the whole city. Only the insertion of new structural materials (such as iron) has displaced this traditional system [53]. A carpentry manual of the twentieth century describes the Pombalino system. Some of its designs are reproduced for illustrative purposes (Figure 61):



A. Wall Plate (Frechal)
B. Upright (Prumo)
C. Crossbar (Travessanho)
D. Pole (Verga)
E. Top Wall Plate (Frechal Superior)
F. Counter-bore (Contra-Frechal)
m. Brace (mao)
p. Stud (Pendural)
t. Diagonal (travadoura)

Figure 61. structure of timber gaiola. floor plan, elevation, architectural cut. [53]

- Vertical elements: Uprights (B) can have a height of one or more floors, spaced at 90.
- Horizontal Elements: Wall Plates (A) and Upper Wall Plates (E)
- Bracing Elements: Horizontal timber pieces, crossbars (C) between the uprights
- The openings are elaborated with poles (D) and sills joined to the uprights; The transverse is joined to the Upper Wall Plate.
- The Braces (m) are timber pieces that join the structure to the masonry.
- The Diagonal (t) are temporary elements used during the construction process.

As shown in Figure 61, after finishing the timber structure, ordinary masonry walls were built and other elements were fixed between each other. These composite walls have large widths varying between 0,90/1,00 meters in regular heights, and about 0,60/0,70 on the higher floors. The pavements are constituted by timber floor beams. Figure 62 presents a structural partition, used to compose the main divisions of the building. These elements are similar to the structure previously presented, but the main difference is that this wall is more slender. Figure 63 presents a simple partition wall used to define the compartmentalization of the building, these divisions have a structural function and due to their lightness, its location can be freely chosen, without the need of a wall for lower support, following only the convenience of the interior distribution. These buildings also have a characteristic type of foundation, made with

wooden stakes, this is because the terrain is weak (composed of rubble and sedimentary deposits) [53].
For illustrative purposes a detailed geometric survey was performed, the third floor shows a common interior distribution for all the floors (except the ground level), so it will be considered as a floor-plan-type for the whole lot, from this survey several assumptions can be presumed:

- The main façade (77 cm thick), the rear façade (73 cm thick) and the middle walls (30 cm aprox. corresponding to half the thickness), are masonry walls with an interior timber structure.
- The longitudinal partition walls (with a thickness of 19/21 cm aprox.), parallel to the façade, ongoing from one wall to another, and another interrupted by the staircase, are structural partition walls. These are supported on the ground floor by four masonry arches and an also an arch above the staircase access.
- The walls of the staircase and probably the wall dividing the two apartments in the front facade area, should also be resistant walls of the same type but narrower due to the lighter loads that they support, fundamentally the staircase itself. Having a central position in the structure, they should act as bracing elements, giving the necessary stiffening to longitudinal walls. An interesting fact is the slimness of the walls that surround the staircase, only 11,25 cm. This fact can only be explained if the structural system is actually a wooden skeleton, as referred to above, and not the traditional sturdy masonry walls.
- The remaining partition walls do not have a structural function, they just divide a space according to the use that they will be given. [53]

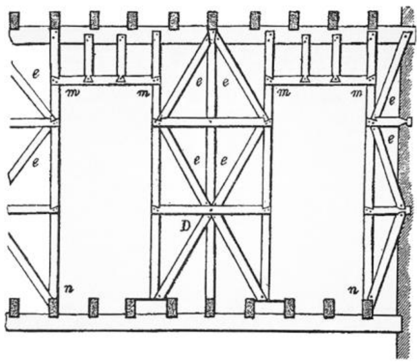


Figure 62. structural partition [53]

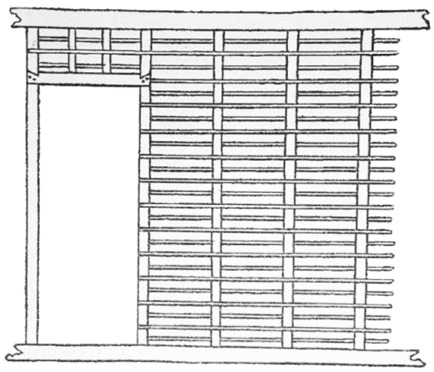


Figure 63. partition [53]

4.2. Model development

For the developmente of the real model Shell Elements we considered for the external walls, due to the great amount of masonry walls on the

ground floor and the perimeters of the buildin, Rigid Diaphragms were considered on the first floor level, due to the important stiffness of the masonry volts on the ground storey, and the macro-model to introduce the frontal wall.
First macro shells were considered in the façade and lateral sides of the building and afterwards smaller shells of maximum 50x50 cm was designed in the lateral shell elements of the buildings (See differences in Figure 64). The coordinates, elements and nodes of the shell elements were elaborated by a simplified model in GID program which were later on imported to OpenSees. It is important to highlight that in order for the model to run no loose nodes and superposition of nodes shall exist, this means that the coincident nodes must be erased and referenced to the existing model. In the elaboration of the shell facade there must be continuity and connectivity between elements.
As the elements of the model are considered as trusses, this will automatically create a rigid diaphragm not having the need to create it as a new element.

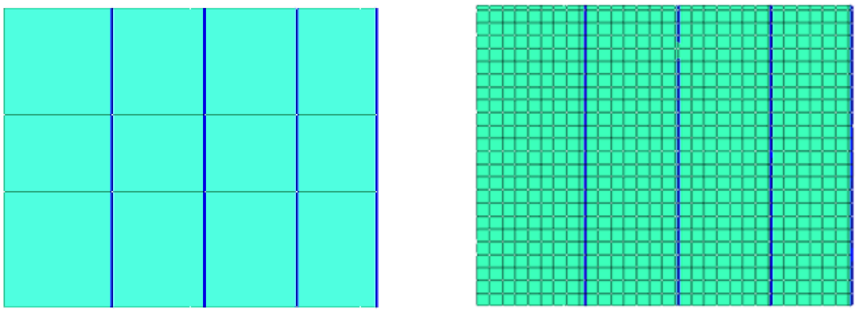


Figure 64. comparison between macro and micro shell elements on lateral facade

4.2.2. Model Geometry

The floorplans show a window façade on front and back which will be represented on the model as vains surrounded by shell elements that will compose the main structure of the building as shown in Figure 65 . The structural partition walls will be considered as composed and shell elements as appropriate. The first floor and external walls as they are built of masonry will be modelled as shell elements, the structure surrounding the staircase will be established as gaiola and represented as a composite material (explained in previous chapters). The masonry properties will be obtained from Cardoso, 2003 [54] and the properties for the gaiola structure will be obtained from the previously shown calibrated model. The floorplans and elevations were scaled in AUTOCAD program as linear elements (see Figure 65) and posteriorly elaborated in OpenSeesLite as shown in Figure 66 (Left) and Figure 67. The Staircase (Figure 67 (B)) is considered on it's lateral walls as a gaiola structure.

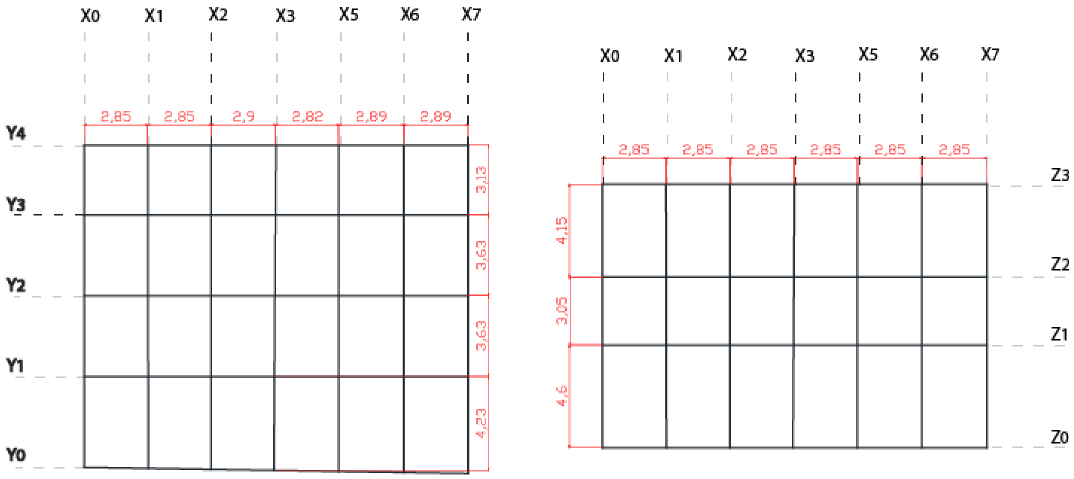


Figure 65. main axis of pombalino structure: (right) elevation view. (Left) floorplan view

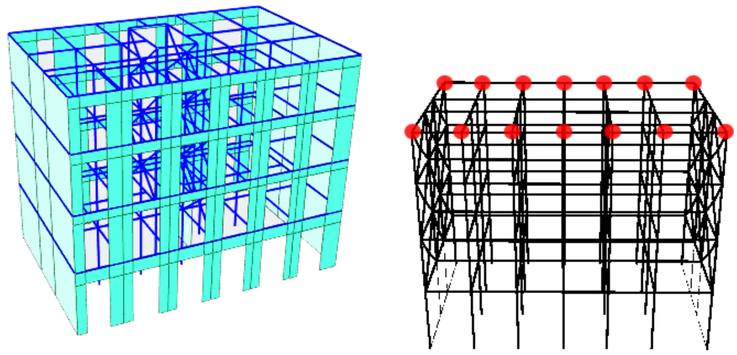
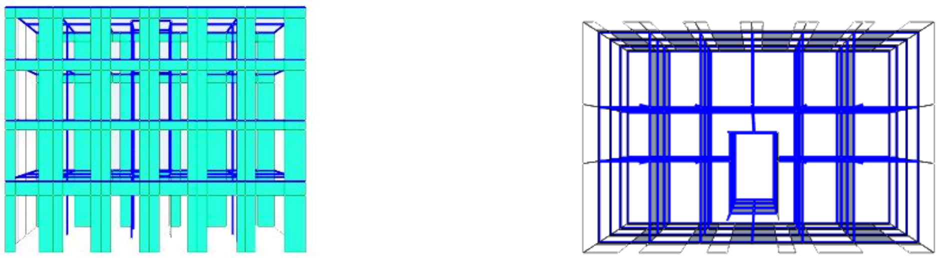


Figure 66 (left) real case study for pombalino structure in opensees lite. (right) vertical roof loads application.



(A) (B)

Figure 67 real case study for pombalino structure in opensees lite (a) front view. (b) bottom view

4.2.1. Material Properties.

The material properties for the masonry ground level will be extracted from Cardoso, 2003 [54] and are presented in Table 9. The mass distribution will be carried out using as basis Figure 68 and assigned massnodes as appropriate (x and z direction), interior and storey level load have mass variations so the calculations will be separated as shown in Table 10. The attic weight will be considered as vertical roof loads which will be assumed as 58 kg/m2, having a total force of 903 kg per node applied according to Figure 66 (Right).

Volumetric mass density	2.2ton/m^3
Young Modulus (E)	400 MPa
Poisson ratio (v)	0.2

Table 9. chosen characteristics for masonry elements [54].

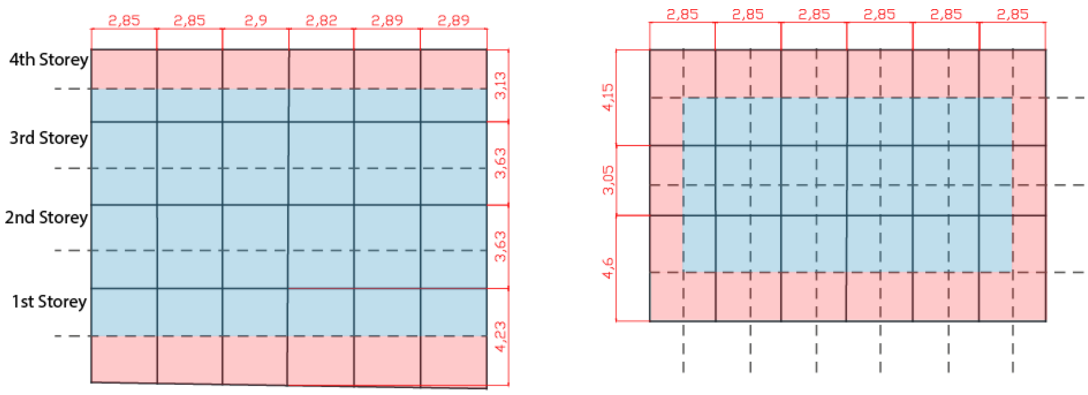


Figure 68. scheme of mass distristribution: (right) elevation view. (left) floorplan view.

Floor	Massnode	Nodes	Timber (Ton)	Masonry (Ton)	Total (Ton)
4th Floor	41	51, 57	0.072	5.85	5,92
	42	522, 528	0,074	6,48	6,55
	43	58, 515, 514, 521	0,116	10,08	10,19
	44	523, 524, 525, 526, 527, 52, 53, 54, 55, 56	0,107	0	0,107
	45	Middle Nodes	0.09	0	0,09
3rd Floor	31	41, 47, 422, 428	0,11	14,94	15,05
	32	48, 415, 414, 421	0.14	23.58	23,72
	33	423, 424, 425, 426, 427, 42, 43, 44, 45, 46	0.11	0	0.11
	34	Middle Nodes	0,11	0	0,11
2nd Floor	21	31, 37,	0,11	13,5	13.6

		322, 328			
	22	38, 315, 314, 321	0,10	23,4	23,56
	23	323, 324, 325, 326, 327, 32, 33, 34, 35, 36	0,16	0	0,16
	24	Middle Nodes	0,11	0	0,11
1st Floor	11	21, 27, 222, 228	0,11	7.56	7,67
	12	28, 215, 214, 221	0,09	23,16	23,71
	13	223, 224, 225, 226, 227, 22, 23, 24, 25, 26	0,09		0,09
	14	Middle Nodes	0,09		0,09

Table 10. summary of mass distribution

4.3. Numerical Modelling Results.

The following results present the numeric study of the structure in three models (large shell, small shell, and bare timber elements) with pushover analysis applied in both horizontal dierection. The gaiola diagonals are placed in the z direction so in order to evaluate properly the pushover test the force shall be placed in this direction.
The presented results correspond to the frequencies and modal shape studies. Also a pushover test was performed in order to analyze the dynamic behavior of the structure.
The frequencies of a structure result from (Equation 8 and (Equation 9, where k corresponds to the stiffness and M the mass of a structure. Although the frequencies are given by OpenSees, it is important to point out the previous equations for an adequate posterior analysis.

$$\omega = \sqrt{\frac{k}{M}}$$ **(Equation 8)**

$$f = \frac{\omega}{2\pi}$$ **(Equation 9)**

Free vibrations of an elastic body are called natural vibrations and occur at a frequency called the natural frequency. Natural vibrations are different from forced vibrations which happen at frequency of applied

force (forced frequency). If forced frequency is equal to the natural frequency, the amplitude of vibration increases many fold (this phenomenon is known as resonance). The natural frequency is the response at which a system tends to oscillate in the absence of any driving or damping force (undamped natural circular frequency, i.e., eigenfrequency) [55]
At each natural frequency of free vibration the structure vibrated in simple harmonic motion where the displaced shape, or mode shape of the structure is constant but the amplitude of the displacement is varying in a sinusoidal manner with time. A system with N degrees of freedom has N natural frequencies of free vibration and N mode shaped of free vibration, one associated with each natural frequency. [55]
The applied load pattern for longitudinal and transversal direction are shown in xxx as appropriate.

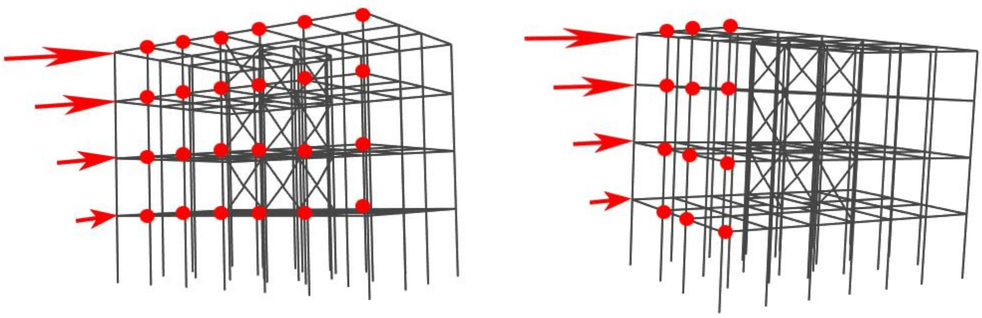


Figure 69 load pattern (left) transversal direction. (right) longitudinal direction.

4.3.1. Large Shell Elements

The following results correspond to the model with larger shell elements. Mode shapes show that no torsion can be observed in the building, mode 1 and 4 presents a deformed shape in the transverse direction and the mode 2 and 3 in the longitudinal direction.
The pushover analysis (Figure 74 and Figure 75) shows that in order to displace the structure in the longitudinal direction more forces are needed. This is due to the mass of the structure in this direction. Until the analyzed displacement, no non-linear behavior was shown, this is due to the shell element that predominates the structure.

Mode 1	Mode 2	Mode 3	Mode 4
2.08 hz	4.95 hz	5.57 hz	5.76 hz

Table 11. summary of frequency values for LARGE-SCALE SHELL ELEMENTS

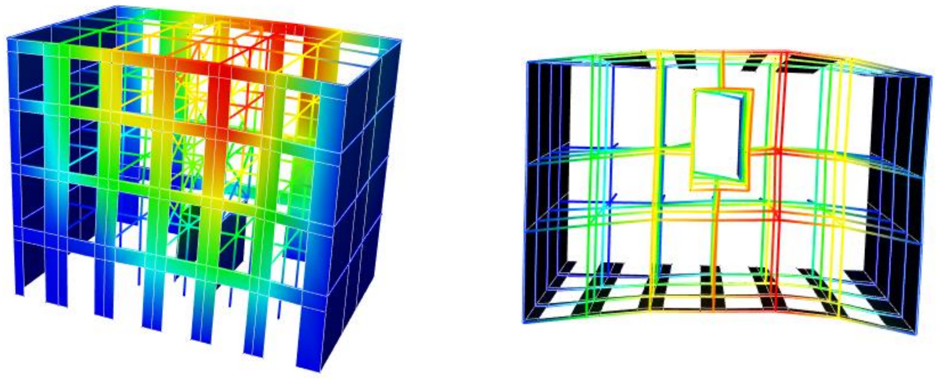


Figure 70. modal shape 1 FOR LARGE SCALE SHELL ELEMENTS.

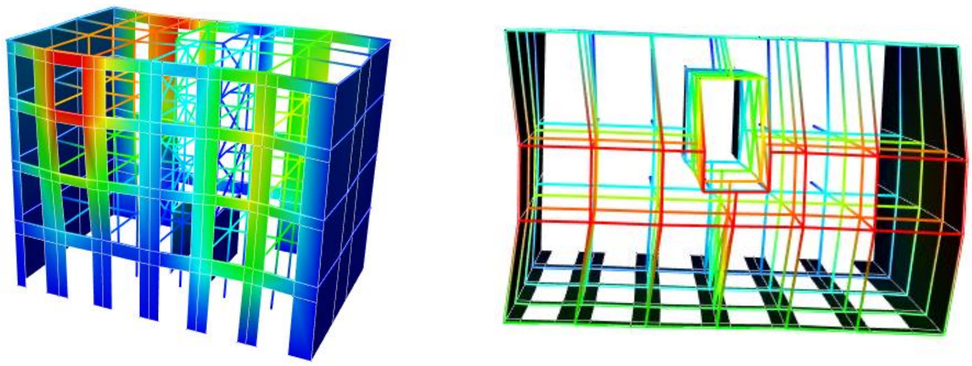


Figure 71. modal shape 2 FOR LARGE SCALE sHELL eLEMENTS.

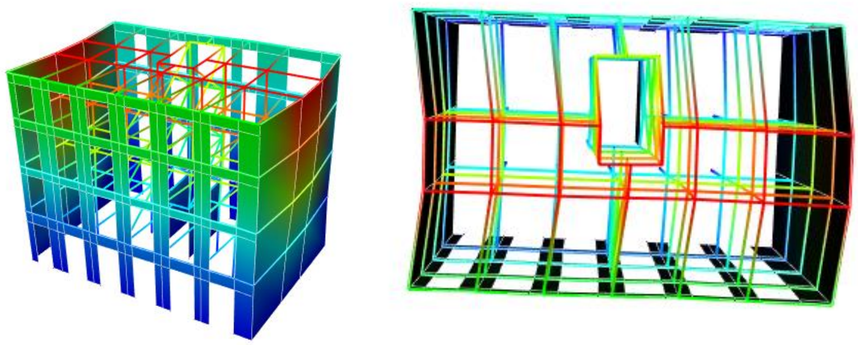


Figure 72. MODAL SHAPE 3 FOR LARGE SCALE SHELL-ELEMENTS

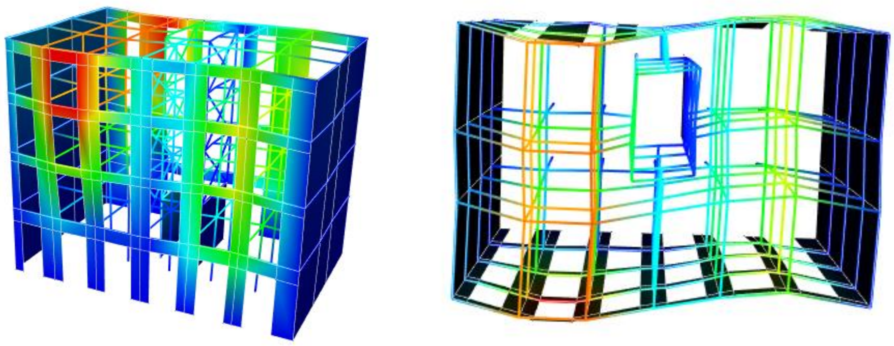


Figure 73. modal shape 4 FOR LARGE SCALE SHELL-ELEMENTS.

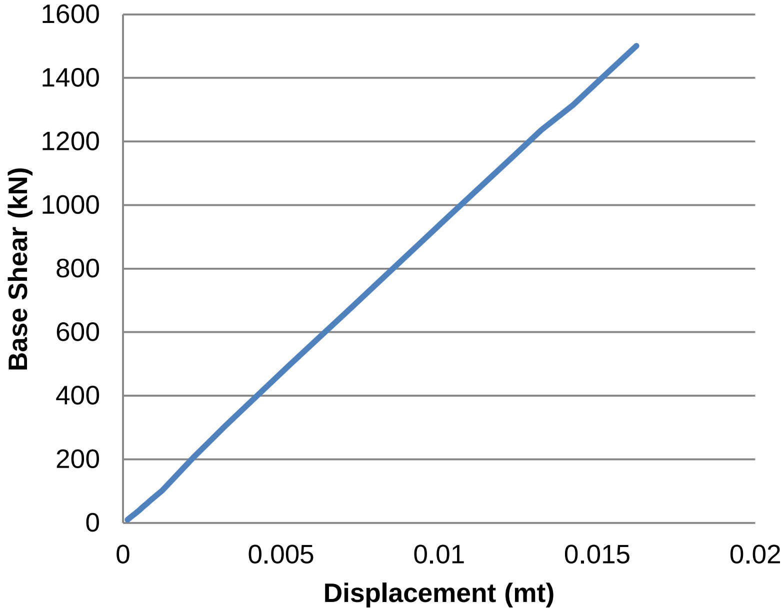


Figure 74. pushover capacity curve (transversal direction forces) for Large- shell elements.

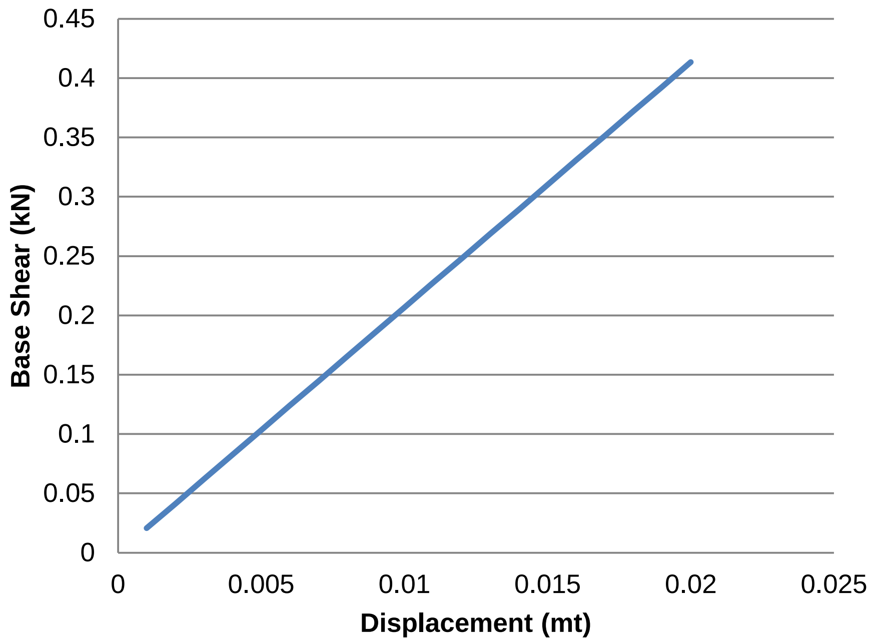


Figure 75. pushover capacity curve for longitudinal direction forces. Large- shell elements

4.3.2. Small shell Model

The frequencies of the small-shell model varies, a lot, when comparing it to the large-scale shell elements, with the discretization of the numerical shell elements, the model presents a higher flexibility. Although the modal shape variation is not shown.
Due to computational resources and lack of time the pushover results are cannot be analyzed.

Mode 1	Mode 2	Mode 3	Mode 4
1.52hz	2.71hz	3.22hz	3.49hz

Table 12. FREQUENCIES OF SMALL-SHELL ELEMENT

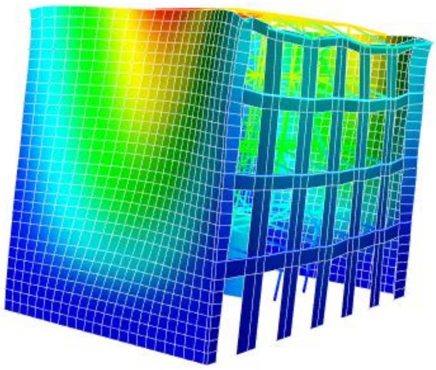
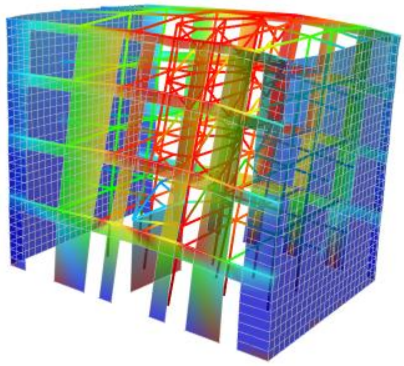



Figure 76. pushover analysis for small-shell model. (left) force in longitudinal direction. (right) force in transversal direction

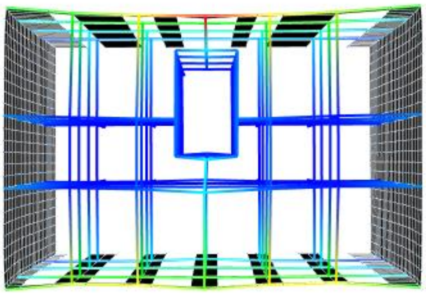
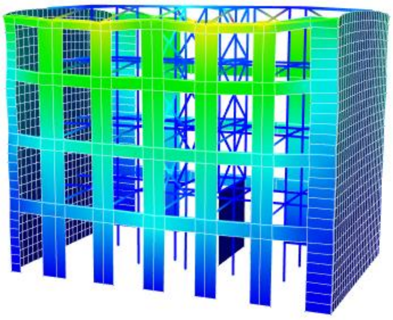



Figure 77. modal shape for small-shell model

4.3.3. Bare timber frame element

Regarding the mode shapes it is shown that they are mainly in the longitudinal direction, this is explained due to the high difference in the stiffness in both directions. It is observed that the diagonals are principally in the transverse direction (Figure 78). This can be shown in a more precise way when we compare differences between the model with and without the peripheral masonry walls. Thirty modal shapes were analyzed, but no response was obtained in the transverse direction.
The difference in force needed to displace the structure in the transversal direction and longitudinal direction is very similar, this can be explained because the mass of the timber structure in both directions is not significantly different.
The pushover curve in longitudinal direction (Figure 85) shows a more elastic response when comparing it to the transversal direction (Figure 84). This is due to the diagonals which are distributed along the transversal direction which concentrates the non-linear behavior of the model. A non-linear behavior is shown in the transversal direction, specifically at 0,18 mt displacement.

Mode 1	Mode 2	Mode 3	Mode 4
0.153hz	0.571hz	0.738hz	1.002hz

Table 13. summary of frequency values for BARE-TIMBER FRAME mode

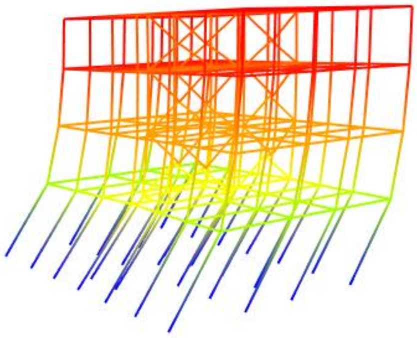


Figure 78. visualization of pushover analysis results for a bare-timber Frame structure (force in transversal direction)

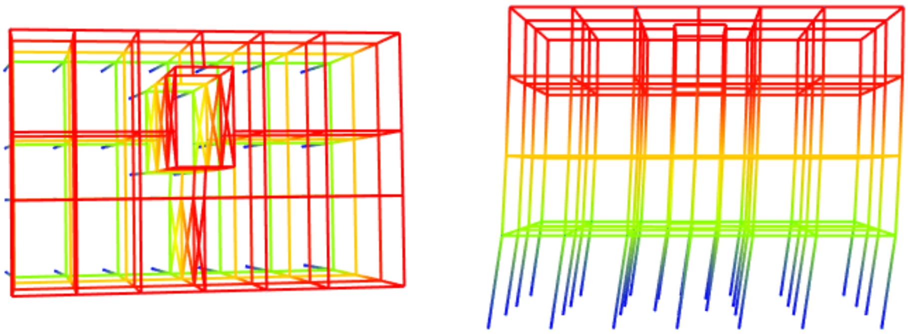


Figure 79. modal shape 1 for bare-timber Frame Structre

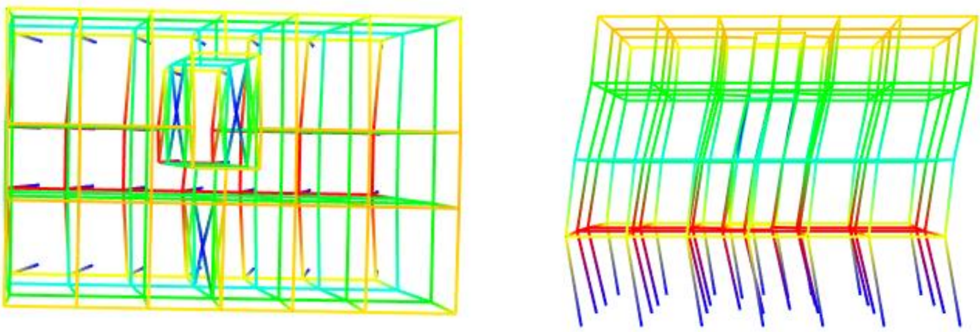


Figure 80. modal shape 2 for bare-timber Frame Structre

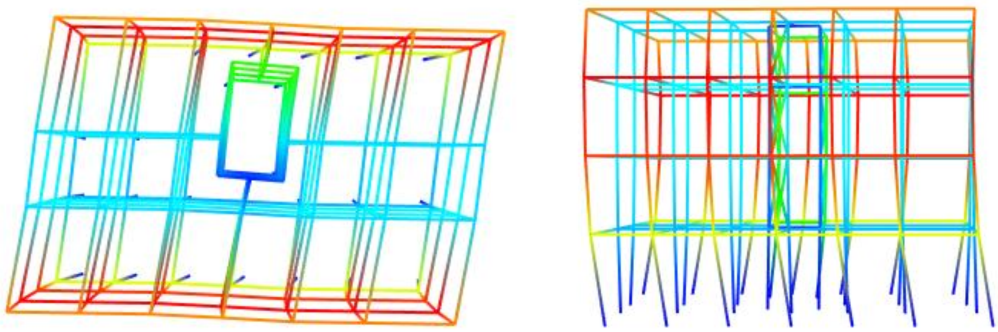


Figure 81. modal shape 3 for bare-timber Frame Structre

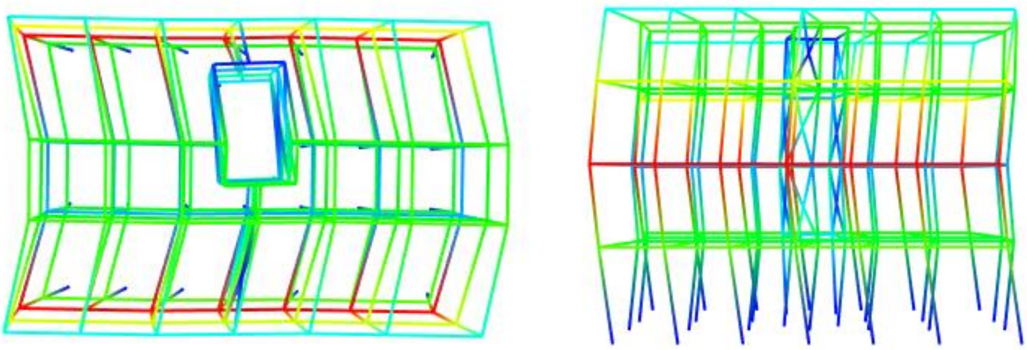


Figure 82. modal shape 4 for bare-timber Frame Structre

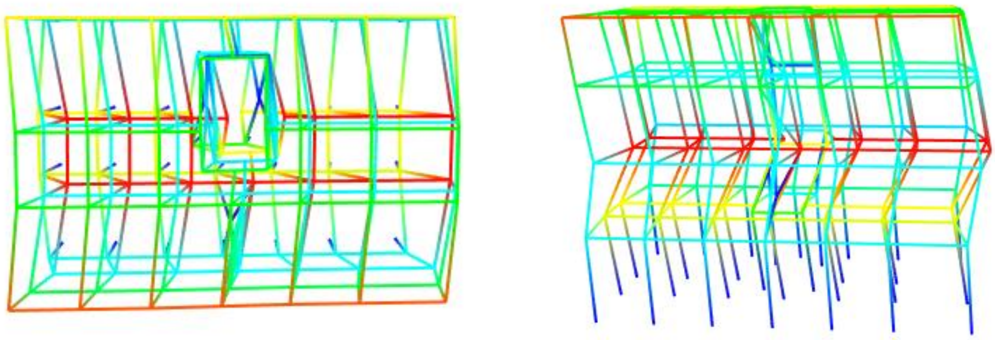


Figure 83. modal shape 5 for bare-timber Frame Structre

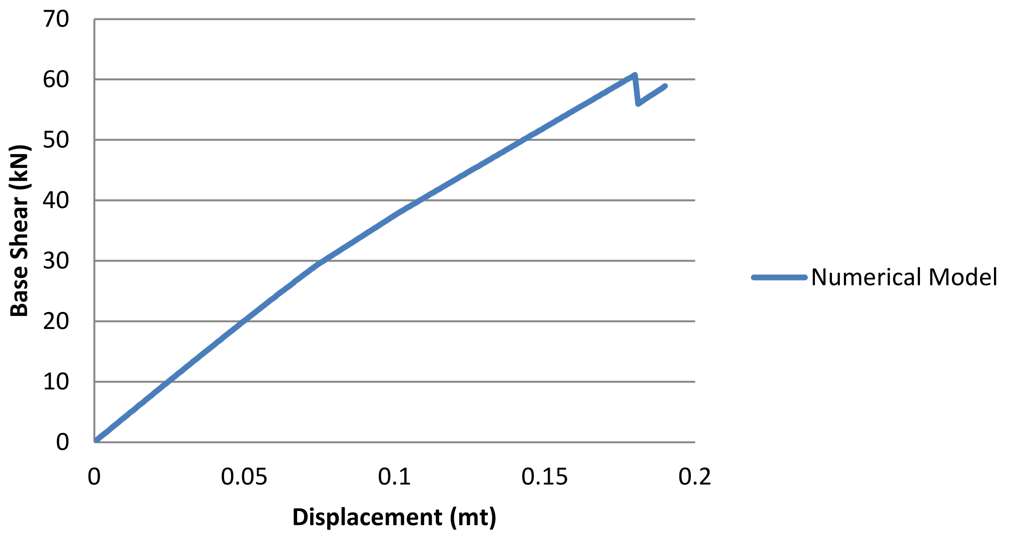


Figure 84. pushover capacity curve for bare-timber frame structure (transversal direction forceS)

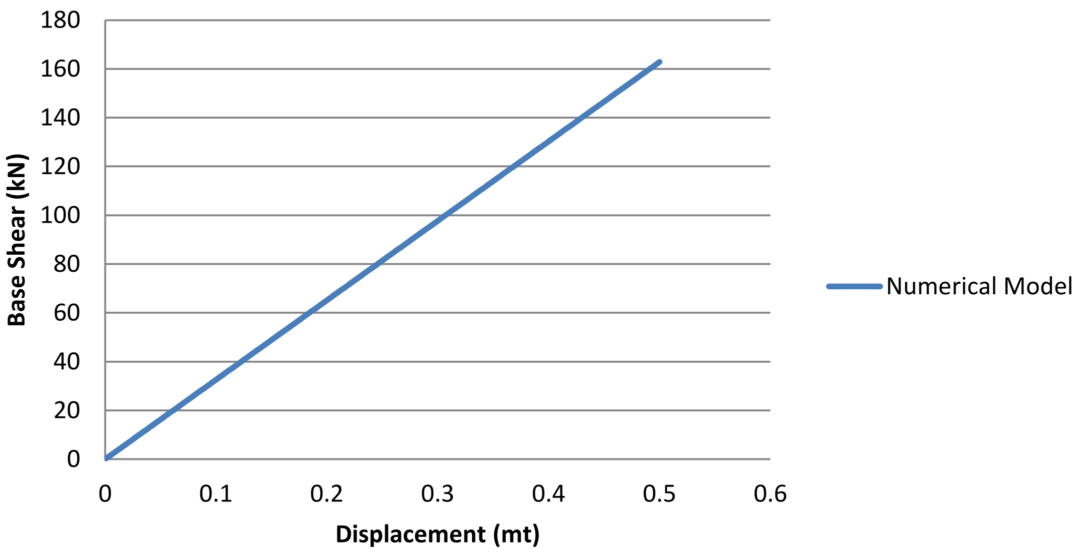


Figure 85. pushover capacity curve for bare-timber frame structure (longitudinal direction forceS)

4.4. Final Remarks

The elaborated real scale model considers shell elements that were not used in previous calibration process of the present work. It is recommended to perform a previous calibration of the lateral masonry walls in order to apply their properties in the present model.
When adding shell masonry elements to the model, the stiffness of this element will vary significantly the results of the structures dynamics. Bare timber frame structure shows a more homogenous stress

distribution that increases to the top levels on the other hand masonry walls increase the rigidity of the whole structure in the perimeters, modifying significantly the interior stress distribution.
The modal shapes vary significantly as the bare timber structure shows a movement that oscillates in the x axis, meanwhile the masonry- timber structure oscillates mostly in the z axis, this can be explained due to the large rigidity of the lateral walls that constrains the lateral movement of the structure.
The Stress concentration on the longitudinal façade, specifically lintel sector (above vains), is higher that the stresses concentrated on the lateral walls.
The timber frame structure shows a non-linear behavior after reaching a maximum force, the pushover results on the mixed masonry wall on the other hand does not show non-linear behavior. Also the forces that are needed to move one structure in comparison to another are significantly different. Due to the higher weight of the mixed timber-masonry structure more forces are needed in order to produce the initial displacement.
The frequencies of the bare timber frame structure are significantly lower than the mixed timber-masonry structure, which is explained due to the mass and stiffness of the structure, this is also shown in the modal shapes which in the bare-timber frame structure shows a much larger movement of the structure.

5. CONCLUSIONS

5.1. Summary

The present work considers a numerical timber-frame/masonry model elaborated by Lukic (2016) [42] which was modified and calibrated for the present work according to experimental survey performed by Goncalves [5]. This model considers the timber and masonry as a mixed composite material [51] represented initially in a linear model.
Calibration procedures were done varying the initial structures materials behavior and parametres obtaining acceptable results that were afterwards applied on a real scale model. This model considers shell and linear elements, the linear elements properties were applied according to previous calibration process and the masonry shell elements properties were considered by experimental survey performed by Cardoso (2005) [37].
Three models were elaborated in order to study and compare the dynamics of the structure.

5.2. Conclusions

It is possible to elaborate a simplified numerical model based on experimental results in OpenSees Program, but we must previously do a rigorous calibration process in order for the results to be accurate. The original dimensions and properties of the structure can be modified in order to obtain the same results as in experimental surveys, considering an error not larger than 10%.

The modification of the materials properties can be done throughout a sensitivity analysis, in which parameters are changed and an iteration process is performed in order to understand the variation and the effect of each parameter on the envelope curve of frequency as appropriate.

The macro-modelling of elements is a useful tool that allows the user to obtain results of the dynamic behaviors of building in a reduced amount of time, due to the small amount of computational resources that it needs in order to perform the analysis.

When elaborating a model (shell, beam-column, or combined) it is recommended to elaborate it from the beginning as such, node superposition is an important issue in the change of one model typology to another and leads to important mistakes that is reflected in iteration problems in OpenSees called “Lackpack” which is traduced as a connectivity issue, the major issue of this is that it is not possible to localize the error and this can become a complicated matter in large scale models that have large amounts of nodes and elements.

It is recommended to combine programs in order to obtain easier node/shell modelling of a large structure. Albeit OpenSees has visualizers, the coordinates have to be set manually, which is a very time-consuming process. In this case GID was used to model the shells, which simplified this process, obtaining automatically the elements, nodes and its coordinates.

Macro-modelling is a viable option for representing the overall response of timber and mixed timber framed structures. It is possible to elaborate a real scale macro-model of an existing building taking information of previously calibrated numerical models of similar characteristics and materials. This information can be used afterwards in seismic assessment of real scale buildings.

The change of materials in a structure will vary significantly the dynamic response of it. In the studied case the rigidity of the masonry walls consequently increases the major stress concentration on timberframe (non-braced) elements. Although it is shown that gaiola (mixed timber-masonry) structure has an important contribution in absorbing the stresses.

Overall, The studied pombalino building has a good seismic behavior in which the high stresses are concentrated on the top section of the building. This is a good indication because the structure will not fail from the middle floors, although it is important to consider the large stress concentrations on the 3rd floor. Seismic assessment can be performed from the obtained results in order to reduce the stress in this section (it could be recommended to include some longitudinal gaiola bracing element).

5.3. Future Works

It is recommended that the calibration process of the experimental survey should improve, in what respects the calibration of the frequencies and cyclic envelope curve simultáneously. In order to do this, masses can be evaluated as distributed loads across the beams.
It is important to evaluate the timber structure behavior in the pinching stage, in order to do this the connections of timber frame must be considered.
The partition walls of the studied pombalino building may have a structural function that is not mentioned in the literature of Mascarenhas (2005) [15], further investigation should be done in order to obtain more detailed information regarding this matter.
A calibration process of the shell elements before applying them to a real scale model is necessary in order to verify the concordance of the applied materials, and also to apply properly a pushover analysis.
It can be useful to have certain parameters of the dynamic response (modal shape, frequencies) of similar real scale structures in order to prove that the elaborated model has a realistic dynamic behavior.
The real scale structure can be submitted to multiple simulations of various earthquakes. It is recommended to perform a cyclic test analysis in order to obtain more parameters for a more adequate seismic assessment.

5.4. Adendum

In Section 3.2.2. (Page 35) the Elasticity Modulus and Shear modulus considered for timber were taken from the code NP 4305, 1995 which is mainly for visualization clasification purposes, the correct values should be taken from ENV 1995-1-1:1993 [56], which are summarized in Table 14.

Properties	Medium Values
Volumetric Mass	530-600 (kg/m3)
Elasticity Modulus	8,0 – 9,38 kN/mm2
Shear Modulus	0,75 – 0,87 kN/mm2

Table 14. wood properties [56]

There is an ongoing study in which shell elements have tried to incorporate the the non-linear behavior of masonry based on non-linear models of concrete elements. The gravity loads work well, but when we run a pushover, there is an iteration problem and the analysis does not run, the shell properties are shown in Figure 86.

```
##################################################
# Shell Elements
##################################################
#
# nDMaterial PlaneStressUserMaterial $matTag $nStatevs $nProps $Prop1 ... $ Propn
#$fc: concrete compressive strength at 28 days (positive)
#$ft: concrete tensile strength (positive)
#$fcu: concrete crushing strength (negative)
#$epsc0: concrete strain at maximum strength (negative)
#$epscu: concrete strain at crushing strength (negative)
#$epstu: ultimate tensile strain (positive)
#$stc: shear retention factor

# nDMaterial PlaneStressUserMaterial $matTag $nStatevs $nProps $Prop1 ... $ Propn
#                                                                fc       ft      fcu     epsc0     epscu  epstu  stc
nDMaterial PlaneStressUserMaterial    1       40        7      41.8e6   4.01e6  -2.1e6   -0.002    -0.03  0.0001  0.1

# nDMaterial PlateFromPlaneStress $matTag $PlaneStressMatTag $OutOfPlaneShearModulus
nDMaterial   PlateFromPlaneStress     4         1                  1.25e10

# section PlateFiber $secTag $fiberTag $h
    #$secTag unique section object tag for section being constructed
    #$fiberTag material tag for a previously-defined plate fiber material (page 177)
    #$h thickness of the plate section
section PlateFiber 1 4 0.75
```

Figure 86. Non-linear Shell Elements properties

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7. APPENDIX

7.1. Small Shell Real Scale Model

```
# units in mt, kN
# --------------------------------------------------------
------------------------------------------
# Cyclic tests on timber frame macro
element -- Build MODEL
# elastic square frame
# all nonlinearities concentrated within the
central connection

####################################
####################################
# SET UP AND SOURCE DEFINITION
####################################
####################################
wipe;                               # clear memory
of all past model definitions

model BasicBuilder -ndm 3 -ndf 6;      #
Define the model builder, ndm=#dimension,
ndf=#dofs
set dataDir Results;                  # set up
name of data directory
file mkdir $dataDir;                 # create
data directory
source DisplayPlane_IR.tcl;            #
procedure for displaying a plane in model
source DisplayModel3D_IR.tcl;          #
procedure for displaying 3D perspectives of
model
source LibUnits.tcl;                  #define units

####################################
####################################
################
# define bulding GEOMETRY, NODES AND
CONSTRAINTS
####################################
####################################
################

#Set MassNodes
#4th Storey
set massnode41 5.92;
set massnode42 6.55;
set massnode43 10.19
set massnode44 0.1;
set massnode45 0.09;

#3rd Storey
set massnode31 15.05;
set massnode32 23.72;
set massnode33 0.11;
set massnode34 0.11;

#2nd Storey
set massnode21 13.6;
set massnode22 23.56;
set massnode23 0.16;
set massnode24 0.11;

#1st Storey
set massnode11 7.67;
set massnode12 23.71;
set massnode13 0;
set massnode14 0;

# define NODAL COORDINATES
# calculate length of beam/column/gird
set X0 0;
set X1 2.85;
set X2 5.7;
set X3 8.59;
set X4 11.41;
set X5 14.3;
set X6 17.9;

set Y0 0;
set Y1 4.23;
set Y2 7.86
set Y3 11.48;
set Y4 14.48;

set Z0 0;
set Z1 4.54;
set Z2 7.55;
set Z3 11.74;

# position of diagonal nodes
set X1Diag 1.43;
set X2Diag 4.28;
set X3Diag 7.14;
set X4Diag 10;
set X5Diag 12.85;
set X6Diag 15.74

set Y1Diag 2.04;
set Y2Diag 5.91;
set Y3Diag 9.54;
set Y4Diag 12.92;

set Z1Diag 2.3;
set Z2Diag 6.13;
set Z3Diag 9.73;

#position of Staircase nodes
set X1Stair 7.35;
set X2Stair 9.99;
set XmStair 8.67;

set Z1Stair 1.62;
set Z2Stair 6.15;
set ZmStair $Z1;
set ZmDiag 3.8

#position of front facade shell nodes
set X01 0.6
set X11 2.01
set X12 3.44
set X21 5.1
set X22 6.29
set X31 8
set X32 9.18
set X41 10.87
set X42 12.03
set X51 13.81
set X52 14.9
set X06 16.63

#position of back facade shell nodes
set X201 1.79
#set X211 2.68
set X212 4.96
set X221 6.3
#set X222 8.08
#set X231 9.37
set X232 10.86
set X241 11.98
#set X242 14.24
set X251 15.4

set Y11 3.5
set Y12 7.23
set Y13 10.86
set Y14 13.98

# define NODAL COORDINATES
# calculate length of beam/column/gird
set X0 0;
set X1 2.85;
set X2 5.7;
set X3 8.59;
set X4 11.41;
set X5 14.3;
set X6 17.9;

set Y0 0;
set Y1 4.23;
set Y2 7.86
set Y3 11.48;
set Y4 14.62;

set Z0 0;
set Z1 4.54;
set Z2 7.55;
set Z3 11.74;

# position of diagonal nodes
set X1Diag 1.43;
set X2Diag 4.28;
set X3Diag 7.14;
set X4Diag 10;
set X5Diag 12.85;
set X6Diag 15.74

set Y1Diag 2.04;
set Y2Diag 5.91;
set Y3Diag 9.54;
set Y4Diag 12.92;

set Z1Diag 2.3;
set Z2Diag 6.13;
set Z3Diag 9.73;

#position of Staircase nodes
set X1Stair 7.35;
set X2Stair 9.99;
set XmStair 8.67;

set Z1Stair 1.62;
set Z2Stair 6.15;
set ZmStair $Z1;
set ZmDiag 3.8

#position of facade shell nodes
set X01 0.6
set X11 2.01
set X12 3.44
set X21 5.1
set X22 6.29
set X31 8
set X32 9.18
set X41 10.87
set X42 12.03
set X51 13.81
set X52 14.9
set X06 16.63

set Y11 3.39

##############################
# create nodes
##############################
#---------------------
#node ID X Y Z
#nodes

#Ground Level
node 11 $X0 $Y0 $Z0 -mass 0. 0. 0.  0. 0.
0.;
node 12 $X1 $Y0 $Z0 -mass 0. 0. 0.  0. 0.
0.;
node 13 $X2 $Y0 $Z0 -mass 0. 0. 0.  0. 0.
0.;
node 14 $X3 $Y0 $Z0 -mass 0. 0. 0.  0. 0.
0.;
node 15 $X4 $Y0 $Z0 -mass 0. 0. 0.  0. 0.
0.;
node 16 $X5 $Y0 $Z0 -mass 0. 0. 0.  0. 0.
0.;
node 17 $X6 $Y0 $Z0 -mass 0. 0. 0.  0. 0.
0.;

node 18 $X0 $Y0 $Z1 -mass 0. 0. 0. 0. 0. 0.;
node 19 $X1 $Y0 $Z1 -mass 0. 0. 0. 0. 0. 0.;
node 110 $X2 $Y0 $Z1 -mass 0. 0. 0. 0. 0.
0.;
node 112 $X4 $Y0 $Z1 -mass 0. 0. 0. 0. 0.
0.;
node 113 $X5 $Y0 $Z1 -mass 0. 0. 0. 0. 0.
0.;
node 114 $X6 $Y0 $Z1 -mass 0. 0. 0. 0. 0.
0.;

node 115 $X0 $Y0 $Z2 -mass 0. 0. 0. 0. 0.
0.;
node 116 $X1 $Y0 $Z2 -mass 0. 0. 0. 0. 0.
0.;
node 117 $X2 $Y0 $Z2 -mass 0. 0. 0. 0. 0.
0.;
node 118 $X3 $Y0 $Z2 -mass 0. 0. 0. 0. 0.
0.;
node 119 $X4 $Y0 $Z2 -mass 0. 0. 0. 0. 0.
0.;
node 120 $X5 $Y0 $Z2 -mass 0. 0. 0. 0. 0.
0.;
node 121 $X6 $Y0 $Z2 -mass 0. 0. 0. 0. 0.
0.;

node 122 $X0 $Y0 $Z3 -mass 0. 0. 0. 0. 0.
0.;
node 123 $X1 $Y0 $Z3 -mass 0. 0. 0. 0. 0.
0.;
node 124 $X2 $Y0 $Z3 -mass 0. 0. 0. 0. 0.
0.;
node 125 $X3 $Y0 $Z3 -mass 0. 0. 0. 0. 0.
0.;
node 126 $X4 $Y0 $Z3 -mass 0. 0. 0. 0. 0.
0.;
node 127 $X5 $Y0 $Z3 -mass 0. 0. 0. 0. 0.
0.;
node 128 $X6 $Y0 $Z3 -mass 0. 0. 0. 0. 0.
0.;

node 129 $X1Stair $Y0 $Z1Stair
node 130 $X2Stair $Y0 $Z1Stair
node 131 $X1Stair $Y0 $Z2Stair
node 132 $X2Stair $Y0 $Z2Stair

#Storey 01
node 21 $X0 $Y1 $Z0 -mass $massnode11
0. 0. 0. 0. 0.;
```

```
node 22 $X1 $Y1 $Z0 -mass $massnode14
0. 0. 0. 0. 0.;
node 23 $X2 $Y1 $Z0 -mass $massnode14
0. 0. 0. 0. 0.;
node 24 $X3 $Y1 $Z0 -mass $massnode14
0. 0. 0. 0. 0.;
node 25 $X4 $Y1 $Z0 -mass $massnode14
0. 0. 0. 0. 0.;
node 26 $X5 $Y1 $Z0 -mass $massnode14
0. 0. 0. 0. 0.;
node 27 $X6 $Y1 $Z0 -mass $massnode11
0. 0. 0. 0. 0.;

node 28 $X0 $Y1 $Z1 -mass $massnode12
0. 0. 0. 0. 0.;
node 29 $X1 $Y1 $Z1 -mass $massnode14
0. 0. 0. 0. 0.;
node 210 $X2 $Y1 $Z1 -mass
$massnode14 0. 0. 0. 0. 0.;
node 212 $X4 $Y1 $Z1 -mass
$massnode14 0. 0. 0. 0. 0.;
node 213 $X5 $Y1 $Z1 -mass
$massnode14 0. 0. 0. 0. 0.;
node 214 $X6 $Y1 $Z1 -mass
$massnode12 0. 0. 0. 0. 0.;

node 215 $X0 $Y1 $Z2 -mass
$massnode12 0. 0. 0. 0. 0.;
node 216 $X1 $Y1 $Z2 -mass
$massnode14 0. 0. 0. 0. 0.;
node 217 $X2 $Y1 $Z2 -mass
$massnode14 0. 0. 0. 0. 0.;
node 218 $X3 $Y1 $Z2 -mass
$massnode14 0. 0. 0. 0. 0.;
node 219 $X4 $Y1 $Z2 -mass
$massnode14 0. 0. 0. 0. 0.;
node 220 $X5 $Y1 $Z2 -mass
$massnode14 0. 0. 0. 0. 0.;
node 221 $X6 $Y1 $Z2 -mass
$massnode12 0. 0. 0. 0. 0.;

node 222 $X0 $Y1 $Z3 -mass
$massnode11 0. 0. 0. 0. 0.;
node 223 $X1 $Y1 $Z3 -mass
$massnode13 0. 0. 0. 0. 0.;
node 224 $X2 $Y1 $Z3 -mass
$massnode13 0. 0. 0. 0. 0.;
node 225 $X3 $Y1 $Z3 -mass
$massnode13 0. 0. 0. 0. 0.;
node 226 $X4 $Y1 $Z3 -mass
$massnode13 0. 0. 0. 0. 0.;
node 227 $X5 $Y1 $Z3 -mass
$massnode13 0. 0. 0. 0. 0.;
node 228 $X6 $Y1 $Z3 -mass
$massnode11 0. 0. 0. 0. 0.;

#Storey 01 (Staircase)
node 901 $X1Stair $Y1 $Z1Stair -mass 0. 0.
0.  0. 0. 0.;
node 902 $X2Stair $Y1 $Z1Stair -mass 0. 0.
0.  0. 0. 0.;
node 903 $X1Stair $Y1 $Z2Stair -mass 0. 0.
0.  0. 0. 0.;
node 904 $X2Stair $Y1 $Z2Stair -mass 0. 0.
0.  0. 0. 0.;

node 905 $XmStair $Y1 $Z2Stair -mass 0.
0. 0.  0. 0. 0.;
node 906 $XmStair $Y1 $Z1Stair -mass 0.
0. 0.  0. 0. 0.;
node 907 $X1Stair $Y1 $ZmStair -mass 0.
0. 0.  0. 0. 0.;
node 908 $X2Stair $Y1 $ZmStair -mass 0.
0. 0.  0. 0. 0.;

#Storey 02
node 31 $X0 $Y2 $Z0 -mass $massnode21
0. 0. 0. 0. 0.;
node 32 $X1 $Y2 $Z0 -mass $massnode24
0. 0. 0. 0. 0.;
node 33 $X2 $Y2 $Z0 -mass $massnode24
0. 0. 0. 0. 0.;
node 34 $X3 $Y2 $Z0 -mass $massnode24
0. 0. 0. 0. 0.;
node 35 $X4 $Y2 $Z0 -mass $massnode24
0. 0. 0. 0. 0.;
node 36 $X5 $Y2 $Z0 -mass $massnode24
0. 0. 0. 0. 0.;
node 37 $X6 $Y2 $Z0 -mass $massnode21
0. 0. 0. 0. 0.;

node 38 $X0 $Y2 $Z1 -mass $massnode22
0. 0. 0. 0. 0.;
node 39 $X1 $Y2 $Z1 -mass $massnode24
0. 0. 0. 0. 0.;
node 310 $X2 $Y2 $Z1 -mass
$massnode24 0. 0. 0. 0. 0.;
node 312 $X4 $Y2 $Z1 -mass
$massnode24 0. 0. 0. 0. 0.;
node 313 $X5 $Y2 $Z1 -mass
$massnode24 0. 0. 0. 0. 0.;
node 314 $X6 $Y2 $Z1 -mass
$massnode22 0. 0. 0. 0. 0.;

node 315 $X0 $Y2 $Z2 -mass
$massnode22 0. 0. 0. 0. 0.;
node 316 $X1 $Y2 $Z2 -mass
$massnode24 0. 0. 0. 0. 0.;
node 317 $X2 $Y2 $Z2 -mass
$massnode24 0. 0. 0. 0. 0.;
node 318 $X3 $Y2 $Z2 -mass
$massnode24 0. 0. 0. 0. 0.;
node 319 $X4 $Y2 $Z2 -mass
$massnode24 0. 0. 0. 0. 0.;
node 320 $X5 $Y2 $Z2 -mass
$massnode24 0. 0. 0. 0. 0.;
node 321 $X6 $Y2 $Z2 -mass
$massnode22 0. 0. 0. 0. 0.;

node 322 $X0 $Y2 $Z3 -mass
$massnode21 0. 0. 0. 0. 0.;
node 323 $X1 $Y2 $Z3 -mass
$massnode23 0. 0. 0. 0. 0.;
node 324 $X2 $Y2 $Z3 -mass
$massnode23 0. 0. 0. 0. 0.;
node 325 $X3 $Y2 $Z3 -mass
$massnode23 0. 0. 0. 0. 0.;
node 326 $X4 $Y2 $Z3 -mass
$massnode23 0. 0. 0. 0. 0.;
node 327 $X5 $Y2 $Z3 -mass
$massnode23 0. 0. 0. 0. 0.;
node 328 $X6 $Y2 $Z3 -mass
$massnode21 0. 0. 0. 0. 0.;

#Storey 02 (diagonal 5XXX)
node 53231 $X3 $Y2Diag [expr $Z3Diag-
0.05] -mass 0. 0. 0.  0. 0. 0.;
node 53232 $X3 $Y2Diag [expr
$Z3Diag+0.05] -mass 0. 0. 0.  0. 0. 0.;

#Storey 02 (Staircase)
node 909 $X1Stair $Y2 $Z1Stair -mass 0. 0.
0.  0. 0. 0.;
node 910 $X2Stair $Y2 $Z1Stair -mass 0. 0.
0.  0. 0. 0.;
node 911 $X1Stair $Y2 $Z2Stair -mass 0. 0.
0.  0. 0. 0.;
node 912 $X2Stair $Y2 $Z2Stair -mass 0. 0.
0.  0. 0. 0.;

node 913 $XmStair $Y2 $Z2Stair -mass 0.
0. 0.  0. 0. 0.;
node 914 $XmStair $Y2 $Z1Stair -mass 0.
0. 0.  0. 0. 0.;
node 915 $X1Stair $Y2 $ZmStair -mass 0.
0. 0.  0. 0. 0.;
node 916 $X2Stair $Y2 $ZmStair -mass 0.
0. 0.  0. 0. 0.;

#Storey 02 (Diagonal Staircase)
node 937 $X2Stair $Y2Diag [expr $ZmDiag-
0.05] -mass 0. 0. 0. 0. 0. 0.;
node 938 $X2Stair $Y2Diag [expr
$ZmDiag+0.05] -mass 0. 0. 0. 0. 0. 0.;

node 943 $X1Stair $Y2Diag [expr $ZmDiag-
0.05] -mass 0. 0. 0. 0. 0. 0.;
node 944 $X1Stair $Y2Diag [expr
$ZmDiag+0.05] -mass 0. 0. 0. 0. 0. 0.;

#Storey 03
node 41 $X0 $Y3 $Z0 -mass $massnode31
0. 0. 0. 0. 0.;
node 42 $X1 $Y3 $Z0 -mass $massnode34
0. 0. 0. 0. 0.;
node 43 $X2 $Y3 $Z0 -mass $massnode34
0. 0. 0. 0. 0.;
node 44 $X3 $Y3 $Z0 -mass $massnode34
0. 0. 0. 0. 0.;
node 45 $X4 $Y3 $Z0 -mass $massnode34
0. 0. 0. 0. 0.;
node 46 $X5 $Y3 $Z0 -mass $massnode34
0. 0. 0. 0. 0.;
node 47 $X6 $Y3 $Z0 -mass $massnode31
0. 0. 0. 0. 0.;
node 48 $X0 $Y3 $Z1 -mass $massnode32
0. 0. 0. 0. 0.;
node 49 $X1 $Y3 $Z1 -mass $massnode34
0. 0. 0. 0. 0.;
node 410 $X2 $Y3 $Z1 -mass
$massnode34 0. 0. 0. 0. 0.;
node 412 $X4 $Y3 $Z1 -mass
$massnode34 0. 0. 0. 0. 0.;
node 413 $X5 $Y3 $Z1 -mass
$massnode34 0. 0. 0. 0. 0.;
node 414 $X6 $Y3 $Z1 -mass
$massnode32 0. 0. 0. 0. 0.;

node 415 $X0 $Y3 $Z2 -mass
$massnode32 0. 0. 0. 0. 0.;
node 416 $X1 $Y3 $Z2 -mass
$massnode34 0. 0. 0. 0. 0.;
node 417 $X2 $Y3 $Z2 -mass
$massnode34 0. 0. 0. 0. 0.;
node 418 $X3 $Y3 $Z2 -mass
$massnode34 0. 0. 0. 0. 0.;
node 419 $X4 $Y3 $Z2 -mass
$massnode34 0. 0. 0. 0. 0.;
node 420 $X5 $Y3 $Z2 -mass
$massnode34 0. 0. 0. 0. 0.;
node 421 $X6 $Y3 $Z2 -mass
$massnode32 0. 0. 0. 0. 0.;

node 422 $X0 $Y3 $Z3 -mass
$massnode31 0. 0. 0. 0. 0.;
node 423 $X1 $Y3 $Z3 -mass
$massnode33 0. 0. 0. 0. 0.;
node 424 $X2 $Y3 $Z3 -mass
$massnode33 0. 0. 0. 0. 0.;
node 425 $X3 $Y3 $Z3 -mass
$massnode33 0. 0. 0. 0. 0.;
node 426 $X4 $Y3 $Z3 -mass
$massnode33 0. 0. 0. 0. 0.;
node 427 $X5 $Y3 $Z3 -mass
$massnode33 0. 0. 0. 0. 0.;
node 428 $X6 $Y3 $Z3 -mass
$massnode31 0. 0. 0. 0. 0.;

#Storey 03 (diagonal 5XXX)
node 53331 $X3 $Y3Diag [expr $Z3Diag-
0.05] -mass 0. 0. 0.  0. 0. 0.;
node 53332 $X3 $Y3Diag [expr
$Z3Diag+0.05] -mass 0. 0. 0.  0. 0. 0.;

#Storey 03 (Staircase)
node 917 $X1Stair $Y3 $Z1Stair -mass 0. 0.
0.  0. 0. 0.;
node 918 $X2Stair $Y3 $Z1Stair -mass 0. 0.
0.  0. 0. 0.;
node 919 $X1Stair $Y3 $Z2Stair -mass 0. 0.
0.  0. 0. 0.;
node 920 $X2Stair $Y3 $Z2Stair -mass 0. 0.
0.  0. 0. 0.;

node 921 $XmStair $Y3 $Z2Stair -mass 0.
0. 0.  0. 0. 0.;
node 922 $XmStair $Y3 $Z1Stair -mass 0.
0. 0.  0. 0. 0.;
node 923 $X1Stair $Y3 $ZmStair -mass 0.
0. 0.  0. 0. 0.;
node 924 $X2Stair $Y3 $ZmStair -mass 0.
0. 0.  0. 0. 0.;

#Storey 03 (Diagonal Staircase)
node 935 $X2Stair $Y3Diag [expr $ZmDiag-
0.05] -mass 0. 0. 0. 0. 0. 0.;
node 936 $X2Stair $Y3Diag [expr
$ZmDiag+0.05] -mass 0. 0. 0. 0. 0. 0.;

node 941 $X1Stair $Y3Diag [expr $ZmDiag-
0.05] -mass 0. 0. 0. 0. 0. 0.;
node 942 $X1Stair $Y3Diag [expr
$ZmDiag+0.05] -mass 0. 0. 0. 0. 0. 0.;

#Storey 04
node 51 $X0 $Y4 $Z0 -mass $massnode41
0. 0. 0. 0. 0.;
node 52 $X1 $Y4 $Z0 -mass $massnode44
0. 0. 0. 0. 0.;
node 53 $X2 $Y4 $Z0 -mass $massnode44
0. 0. 0. 0. 0.;
node 54 $X3 $Y4 $Z0 -mass $massnode44
0. 0. 0. 0. 0.;
node 55 $X4 $Y4 $Z0 -mass $massnode44
0. 0. 0. 0. 0.;
node 56 $X5 $Y4 $Z0 -mass $massnode44
0. 0. 0. 0. 0.;
node 57 $X6 $Y4 $Z0 -mass $massnode41
0. 0. 0. 0. 0.;
```

```
node 58 $X0 $Y4 $Z1 -mass $massnode43
0. 0. 0. 0. 0.;
node 59 $X1 $Y4 $Z1 -mass $massnode45
0. 0. 0. 0. 0.;
node 510 $X2 $Y4 $Z1 -mass
$massnode45 0. 0. 0. 0. 0.;
#node 511 $X3 $Y4 $Z1 -mass
$massnode45 0. 0. 0. 0. 0.;
node 512 $X4 $Y4 $Z1 -mass
$massnode45 0. 0. 0. 0. 0.;
node 513 $X5 $Y4 $Z1 -mass
$massnode45 0. 0. 0. 0. 0.;
node 514 $X6 $Y4 $Z1 -mass
$massnode43 0. 0. 0. 0. 0.;

node 515 $X0 $Y4 $Z2 -mass
$massnode43 0. 0. 0. 0. 0.;
node 516 $X1 $Y4 $Z2 -mass
$massnode45 0. 0. 0. 0. 0.;
node 517 $X2 $Y4 $Z2 -mass
$massnode45 0. 0. 0. 0. 0.;
node 518 $X3 $Y4 $Z2 -mass
$massnode45 0. 0. 0. 0. 0.;
node 519 $X4 $Y4 $Z2 -mass
$massnode45 0. 0. 0. 0. 0.;
node 520 $X5 $Y4 $Z2 -mass
$massnode45 0. 0. 0. 0. 0.;
node 521 $X6 $Y4 $Z2 -mass
$massnode43 0. 0. 0. 0. 0.;

node 522 $X0 $Y4 $Z3 -mass
$massnode41 0. 0. 0. 0. 0.;
node 523 $X1 $Y4 $Z3 -mass
$massnode44 0. 0. 0. 0. 0.;
node 524 $X2 $Y4 $Z3 -mass
$massnode44 0. 0. 0. 0. 0.;
node 525 $X3 $Y4 $Z3 -mass
$massnode44 0. 0. 0. 0. 0.;
node 526 $X4 $Y4 $Z3 -mass
$massnode44 0. 0. 0. 0. 0.;
node 527 $X5 $Y4 $Z3 -mass
$massnode44 0. 0. 0. 0. 0.;
node 528 $X6 $Y4 $Z3 -mass
$massnode41 0. 0. 0. 0. 0.;

#Storey 04 (diagonal 5XXX)
node 53431 $X3 $Y4Diag [expr $Z3Diag-
0.05] -mass 0. 0. 0.  0. 0. 0.;
node 53432 $X3 $Y4Diag [expr
$Z3Diag+0.05] -mass 0. 0. 0.  0. 0. 0.;

#Storey 04 (Staircase)
node 925 $X1Stair $Y4 $Z1Stair -mass 0. 0.
0.  0. 0. 0.;
node 926 $X2Stair $Y4 $Z1Stair -mass 0. 0.
0.  0. 0. 0.;
node 927 $X1Stair $Y4 $Z2Stair -mass 0. 0.
0.  0. 0. 0.;
node 928 $X2Stair $Y4 $Z2Stair -mass 0. 0.
0.  0. 0. 0.;

node 929 $XmStair $Y4 $Z2Stair -mass 0.
0. 0.  0. 0. 0.;
node 930 $XmStair $Y4 $Z1Stair -mass 0.
0. 0.  0. 0. 0.;
node 931 $X1Stair $Y4 $ZmStair -mass 0.
0. 0.  0. 0. 0.;
node 932 $X2Stair $Y4 $ZmStair -mass 0.
0. 0.  0. 0. 0.;

#Storey 04 (Diagonal Staircase)
node 933 $X2Stair $Y4Diag [expr $ZmDiag-
0.05] -mass 0. 0. 0.  0. 0. 0.;
node 934 $X2Stair $Y4Diag [expr
$ZmDiag+0.05] -mass 0. 0. 0.  0. 0. 0.;

node 939 $X1Stair $Y4Diag [expr $ZmDiag-
0.05] -mass 0. 0. 0.  0. 0. 0.;
node 940 $X1Stair $Y4Diag [expr
$ZmDiag+0.05] -mass 0. 0. 0.  0. 0. 0.;

#Storey 04 (Front Facade)
node 529 $X0 $Y14 $Z3
node 5210 $X01 $Y14 $Z3
node 5211 $X01 $Y4 $Z3
node 5212 $X11 $Y4 $Z3
node 5213 $X11 $Y14 $Z3
node 5214 $X1 $Y14 $Z3
node 5215 $X12 $Y4 $Z3
node 5216 $X12 $Y14 $Z3
node 5217 $X21 $Y4 $Z3
node 5218 $X21 $Y14 $Z3
node 5219 $X2 $Y14 $Z3
node 5220 $X22 $Y4 $Z3
node 5221 $X22 $Y14 $Z3
node 5222 $X31 $Y4 $Z3
node 5223 $X31 $Y14 $Z3
node 5224 $X3 $Y14 $Z3
node 5225 $X32 $Y4 $Z3
node 5227 $X32 $Y14 $Z3
node 5228 $X41 $Y4 $Z3
node 5229 $X41 $Y14 $Z3
node 5230 $X4 $Y14 $Z3
node 5231 $X42 $Y4 $Z3
node 5232 $X42 $Y14 $Z3
node 5233 $X51 $Y4 $Z3
node 5234 $X51 $Y14 $Z3
node 5235 $X5 $Y14 $Z3
node 5236 $X52 $Y4 $Z3
node 5237 $X52 $Y14 $Z3
node 5238 $X06 $Y4 $Z3
node 5239 $X06 $Y14 $Z3
node 5240 $X6 $Y14 $Z3

#Storey 04 (Back Facade)
node 5241 $X0 $Y14 $Z0
node 5242 $X201 $Y14 $Z0
node 5243 $X201 $Y4 $Z0
node 5244 $X1 $Y14 $Z0
node 5245 $X212 $Y14 $Z0
node 5246 $X212 $Y4 $Z0
node 5247 $X2 $Y14 $Z0
node 5248 $X221 $Y4 $Z0
node 5249 $X221 $Y14 $Z0
node 5250 $X1Stair $Y4 $Z0
node 5251 $X1Stair $Y14 $Z0
node 5252 $X3 $Y14 $Z0
node 5253 $X2Stair $Y4 $Z0
node 5254 $X2Stair $Y14 $Z0
node 5255 $X232 $Y4 $Z0
node 5256 $X232 $Y14 $Z0
node 5257 $X4 $Y14 $Z0
node 5258 $X241 $Y4 $Z0
node 5259 $X241 $Y14 $Z0
node 5260 $X5 $Y14 $Z0
node 5261 $X06 $Y4 $Z0
node 5262 $X06 $Y14 $Z0
node 5263 $X6 $Y14 $Z0

puts "bare frame geometry done"

# Set base constraints with "fix" command:
fix nodeID DX DY DZ RX RY RZ
    # fixity values: 1 = constrained; 0 =
unconstrained
fix 11 1  1  1  1  1  1
fix 12 1  1  1  1  1  1
fix 16 1  1  1  1  1  1
fix 17 1  1  1  1  1  1

fix 18 1  1  1  1  1  1
fix 19 1  1  1  1  1  1
fix 110 1  1  1  1  1  1
fix 111 1  1  1  1  1  1
fix 112 1  1  1  1  1  1
fix 113 1  1  1  1  1  1
fix 114 1  1  1  1  1  1

fix 115 1  1  1  1  1  1
fix 116 1  1  1  1  1  1
fix 117 1  1  1  1  1  1
fix 118 1  1  1  1  1  1
fix 119 1  1  1  1  1  1
fix 120 1  1  1  1  1  1
fix 121 1  1  1  1  1  1

fix 122 1  1  1  1  1  1
fix 123 1  1  1  1  1  1
fix 124 1  1  1  1  1  1
fix 125 1  1  1  1  1  1
fix 126 1  1  1  1  1  1
fix 127 1  1  1  1  1  1
fix 128 1  1  1  1  1  1
fix 129 1  1  1  1  1  1

fix 130 1  1  1  1  1  1
fix 131 1  1  1  1  1  1
fix 133 1  1  1  1  1  1

fix 134 1  1  1  1  1  1
fix 135 1  1  1  1  1  1
fix 136 1  1  1  1  1  1
fix 137 1  1  1  1  1  1
fix 138 1  1  1  1  1  1
fix 139 1  1  1  1  1  1
fix 140 1  1  1  1  1  1

#Front Facade
fix 142 1  1  1  1  1  1
fix 143 1  1  1  1  1  1
fix 144 1  1  1  1  1  1
fix 145 1  1  1  1  1  1
fix 146 1  1  1  1  1  1
fix 147 1  1  1  1  1  1
fix 148 1  1  1  1  1  1
fix 149 1  1  1  1  1  1
fix 150 1  1  1  1  1  1
fix 151 1  1  1  1  1  1
fix 152 1  1  1  1  1  1
fix 153 1  1  1  1  1  1

#Lateral Facade
fix 9101059 1  1  1  1  1  1
fix 9101045 1  1  1  1  1  1
fix 9101035 1  1  1  1  1  1
fix 9101026 1  1  1  1  1  1
fix 9101017 1  1  1  1  1  1
fix 9101011 1  1  1  1  1  1
fix 9101006 1  1  1  1  1  1
fix 9101003 1  1  1  1  1  1

fix 9102026 1  1  1  1  1  1
fix 9102017 1  1  1  1  1  1
fix 9102011 1  1  1  1  1  1
fix 9102006 1  1  1  1  1  1
fix 9102003 1  1  1  1  1  1

fix 9103003 1  1  1  1  1  1
fix 9103006 1  1  1  1  1  1
fix 9103011 1  1  1  1  1  1
fix 9103017 1  1  1  1  1  1
fix 9103025 1  1  1  1  1  1
fix 9103035 1  1  1  1  1  1
fix 9103045 1  1  1  1  1  1
fix 9103058 1  1  1  1  1  1

fix 9601059 1  1  1  1  1  1
fix 9601045 1  1  1  1  1  1
fix 9601035 1  1  1  1  1  1
fix 9601026 1  1  1  1  1  1
fix 9601017 1  1  1  1  1  1
fix 9601011 1  1  1  1  1  1
fix 9601006 1  1  1  1  1  1
fix 9601003 1  1  1  1  1  1

fix 9602026 1  1  1  1  1  1
fix 9602017 1  1  1  1  1  1
fix 9602011 1  1  1  1  1  1
fix 9602006 1  1  1  1  1  1
fix 9602003 1  1  1  1  1  1

fix 9603003 1  1  1  1  1  1
fix 9603006 1  1  1  1  1  1
fix 9603011 1  1  1  1  1  1
fix 9603017 1  1  1  1  1  1
fix 9603025 1  1  1  1  1  1
fix 9603035 1  1  1  1  1  1
fix 9603045 1  1  1  1  1  1
fix 9603058 1  1  1  1  1  1

puts "Constraints done"

####################################
####################################
################
# Define Geometric Variables
####################################
####################################
################

# define material properties
set Et 1000000;     #Young's Modulus
Timber in kN/m2
set Em 400000; #Young Modulus Masonry
in kN/m2

set Gt 645300; #Shear Modulus Timber
set Gm 435000; #Shear Modulus Masonry

set Jt 100000; #torsional moment of inertia
of cross section (timber)
set Jm $Jt; #torsional moment of inertia of
cross section (masonry)

set inertiaT 0.00035; #element inertia for
timber
set inertiaM $inertiaT; #element inertia for
masonry
set areaT 1.e4; #element inertia for timber
set areaM 1e4; #element inertia for masonry
```

```
puts "Geometric Variables Defined"

####################################
####################################
################
# Define Geometric Transformation
# performs a linear geometric transformation
of beam stiffness and resisting force from
the basic system to the global-coordinate
system
####################################
####################################
################

# Define Column Elements
set IDColTransf 01;        # associate a tag
to column transformation
set IDBeamTransf 02;       # associate a tag
to beam transformation
set IDDiagGirdTrans 03;    # associate a
tag to diagonal (gird) transformation
set IDGirdTransf 04;       # associate a tag
to all girder
set IDDiagBeamTransf 05;   # associate a
tag to diagonal (beam) transformation

# geomTransf TransfType $transfTag
$vecxzX $vecxzY $vecxzZ
   #TransfType: define geometric
transformation: Linear, PDelta, Corotational
   #$vecxzX $vecxzY $vecxzZ: X, Y, and Z
components of vecxz, the vector used to
define the local x-z plane of the local-
coordinate system. The local y-axis is
defined by taking the cross product of the
vecxz vector and the x-axis.
   # 1: fixed in that axis
geomTransf Linear 01 0 0 1; #Columns
geomTransf Linear 02 0 0 1; #Beams
geomTransf Linear 03 0 0 1; #Diagonal
(Beam)
geomTransf Linear 04 1 0 0; #Gird
geomTransf Linear 05 1 0 0; #Diagonal
(Gird)
geomTransf Linear 06 0 0 1; #Shell (Gird)

puts "Geometric Transformation Defined"

####################################
####################################
################
# Total Frame Properties and Geometric
Transformation
####################################
####################################
################

# define elastic column elements using
"element" command
#                    tag ndI ndJ secID   transf
# command: element elasticBeamColumn
$eleTag $iNode $jNode ($A $E $G $J $Iy
$Iz) $transfTag <-mass $massDens> <-
cMass>
   #$transfTag identifier for previously-
defined coordinate-transformation
(CrdTransf) object
   #$massDens  element mass per unit
length (optional, default = 0.0)
   #-cMass to form consistent mass matrix
(optional, default = lumped mass matrix)

#COLUMNS (1)
#Ground Storey
element elasticBeamColumn  109 19 29
$areaM $Em $Gm $Jm $inertiaM $inertiaM
01;
element elasticBeamColumn  110 110 210
$areaM $Em $Gm $Jm $inertiaM $inertiaM
01;
element elasticBeamColumn  112 112 212
$areaM $Em $Gm $Jm $inertiaM $inertiaM
01;
element elasticBeamColumn  113 113 213
$areaM $Em $Gm $Jm $inertiaM $inertiaM
01;

element elasticBeamColumn  116 116 216
$areaM $Em $Gm $Jm $inertiaM $inertiaM
01;
element elasticBeamColumn  117 117 217
$areaM $Em $Gm $Jm $inertiaM $inertiaM
01;
element elasticBeamColumn  118 118 218
$areaM $Em $Gm $Jm $inertiaM $inertiaM
01;
element elasticBeamColumn  119 119 219
$areaM $Em $Gm $Jm $inertiaM $inertiaM
01;
element elasticBeamColumn  120 120 220
$areaM $Em $Gm $Jm $inertiaM $inertiaM
01;

element elasticBeamColumn  1113 131 903
$areaM $Em $Gm $Jm $inertiaM $inertiaM
01;
element elasticBeamColumn  1116 129 901
$areaM $Em $Gm $Jm $inertiaM $inertiaM
01;

#Storey 02
element elasticBeamColumn  130 29 39
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  131 210 310
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  133 212 312
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  134 213 313
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;

element elasticBeamColumn  137 216 316
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  138 217 317
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  139 218 318
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  140 219 319
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  141 220 320
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;

element elasticBeamColumn  1117 903 911
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  1118 904 912
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  1119 902 910
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  1120 901 909
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;

#Storey 03
element elasticBeamColumn  158 39 49
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  159 310 410
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  161 312 412
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  162 313 413
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;

element elasticBeamColumn  172 316 416
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  173 317 417
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  174 318 418
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  175 319 419
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  176 320 420
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;

element elasticBeamColumn  1121 911 919
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  1122 912 920
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  1123 909 917
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  1124 910 918
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;

#Storey 04
element elasticBeamColumn  186 49 59
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  187 410 510
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
#element elasticBeamColumn  188 411 511
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  189 412 512
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  190 413 513
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;

element elasticBeamColumn  1100 416 516
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  1101 417 517
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  1102 418 518
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  1103 419 519
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  1104 420 520
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;

element elasticBeamColumn  1125 919 927
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  1126 920 928
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  1127 917 925
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;
element elasticBeamColumn  1128 918 926
$areaT $Et $Gt $Jt $inertiaT $inertiaT 01;

#BEAM ELEMENTS (2)
#1st Storey
element elasticBeamColumn  201 21 248
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;
element elasticBeamColumn  2011 248 22
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;
element elasticBeamColumn  202 22 141
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;
element elasticBeamColumn  2021 141 23
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;
element elasticBeamColumn  203 23 249
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;
element elasticBeamColumn  2031 249 236
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;
element elasticBeamColumn  2032 236 24
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;
element elasticBeamColumn  204 24 239
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;
element elasticBeamColumn  2041 239 250
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;
element elasticBeamColumn  2042 250 25
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;
element elasticBeamColumn  205 25 246
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;
element elasticBeamColumn  2051 246 26
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;
element elasticBeamColumn  206 26 247
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;
element elasticBeamColumn  2061 247 27
$areaM $Et $Gt $Jm $inertiaM $inertiaM 02;

element elasticBeamColumn  207 28 29
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  208 29 210
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  209 210 907
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  210 908 212
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  211 212 213
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  212 213 214
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  213 215 216
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  214 216 217
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  215 217 218
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  216 218 219
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  217 219 220
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  218 220 221
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;

element elasticBeamColumn  219 228 283
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  2191 283 281
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  2192 281 227
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  220 227 278
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  2201 278 275
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  2202 275 226
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  221 226 273
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  2211 273 269
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  2212 269 225
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  222 225 266
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  2221 266 264
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
```

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element elasticBeamColumn  2222 264 224
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  223 224 262
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  2231 262 258
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  2232 258 223
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  224 223 256
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  2241 256 253
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;
element elasticBeamColumn  2242 253 222
$areaM $Et $Gt $Jt $inertiaM $inertiaM 02;

element elasticBeamColumn  2910 903 905
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2911 904 905
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2912 901 906
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2913 902 906
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;

#2nd Storey
element elasticBeamColumn  225 31 3243
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2251 3243 32
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  226 32 3246
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2261 3246 33
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn 227 33 3248
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn 2271 3248
3250 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn 2272 3250 34
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn 228 34 3253
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn 2281 3253
3255 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn 2282 3255 35
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  229 35 3258
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2291 3258 36
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  230 36 3261
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2301 3261 37
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;

element elasticBeamColumn  231 38 39
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  232 39 310
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  233 310 915
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  234 916 312
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  235 312 313
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  236 313 314
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;

element elasticBeamColumn  237 315 316
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  238 316 317
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  239 317 318
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  240 318 319
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  241 319 320
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  242 320 321
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;

element elasticBeamColumn  243 323 3213
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2431 3213
3211 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2432 3211
322 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  244 324 3218
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
```

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element elasticBeamColumn  2441 3218
3216 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2442 3216
323 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  245 325 3223
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2451 3223
3221 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2452 3221
324 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  246 326 3228
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2461 3228
3226 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2462 3226
325 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  247 327 3233
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2471 3233
3231 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2472 3231
326 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  248 328 3238
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2481 3238
3236 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2482 3236
327 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;

element elasticBeamColumn  2914 912 913
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2915 913 911
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2916 910 914
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2917 909 914
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;

#3rd Storey
element elasticBeamColumn  249 41 4243
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2491 4243 42
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  250 42 4246
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2501 4246 43
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  251 43 4248
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2511 4248
4250 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2512 4250 44
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  252 44 4253
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2521 4253
4255 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2522 4255 45
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  253 45 4258
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2531 4258 46
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  254 46 4261
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2541 4261 47
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2542 46 47
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;

element elasticBeamColumn  255 48 49
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  256 49 410
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  257 410 923
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  258 924 412
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  259 412 413
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  260 413 414
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
```

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element elasticBeamColumn  261 415 416
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  262 416 417
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  263 417 418
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  264 418 419
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  265 419 420
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  266 420 421
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;

element elasticBeamColumn  267 422 4211
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2671 4211
4212 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2672 4212
423 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  268 423 4215
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2681 4215
4217 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2682 4217
424 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  269 424 4220
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2691 4220
4222 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2692 4222
425 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  270 425 4226
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2701 4226
4228 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2702 4228
426 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  271 426 4231
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2711 4231
4233 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2712 4233
427 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  272 427 4236
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2721 4236
4238 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;
element elasticBeamColumn  2722 4238
428 $areaT $Et $Gt $Jt $inertiaT $inertiaT
02;

element elasticBeamColumn  2918 919 921
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2919 921 920
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2920 917 922
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2921 922 918
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;

#4th Storey
element elasticBeamColumn  273 51 52
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  274 52 53
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  275 53 54
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  276 54 55
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  277 55 56
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  278 56 57
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;

element elasticBeamColumn  279 58 59
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  280 59 510
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  281 510 931
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  282 932 512
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
```

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element elasticBeamColumn  283 512 513
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  284 513 514
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;

element elasticBeamColumn  285 515 516
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  286 516 517
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  287 517 518
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  288 518 519
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  289 519 520
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  290 520 521
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;

element elasticBeamColumn  291 522 523
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  292 523 524
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  293 524 525
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  294 525 526
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  295 526 527
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  296 527 528
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;

element elasticBeamColumn  2922 927 929
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2923 929 928
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2924 925 930
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;
element elasticBeamColumn  2925 930 926
$areaT $Et $Gt $Jt $inertiaT $inertiaT 02;

#GIRDERS (3)
#1st Floor
element elasticBeamColumn  302 22 29
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  303 23 210
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  305 25 212
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  306 26 213
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  310 29 216
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  311 210 217
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  313 212 219
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  314 213 220
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;

element elasticBeamColumn  317 216 223
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  318 217 224
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  319 218 225
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  320 219 226
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  321 220 227
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;

element elasticBeamColumn  3100 218 905
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  3101 24 906
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;

element elasticBeamColumn  3102 901 907
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  3103 903 907
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  3104 902 908
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  3105 904 908
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;

#2nd Floor
element elasticBeamColumn  324 32 39
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  325 33 310
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  326 34 914
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  327 35 312
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  328 36 313
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;

element elasticBeamColumn  331 39 316
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  332 310 317
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  333 913 318
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  334 312 319
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  335 313 320
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;

#element elasticBeamColumn  337 315 322
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  338 316 323
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  339 317 324
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  340 318 325
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  341 319 326
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  342 320 327
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;

element elasticBeamColumn  3106 909 915
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  3107 915 911
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  3108 910 916
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  3109 916 912
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;

#3rd Floor
element elasticBeamColumn  345 42 49
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  346 43 410
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  347 44 922
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  348 45 412
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  349 46 413
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;

element elasticBeamColumn  352 49 416
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  353 410 417
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  354 921 418
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  355 412 419
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  356 413 420
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;

element elasticBeamColumn  359 416 423
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  360 417 424
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  361 418 425
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  362 419 426
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  363 420 427
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;

element elasticBeamColumn  3110 917 923
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  3111 923 919
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  3112 918 924
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  3113 924 920
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;

#4th Floor
element elasticBeamColumn  366 52 59
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  367 53 510
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  368 54 930
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  369 55 512
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  370 56 513
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;

element elasticBeamColumn  373 59 516
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  374 510 517
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  375 929 518
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  376 512 519
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  377 513 520
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;

element elasticBeamColumn  380 516 523
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  381 517 524
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  382 518 525
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  383 519 526
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;
element elasticBeamColumn  384 520 527
$areaT $Et $Gt $Jt $inertiaT $inertiaT 04;

element elasticBeamColumn  3114 925 931
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  3115 931 927
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  3116 926 932
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;
element elasticBeamColumn  3117 932 928
$areaM $Et $Gt $Jt $inertiaM $inertiaM 04;

#DIAGONAL ELEMENTS (4)
# 2nd Storey (middle)
element elasticBeamColumn 501 225 53231
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 502 218 53231
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 503 325 53232
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 504 318 53232
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;

#2nd Storey (staircase)
element elasticBeamColumn 521 910 937
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 522 912 937
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 523 904 938
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 524 902 938
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;

element elasticBeamColumn 533 909 943
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 534 911 943
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 535 901 944
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 536 903 944
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;

## 3rd Storey (Eje X0)
#
#3rd Storey (middle)
element elasticBeamColumn 505 325 53331
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 506 318 53331
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 507 425 53332
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 508 418 53332
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;

#3rd Storey (staircase)
element elasticBeamColumn 517 920 935
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 518 918 935
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 519 912 936
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 520 910 936
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;

element elasticBeamColumn 529 917 941
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 530 919 941
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 531 909 942
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 532 911 942
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;


## 4th Storey (Eje 6)
#middle
```

```
element elasticBeamColumn 509 425 53431
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 510 418 53431
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 511 525 53432
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 512 518 53432
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;

#staircase
element elasticBeamColumn 513 928 933
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 514 926 933
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 515 920 934
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 516 918 934
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;

element elasticBeamColumn 525 925 939
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 526 927 939
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 527 917 940
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;
element elasticBeamColumn 528 919 940
$areaT $Et $Gt $Jt $inertiaT $inertiaT 05;

puts "geometric transformation done"

####################################
##############
# Shell Elements
####################################
##############
# ----------------------------
# Start of model generation
# ----------------------------

####################################
##############
# Shell Elements
####################################
##############
#http://opensees.berkeley.edu/wiki/index.ph
p/Shell_Element

#nDMaterial ElasticIsotropic $matTag $E $v
        #E: Elasticity Modulus
        #v: Poisson
nDMaterial ElasticIsotropic 2 $Em 0.3

#nDMaterial PlateFiber $matTag $fiberTag
        #h: thickness
nDMaterial PlateFiber 4 2

# section PlateFiber $secTag $fiberTag $h
        #$secTag unique section
object tag for section being constructed
        #$fiberTag material tag for a
previously-defined plate fiber material (page
177)
        #$h thickness of the plate
section
section PlateFiber 1 4 0.75


#create the shell
#element ShellMITC4 $eleTag $iNode
$jNode $kNode $lNode $secTag

####################################
#####
#Back Shell
####################################
#####
node 2256008 16.63 0.5 0.0
node 2256009 16.63 1 0.0
node 2256010 16.63 1.5 0.0
node 2256012 16.63 2 0.0
node 2256014 16.63 2.5 0.0
node 2256015 16.63 3 0.0
node 2256024 16.63 4.73 0.0
node 2256028 16.63 5.23 0.0
node 2256030 16.63 5.73 0.0
node 2256031 16.63 6.23 0.0
node 2256035 16.63 6.73 0.0
node 2256054 16.63 8.36 0.0
node 2256058 16.63 8.86 0.0
node 2256061 16.63 9.36 0.0
node 2256070 16.63 9.86 0.0
node 2256076 16.63 10.36 0
node 2256097 16.63 11.98 0.0
node 2256104 16.63 12.48 0.0
node 2256116 16.63 12.98 0.0
node 2256125 16.63 13.48 0.0
node 2256162 1.79 0.5 0.0
node 2256163 1.79 1 0.0
node 2256164 1.79 1.5 0.0
node 2256166 1.79 2 0.0
node 2256168 1.79 2.5 0.0
node 2256171 1.79 3 0.0
node 2256180 1.79 4.73 0.0
node 2256184 1.79 5.23 0.0
node 2256186 1.79 5.73 0.0
node 2256189 1.79 6.23 0.0
node 2256192 1.79 6.73 0.0
node 2256206 1.79 8.36 0.0
node 2256210 1.79 8.86 0.0
node 2256216 1.79 9.36 0.0
node 2256221 1.79 9.86 0.0
node 2256228 1.79 10.36 0.0
node 2256239 1.79 11.98 0.0
node 2256241 1.79 12.48 0.0
node 2256245 1.79 12.98 0.0
node 2256249 1.79 13.48 0.0

####################################
#####
# Front Shell
####################################
#####
node 2257007 16.63 13.48 11.74
node 2257008 16.63 12.98 11.74
node 2257010 16.63 12.48 11.74
node 2257012 16.63 11.98 11.74
node 2257018 16.63 10.36 11.74
node 2257020 16.63 9.86 11.74
node 2257022 16.63 9.36 11.74
node 2257024 16.63 8.86 11.74
node 2257026 16.63 8.36 11.74
node 2257032 16.63 6.73 11.74
node 2257034 16.63 6.23 11.74
node 2257036 16.63 5.73 11.74
node 2257038 16.63 5.23 11.74
node 2257040 16.63 4.73 11.74
node 2257046 16.63 3 11.74
node 2257048 16.63 2.5 11.74
node 2257050 16.63 2 11.74
node 2257052 16.63 1.5 11.74
node 2257054 16.63 1 11.74
node 2257056 16.63 0.5 11.74
node 2257061 0.6 13.48 11.74
node 2257062 0.6 12.98 11.74
node 2257063 0.6 12.48 11.74
node 2257064 0.6 11.98 11.74
node 2257067 0.6 10.36 11.74
node 2257071 0.6 9.86 11.74
node 2257074 0.6 9.36 11.74
node 2257077 0.6 8.86 11.74
node 2257079 0.6 8.36 11.74
node 2257087 0.6 6.73 11.74
node 2257089 0.6 6.23 11.74
node 2257091 0.6 5.73 11.74
node 2257093 0.6 5.23 11.74
node 2257095 0.6 4.73 11.74
node 2257102 0.6 3 11.74
node 2257104 0.6 2.5 11.74
node 2257106 0.6 2 11.74
node 2257108 0.6 1.5 11.74
node 2257110 0.6 1 11.74
node 2257112 0.6 0.5 11.74

####################################
#####
#Lateral Shell
####################################
#####

# 1st Floor
#-------------------------------------

#X001
node 9101002 0.0 0.5 4.54
node 9101003 0.0 0 4
node 9101004 0.0 0.5 4
node 9101005 0.0 1 4.54
node 9101006 0.0 0.0 3.5
node 9101007 0.0 1 4
node 9101008 0.0 0.5 3.5
node 9101009 0.0 1 3.5
node 9101010 0.0 1.5 4.54
node 9101011 0.0 0 3
node 9101012 0.0 1.5 4
node 9101013 0.0 0.5 3
node 9101014 0.0 1.5 3.5
node 9101015 0.0 1 3
node 9101016 0.0 2 4.54
node 9101017 0.0 0.0 2.5
node 9101018 0 2 4
node 9101019 0 0.5 2.5
node 9101020 0 1.5 3
node 9101021 0 2 3.5
node 9101022 0 1 2.5
node 9101023 0 2.5 4.54
node 9101024 0 2 3
node 9101025 0 1.5 2.5
node 9101026 0 0 2
node 9101027 0 2.5 4
node 9101028 0 0.5 2
node 9101029 0 2.5 3.5
node 9101030 0 1 2
node 9101031 0 2 2.5
node 9101032 0 2.5 3
node 9101033 0 1.5 2
node 9101034 0 3 4.54
node 9101035 0 0 1.5
node 9101036 0 3 4
node 9101037 0 0.5 1.5
node 9101038 0 3 3.5
node 9101039 0 1 1.5
node 9101040 0 2.5 2.5
node 9101041 0 2 2
node 9101042 0 3 3
node 9101043 0 1.5 1.5
node 9101044 0 3.5 4.54
node 9101045 0 0 1
node 9101046 0 3.5 4
node 9101047 0 2.5 2
node 9101048 0 0.5 1
node 9101049 0 3 2.5
node 9101050 0 2 1.5
node 9101051 0 3.5 3.5
node 9101052 0 1 1
node 9101053 0 3.5 3
node 9101054 0 1.5 1
node 9101055 0 3 2
node 9101056 0 2.5 1.5
node 9101059 0 0 0.5
node 9101060 0 3.5 2.5
node 9101061 0 2 1
node 9101062 0 0.5 0.5
node 9101064 0 1 0.5
node 9101066 0 4.23 4
node 9101067 0 3 1.5
node 9101069 0 1.5 0.5
node 9101070 0 3.5 2
node 9101071 0 2.5 1
node 9101072 0 4.23 3.5
node 9101074 0 4.23 3
node 9101075 0 2 0.5
node 9101077 0 0.5 0
node 9101078 0 3.5 1.5
node 9101079 0 3 1
node 9101080 0 1 0
node 9101081 0 4.23 2.5
node 9101083 0 2.5 0.5
node 9101084 0 1.5 0
node 9101085 0 4.23 2
node 9101086 0 2 0
node 9101087 0 3.5 1
node 9101089 0 3 0.5
node 9101090 0 2.5 0
node 9101091 0 4.23 1.5
node 9101093 0 3.5 0.5
node 9101094 0 3 0
node 9101095 0 4.23 1
node 9101098 0 4.23 0.5

#X002
node 9102002 0 0.5 7.55
node 9102003 0 0 7.04
node 9102004 0 0.5 7.04
node 9102005 0 1 7.55
node 9102006 0 0 6.54
node 9102007 0 1 7.04
node 9102008 0 0.5 6.54
node 9102009 0 1 6.54
node 9102010 0 1.5 7.55
node 9102011 0 0 6.04
node 9102012 0 1.5 7.04
node 9102013 0 0.5 6.04
node 9102014 0 1.5 6.54
node 9102015 0 1 6.04
node 9102016 0 2 7.55
node 9102017 0 0 5.54
node 9102018 0 2 7.04
node 9102019 0 0.5 5.54
node 9102020 0 1.5 6.04
node 9102021 0 2 6.54
node 9102022 0 1 5.54
node 9102023 0 2.5 7.55
```

```
node    9102024 0   2   6.04
node    9102025 0   1.5 5.54
node    9102026 0   0   5.04
node    9102027 0   2.5 7.04
node    9102028 0   0.5 5.04
node    9102029 0   2.5 6.54
node    9102030 0   1   5.04
node    9102031 0   2   5.54
node    9102032 0   2.5 6.04
node    9102033 0   1.5 5.04
node    9102034 0   3   7.55
#node   9102035 0   0   4.54
node    9102036 0   3   7.04
#node   9102037 0   0.5 4.54
node    9102038 0   3   6.54
#node   9102039 0   1   4.54
node    9102040 0   2.5 5.54
node    9102041 0   2   5.04
node    9102042 0   3   6.04
#node   9102043 0   1.5 4.54
node    9102044 0   3.5 7.55
node    9102045 0   3.5 7.04
node    9102046 0   2.5 5.04
node    9102047 0   3   5.54
#node   9102048 0   2   4.54
node    9102049 0   3.5 6.54
node    9102050 0   3.5 6.04
node    9102051 0   3   5.04
node    9102055 0   3.5 5.54
node    9102059 0   4.23    7.04
#node   9102060 0   4   6.04
node    9102061 0   3.5 5.04
node    9102062 0   4.23    6.54
node    9102064 0   4.23    6.04
node    9102066 0   4.23    5.54
node    9102068 0   4.23    5.04

#X003
#node   9103001 0   0   7.55
#node   9103002 0   0.5 7.55
node    9103003 0   0   8.05
node    9103004 0   0.5 8.05
#node   9103005 0   1   7.55
node    9103006 0   0   8.55
node    9103007 0   1   8.05
node    9103008 0   0.5 8.55
node    9103009 0   1   8.55
#node   9103010 0   1.5 7.55
node    9103011 0   0   9.05
node    9103012 0   1.5 8.05
node    9103013 0   0.5 9.05
node    9103014 0   1.5 8.55
node    9103015 0   1   9.05
#node   9103016 0   2   7.55
node    9103017 0   0   9.55
node    9103018 0   2   8.05
node    9103019 0   0.5 9.55
node    9103020 0   1.5 9.05
node    9103021 0   1   9.55
node    9103022 0   2   8.55
#node   9103023 0   2.5 7.55
node    9103024 0   1.5 9.55
node    9103025 0   0   10.05
node    9103026 0   2   9.05
node    9103027 0   2.5 8.05
node    9103028 0   0.5 10.05
node    9103029 0   2.5 8.55
node    9103030 0   1   10.05
node    9103031 0   2   9.55
node    9103032 0   2.5 9.05
node    9103033 0   1.5 10.05
#node   9103034 0   3   7.55
node    9103035 0   0   10.55
node    9103036 0   3   8.05
node    9103037 0   0.5 10.55
node    9103038 0   3   8.55
node    9103039 0   1   10.55
node    9103040 0   2.5 9.55
node    9103041 0   2   10.05
node    9103042 0   3   9.05
node    9103043 0   1.5 10.55
#node   9103044 0   3.5 7.55
node    9103045 0   0   11.05
node    9103046 0   3.5 8.05
node    9103047 0   2.5 10.05
node    9103048 0   0.5 11.05
node    9103049 0   3   9.55
node    9103050 0   2   10.55
node    9103051 0   3.5 8.55
node    9103052 0   1   11.05
node    9103053 0   3.5 9.05
node    9103054 0   1.5 11.05
node    9103055 0   3   10.05
node    9103056 0   2.5 10.55
#node   9103057 0   4   7.55
node    9103058 0   0   11.55
#node   9103059 0   4   8.05
node    9103060 0   3.5 9.55
node    9103061 0   2   11.05
node    9103062 0   0.5 11.55
#node   9103063 0   4   8.55
node    9103064 0   1   11.55
#node   9103065 0   0   11.74
node    9103066 0   0.5 11.74
#node   9103067 0   4.23    7.55
node    9103068 0   3   10.55
node    9103069 0   4.23    8.05
#node   9103070 0   4   9.05
node    9103071 0   1.5 11.55
node    9103072 0   3.5 10.05
node    9103073 0   2.5 11.05
node    9103074 0   1   11.74
node    9103075 0   4.23    8.55
node    9103076 0   1.5 11.74
#node   9103077 0   4   9.55
node    9103078 0   2   11.55
node    9103079 0   4.23    9.05
node    9103080 0   3   11.05
node    9103081 0   3.5 10.55
node    9103082 0   2   11.74
node    9103083 0   4.23    9.55
#node   9103084 0   4   10.05
node    9103085 0   2.5 11.55
node    9103086 0   2.5 11.74
node    9103087 0   4.23    10.05
node    9103088 0   3.5 11.05
#node   9103089 0   4   10.55
node    9103090 0   3   11.55
node    9103091 0   3   11.74
node    9103092 0   4.23    10.55
#node   9103093 0   4   11.05
node    9103094 0   3.5 11.55
#node   9103095 0   3.5 11.74
node    9103096 0   4.23    11.05
#node   9103097 0   4   11.55
#node   9103098 0   4   11.74
node    9103099 0   4.23    11.55
#node   9103100 0   4.23    11.74

#X601
#node   9601001 17.9    0   4.54
node    9601002 17.9    0.5 4.54
node    9601003 17.9    0   4
node    9601004 17.9    0.5 4
node    9601005 17.9    1   4.54
node    9601006 17.9    0   3.5
node    9601007 17.9    1   4
node    9601008 17.9    0.5 3.5
node    9601009 17.9    1   3.5
node    9601010 17.9    1.5 4.54
node    9601011 17.9    0   3
node    9601012 17.9    1.5 4
node    9601013 17.9    0.5 3
node    9601014 17.9    1.5 3.5
node    9601015 17.9    1   3
node    9601016 17.9    2   4.54
node    9601017 17.9    0   2.5
node    9601018 17.9    2   4
node    9601019 17.9    0.5 2.5
node    9601020 17.9    1.5 3
node    9601021 17.9    2   3.5
node    9601022 17.9    1   2.5
node    9601023 17.9    2.5 4.54
node    9601024 17.9    2   3
node    9601025 17.9    1.5 2.5
node    9601026 17.9    0   2
node    9601027 17.9    2.5 4
node    9601028 17.9    0.5 2
node    9601029 17.9    2.5 3.5
node    9601030 17.9    1   2
node    9601031 17.9    2   2.5
node    9601032 17.9    2.5 3
node    9601033 17.9    1.5 2
node    9601034 17.9    3   4.54
node    9601035 17.9    0   1.5
node    9601036 17.9    3   4
node    9601037 17.9    0.5 1.5
node    9601038 17.9    3   3.5
node    9601039 17.9    1   1.5
node    9601040 17.9    2.5 2.5
node    9601041 17.9    2   2
node    9601042 17.9    3   3
node    9601043 17.9    1.5 1.5
node    9601044 17.9    3.5 4.54
node    9601045 17.9    0   1
node    9601046 17.9    3.5 4
node    9601047 17.9    2.5 2
node    9601048 17.9    0.5 1
node    9601049 17.9    3   2.5
node    9601050 17.9    2   1.5
node    9601051 17.9    3.5 3.5
node    9601052 17.9    1   1
node    9601053 17.9    3.5 3
node    9601054 17.9    1.5 1
node    9601055 17.9    3   2
node    9601056 17.9    2.5 1.5
#node   9601057 17.9    4   4.54
#node   9601058 17.9    4   4
node    9601059 17.9    0   0.5
node    9601060 17.9    3.5 2.5
node    9601061 17.9    2   1
node    9601062 17.9    0.5 0.5
#node   9601063 17.9    4   3.5
node    9601064 17.9    1   0.5
#node   9601065 17.9    4.23    4.54
node    9601066 17.9    4.23    4
node    9601067 17.9    3   1.5
#node   9601068 17.9    4   3
node    9601069 17.9    1.5 0.5
node    9601070 17.9    3.5 2
node    9601071 17.9    2.5 1
node    9601072 17.9    4.23    3.5
#node   9601073 17.9    4   2.5
node    9601074 17.9    4.23    3
node    9601075 17.9    2   0.5
#node   9601076 17.9    0   0
node    9601077 17.9    0.5 0
node    9601078 17.9    3.5 1.5
node    9601079 17.9    3   1
node    9601080 17.9    1   0
node    9601081 17.9    4.23    2.5
#node   9601082 17.9    4   2
node    9601083 17.9    2.5 0.5
node    9601084 17.9    1.5 0
node    9601085 17.9    4.23    2
node    9601086 17.9    2   0
node    9601087 17.9    3.5 1
#node   9601088 17.9    4   1.5
node    9601089 17.9    3   0.5
node    9601090 17.9    2.5 0
node    9601091 17.9    4.23    1.5
#node   9601092 17.9    4   1
node    9601093 17.9    3.5 0.5
node    9601094 17.9    3   0
node    9601095 17.9    4.23    1
#node   9601096 17.9    4   0.5
#node   9601097 17.9    3.5 0
node    9601098 17.9    4.23    0.5
#node   9601099 17.9    4   0
#node   9601100 17.9    4.23    0

#2nd Storey
#-------------------------------------

#X602
#node   9602001 17.9    0   7.55
node    9602002 17.9    0.5 7.55
node    9602003 17.9    0   7.04
node    9602004 17.9    0.5 7.04
node    9602005 17.9    1   7.55
node    9602006 17.9    0   6.54
node    9602007 17.9    1   7.04
node    9602008 17.9    0.5 6.54
node    9602009 17.9    1   6.54
node    9602010 17.9    1.5 7.55
node    9602011 17.9    0   6.04
node    9602012 17.9    1.5 7.04
node    9602013 17.9    0.5 6.04
node    9602014 17.9    1.5 6.54
node    9602015 17.9    1   6.04
node    9602016 17.9    2   7.55
node    9602017 17.9    0   5.54
node    9602018 17.9    2   7.04
node    9602019 17.9    0.5 5.54
node    9602020 17.9    1.5 6.04
node    9602021 17.9    2   6.54
node    9602022 17.9    1   5.54
node    9602023 17.9    2.5 7.55
node    9602024 17.9    2   6.04
node    9602025 17.9    1.5 5.54
node    9602026 17.9    0   5.04
node    9602027 17.9    2.5 7.04
node    9602028 17.9    0.5 5.04
node    9602029 17.9    2.5 6.54
node    9602030 17.9    1   5.04
node    9602031 17.9    2   5.54
node    9602032 17.9    2.5 6.04
node    9602033 17.9    1.5 5.04
node    9602034 17.9    3   7.55
#node   9602035 17.9    0   4.54
node    9602036 17.9    3   7.04
#node   9602037 17.9    0.5 4.54
```

```
node 9602038 17.9 3 6.54
#node 9602039 17.9 1 4.54
node 9602040 17.9 2.5 5.54
node 9602041 17.9 2 5.04
node 9602042 17.9 3 6.04
#node 9602043 17.9 1.5 4.54
node 9602044 17.9 3.5 7.55
node 9602045 17.9 3.5 7.04
node 9602046 17.9 2.5 5.04
node 9602047 17.9 3 5.54
#node 9602048 17.9 2 4.54
node 9602049 17.9 3.5 6.54
node 9602050 17.9 3.5 6.04
node 9602051 17.9 3 5.04
#node 9602052 17.9 2.5 4.54
#node 9602053 17.9 4 7.55
#node 9602054 17.9 4 7.04
node 9602055 17.9 3.5 5.54
#node 9602056 17.9 4 6.54
#node 9602057 17.9 4.23 7.55
#node 9602058 17.9 3 4.54
node 9602059 17.9 4.23 7.04
#node 9602060 17.9 4 6.04
node 9602061 17.9 3.5 5.04
node 9602062 17.9 4.23 6.54
#node 9602063 17.9 4 5.54
node 9602064 17.9 4.23 6.04
#node 9602065 17.9 3.5 4.54
node 9602066 17.9 4.23 5.54
#node 9602067 17.9 4 5.04
node 9602068 17.9 4.23 5.04
#node 9602069 17.9 4 4.54
#node 9602070 17.9 4.23 4.54

#X603
#node 9603001 17.9 0 7.55
#node 9603002 17.9 0.5 7.55
node 9603003 17.9 0 8.05
node 9603004 17.9 0.5 8.05
##node 9603005 17.9 1 7.55
node 9603006 17.9 0 8.55
node 9603007 17.9 1 8.05
node 9603008 17.9 0.5 8.55
node 9603009 17.9 1 8.55
##node 9603010 17.9 1.5 7.55
node 9603011 17.9 0 9.05
node 9603012 17.9 1.5 8.05
node 9603013 17.9 0.5 9.05
node 9603014 17.9 1.5 8.55
node 9603015 17.9 1 9.05
##node 9603016 17.9 2 7.55
node 9603017 17.9 0 9.55
node 9603018 17.9 2 8.05
node 9603019 17.9 0.5 9.55
node 9603020 17.9 1.5 9.05
node 9603021 17.9 1 9.55
node 9603022 17.9 2 8.55
##node 9603023 17.9 2.5 7.55
node 9603024 17.9 1.5 9.55
node 9603025 17.9 0 10.05
node 9603026 17.9 2 9.05
node 9603027 17.9 2.5 8.05
node 9603028 17.9 0.5 10.05
node 9603029 17.9 2.5 8.55
node 9603030 17.9 1 10.05
node 9603031 17.9 2 9.55
node 9603032 17.9 2.5 9.05
node 9603033 17.9 1.5 10.05
##node 9603034 17.9 3 7.55
node 9603035 17.9 0 10.55
node 9603036 17.9 3 8.05
node 9603037 17.9 0.5 10.55
node 9603038 17.9 3 8.55
node 9603039 17.9 1 10.55
node 9603040 17.9 2.5 9.55
node 9603041 17.9 2 10.05
node 9603042 17.9 3 9.05
node 9603043 17.9 1.5 10.55
##node 9603044 17.9 3.5 7.55
node 9603045 17.9 0 11.05
node 9603046 17.9 3.5 8.05
node 9603047 17.9 2.5 10.05
node 9603048 17.9 0.5 11.05
node 9603049 17.9 3 9.55
node 9603050 17.9 2 10.55
node 9603051 17.9 3.5 8.55
node 9603052 17.9 1 11.05
node 9603053 17.9 3.5 9.05
node 9603054 17.9 1.5 11.05
node 9603055 17.9 3 10.05
node 9603056 17.9 2.5 10.55
##node 9603057 17.9 4 7.55
node 9603058 17.9 0 11.55
#node 9603059 17.9 4 8.05
node 9603060 17.9 3.5 9.55
node 9603061 17.9 2 11.05
node 9603062 17.9 0.5 11.55
#node 9603063 17.9 4 8.55
node 9603064 17.9 1 11.55
##node 9603065 17.9 0 11.74
node 9603066 17.9 0.5 11.74
##node 9603067 17.9 4.23 7.55
node 9603068 17.9 3 10.55
node 9603069 17.9 4.23 8.05
#node 9603070 17.9 4 9.05
node 9603071 17.9 1.5 11.55
node 9603072 17.9 3.5 10.05
node 9603073 17.9 2.5 11.05
node 9603074 17.9 1 11.74
node 9603075 17.9 4.23 8.55
node 9603076 17.9 1.5 11.74
#node 9603077 17.9 4 9.55
node 9603078 17.9 2 11.55
node 9603079 17.9 4.23 9.05
node 9603080 17.9 3 11.05
node 9603081 17.9 3.5 10.55
node 9603082 17.9 2 11.74
node 9603083 17.9 4.23 9.55
#node 9603084 17.9 4 10.05
node 9603085 17.9 2.5 11.55
node 9603086 17.9 2.5 11.74
node 9603087 17.9 4.23 10.05
node 9603088 17.9 3.5 11.05
#node 9603089 17.9 4 10.55
node 9603090 17.9 3 11.55
node 9603091 17.9 3 11.74
node 9603092 17.9 4.23 10.55
#node 9603093 17.9 4 11.05
node 9603094 17.9 3.5 11.55
#node 9603095 17.9 3.5 11.74
node 9603096 17.9 4.23 11.05
#node 9603097 17.9 4 11.55
#node 9603098 17.9 4 11.74
node 9603099 17.9 4.23 11.55
##node 9603100 17.9 4.23 11.74

#2do Piso
#X021
##node 9021001 0 4.23 4.54
node 9021002 0 4.73 4.54
##node 9021003 0 4.23 4
node 9021004 0 4.73 4
node 9021005 0 5.23 4.54
##node 9021006 0 4.23 3.5
node 9021007 0 5.23 4
node 9021008 0 4.73 3.5
node 9021009 0 5.23 3.5
node 9021010 0 5.73 4.54
##node 9021011 0 4.23 3
node 9021012 0 5.73 4
node 9021013 0 4.73 3
node 9021014 0 5.73 3.5
node 9021015 0 5.23 3
node 9021016 0 6.23 4.54
##node 9021017 0 4.23 2.5
node 9021018 0 6.23 4
node 9021019 0 4.73 2.5
node 9021020 0 5.73 3
node 9021021 0 6.23 3.5
node 9021022 0 5.23 2.5
node 9021023 0 6.73 4.54
node 9021024 0 6.23 3
node 9021025 0 5.73 2.5
##node 9021026 0 4.23 2
node 9021027 0 6.73 4
node 9021028 0 4.73 2
node 9021029 0 6.73 3.5
node 9021030 0 5.23 2
node 9021031 0 6.23 2.5
node 9021032 0 6.73 3
node 9021033 0 5.73 2
node 9021034 0 7.23 4.54
##node 9021035 0 4.23 1.5
node 9021036 0 7.23 4
node 9021037 0 4.73 1.5
node 9021038 0 7.23 3.5
node 9021039 0 5.23 1.5
node 9021040 0 6.73 2.5
node 9021041 0 6.23 2
node 9021042 0 7.23 3
node 9021043 0 5.73 1.5
#node 9021044 0 7.73 4.54
##node 9021045 0 4.23 1
#node 9021046 0 7.73 4
node 9021047 0 6.73 2
node 9021048 0 4.73 1
node 9021049 0 7.23 2.5
node 9021050 0 6.23 1.5
#node 9021051 0 7.73 3.5
node 9021052 0 5.23 1
#node 9021053 0 7.73 3
node 9021054 0 5.73 1
node 9021055 0 7.23 2
node 9021056 0 6.73 1.5
#node 9021057 0 8.23 4.54
node 9021058 0 7.86 4
##node 9021059 0 4.23 0.5
#node 9021060 0 7.73 2.5
node 9021061 0 6.23 1
node 9021062 0 4.73 0.5
node 9021063 0 7.86 3.5
node 9021064 0 5.23 0.5
##node 9021065 0 8.46 4.54
##node 9021066 0 8.46 4
node 9021067 0 7.23 1.5
node 9021068 0 7.86 3
node 9021069 0 5.73 0.5
#node 9021070 0 7.73 2
node 9021071 0 6.73 1
##node 9021072 0 8.46 3.5
node 9021073 0 7.86 2.5
##node 9021074 0 8.46 3
node 9021075 0 6.23 0.5
##node 9021076 0 4.23 0
node 9021077 0 4.73 0
#node 9021078 0 7.73 1.5
node 9021079 0 7.23 1
node 9021080 0 5.23 0
##node 9021081 0 8.46 2.5
node 9021082 0 7.86 2
node 9021083 0 6.73 0.5
node 9021084 0 5.73 0
##node 9021085 0 8.46 2
node 9021086 0 6.23 0
#node 9021087 0 7.73 1
node 9021088 0 7.86 1.5
node 9021089 0 7.23 0.5
node 9021090 0 6.73 0
##node 9021091 0 8.46 1.5
node 9021092 0 7.86 1
#node 9021093 0 7.73 0.5
#node 9021094 0 7.23 0
##node 9021095 0 8.46 1
node 9021096 0 7.86 0.5
#node 9021097 0 7.73 0
##node 9021098 0 8.46 0.5
#node 9021099 0 7.86 0
#node 9021100 0 8.46 0

#X022
#node 9022001 0 4.23 7.55
node 9022002 0 4.73 7.55
#node 9022003 0 4.23 7.04
node 9022004 0 4.73 7.04
node 9022005 0 5.23 7.55
#node 9022006 0 4.23 6.54
node 9022007 0 5.23 7.04
node 9022008 0 4.73 6.54
node 9022009 0 5.23 6.54
node 9022010 0 5.73 7.55
#node 9022011 0 4.23 6.04
node 9022012 0 5.73 7.04
node 9022013 0 4.73 6.04
node 9022014 0 5.73 6.54
node 9022015 0 5.23 6.04
node 9022016 0 6.23 7.55
#node 9022017 0 4.23 5.54
node 9022018 0 6.23 7.04
node 9022019 0 4.73 5.54
node 9022020 0 5.73 6.04
node 9022021 0 6.23 6.54
node 9022022 0 5.23 5.54
node 9022023 0 6.73 7.55
node 9022024 0 6.23 6.04
node 9022025 0 5.73 5.54
#node 9022026 0 4.23 5.04
node 9022027 0 6.73 7.04
node 9022028 0 4.73 5.04
node 9022029 0 6.73 6.54
node 9022030 0 5.23 5.04
node 9022031 0 6.23 5.54
node 9022032 0 6.73 6.04
node 9022033 0 5.73 5.04
node 9022034 0 7.23 7.55
#node 9022035 0 4.23 4.54
node 9022036 0 7.23 7.04
#node 9022037 0 4.73 4.54
node 9022038 0 7.23 6.54
#node 9022039 0 5.23 4.54
node 9022040 0 6.73 5.54
node 9022041 0 6.23 5.04
node 9022042 0 7.23 6.04
```

```
#node 9022043 0 5.73 4.54
#node 9022044 0 7.73 7.55
#node 9022045 0 7.73 7.04
node 9022046 0 6.73 5.04
node 9022047 0 7.23 5.54
#node 9022048 0 6.23 4.54
#node 9022049 0 7.73 6.54
#node 9022050 0 7.73 6.04
node 9022051 0 7.23 5.04
#node 9022052 0 6.73 4.54
#node 9022053 0 7.86 7.55
node 9022054 0 7.86 7.04
#node 9022055 0 7.73 5.54
node 9022056 0 7.86 6.54
#node 9022057 0 8.46 7.55
#node 9022058 0 7.23 4.54
#node 9022059 0 8.46 7.04
node 9022060 0 7.86 6.04
#node 9022061 0 7.73 5.04
#node 9022062 0 8.46 6.54
node 9022063 0 7.86 5.54
#node 9022064 0 8.46 6.04
#node 9022065 0 7.73 4.54
#node 9022066 0 8.46 5.54
node 9022067 0 7.86 5.04
#node 9022068 0 8.46 5.04
#node 9022069 0 7.86 4.54
#node 9022070 0 8.46 4.54

#X023
#node 9623001 0 4.23 7.55
#node 9623002 0 4.73 7.55
#node 9623003 0 4.23 8.05
node 9623004 0 4.73 8.05
#node 9623005 0 5.23 7.55
#node 9623006 0 4.23 8.55
node 9623007 0 5.23 8.05
node 9623008 0 4.73 8.55
node 9623009 0 5.23 8.55
#node 9623010 0 5.73 7.55
#node 9623011 0 4.23 9.05
node 9623012 0 5.73 8.05
node 9623013 0 4.73 9.05
node 9623014 0 5.73 8.55
node 9623015 0 5.23 9.05
#node 9623016 0 6.23 7.55
#node 9623017 0 4.23 9.55
node 9623018 0 6.23 8.05
node 9623019 0 4.73 9.55
node 9623020 0 5.73 9.05
node 9623021 0 5.23 9.55
node 9623022 0 6.23 8.55
#node 9623023 0 6.73 7.55
node 9623024 0 5.73 9.55
#node 9623025 0 4.23 10.05
node 9623026 0 6.23 9.05
node 9623027 0 6.73 8.05
node 9623028 0 4.73 10.05
node 9623029 0 6.73 8.55
node 9623030 0 5.23 10.05
node 9623031 0 6.23 9.55
node 9623032 0 6.73 9.05
node 9623033 0 5.73 10.05
#node 9623034 0 7.23 7.55
#node 9623035 0 4.23 10.55
node 9623036 0 7.23 8.05
node 9623037 0 4.73 10.55
node 9623038 0 7.23 8.55
node 9623039 0 5.23 10.55
node 9623040 0 6.73 9.55
node 9623041 0 6.23 10.05
node 9623042 0 7.23 9.05
node 9623043 0 5.73 10.55
#node 9623044 0 7.73 7.55
#node 9623045 0 4.23 11.05
#node 9623046 0 7.73 8.05
node 9623047 0 6.73 10.05
node 9623048 0 4.73 11.05
node 9623049 0 7.23 9.55
node 9623050 0 6.23 10.55
#node 9623051 0 7.73 8.55
node 9623052 0 5.23 11.05
#node 9623053 0 7.73 9.05
node 9623054 0 5.73 11.05
node 9623055 0 7.23 10.05
node 9623056 0 6.73 10.55
#node 9623057 0 7.86 7.55
#node 9623058 0 4.23 11.55
node 9623059 0 7.86 8.05
#node 9623060 0 7.73 9.55
node 9623061 0 6.23 11.05
node 9623062 0 4.73 11.55
node 9623063 0 7.86 8.55
node 9623064 0 5.23 11.55
#node 9623065 0 4.23 11.74
node 9623066 0 4.73 11.74
#node 9623067 0 8.46 7.55
node 9623068 0 7.23 10.55
#node 9623069 0 8.46 8.05
node 9623070 0 7.86 9.05
node 9623071 0 5.73 11.55
#node 9623072 0 7.73 10.05
node 9623073 0 6.73 11.05
node 9623074 0 5.23 11.74
#node 9623075 0 8.46 8.55
node 9623076 0 5.73 11.74
node 9623077 0 7.86 9.55
node 9623078 0 6.23 11.55
#node 9623079 0 8.46 9.05
node 9623080 0 7.23 11.05
#node 9623081 0 7.73 10.55
node 9623082 0 6.23 11.74
#node 9623083 0 8.46 9.55
node 9623084 0 7.86 10.05
node 9623085 0 6.73 11.55
node 9623086 0 6.73 11.74
#node 9623087 0 8.46 10.05
#node 9623088 0 7.73 11.05
node 9623089 0 7.86 10.55
node 9623090 0 7.23 11.55
#node 9623091 0 7.23 11.74
#node 9623092 0 8.46 10.55
node 9623093 0 7.86 11.05
#node 9623094 0 7.73 11.55
#node 9623095 0 7.73 11.74
#node 9623096 0 8.46 11.05
node 9623097 0 7.86 11.55
#node 9623098 0 7.86 11.74
#node 9623099 0 8.46 11.55
#node 9623100 0 8.46 11.74

#X023
#node 9621001 17.9 4.23 4.54
node 9621002 17.9 4.73 4.54
#node 9621003 17.9 4.23 4
node 9621004 17.9 4.73 4
node 9621005 17.9 5.23 4.54
#node 9621006 17.9 4.23 3.5
node 9621007 17.9 5.23 4
node 9621008 17.9 4.73 3.5
node 9621009 17.9 5.23 3.5
node 9621010 17.9 5.73 4.54
#node 9621011 17.9 4.23 3
node 9621012 17.9 5.73 4
node 9621013 17.9 4.73 3
node 9621014 17.9 5.73 3.5
node 9621015 17.9 5.23 3
node 9621016 17.9 6.23 4.54
#node 9621017 17.9 4.23 2.5
node 9621018 17.9 6.23 4
node 9621019 17.9 4.73 2.5
node 9621020 17.9 5.73 3
node 9621021 17.9 6.23 3.5
node 9621022 17.9 5.23 2.5
node 9621023 17.9 6.73 4.54
node 9621024 17.9 6.23 3
node 9621025 17.9 5.73 2.5
#node 9621026 17.9 4.23 2
node 9621027 17.9 6.73 4
node 9621028 17.9 4.73 2
node 9621029 17.9 6.73 3.5
node 9621030 17.9 5.23 2
node 9621031 17.9 6.23 2.5
node 9621032 17.9 6.73 3
node 9621033 17.9 5.73 2
node 9621034 17.9 7.23 4.54
#node 9621035 17.9 4.23 1.5
node 9621036 17.9 7.23 4
node 9621037 17.9 4.73 1.5
node 9621038 17.9 7.23 3.5
node 9621039 17.9 5.23 1.5
node 9621040 17.9 6.73 2.5
node 9621041 17.9 6.23 2
node 9621042 17.9 7.23 3
node 9621043 17.9 5.73 1.5
#node 9621044 17.9 7.73 4.54
#node 9621045 17.9 4.23 1
#node 9621046 17.9 7.73 4
node 9621047 17.9 6.73 2
node 9621048 17.9 4.73 1
node 9621049 17.9 7.23 2.5
node 9621050 17.9 6.23 1.5
#node 9621051 17.9 7.73 3.5
node 9621052 17.9 5.23 1
#node 9621053 17.9 7.73 3
node 9621054 17.9 5.73 1
node 9621055 17.9 7.23 2
node 9621056 17.9 6.73 1.5
#node 9621057 17.9 7.86 4.54
node 9621058 17.9 7.86 4
#node 9621059 17.9 4.23 0.5
#node 9621060 17.9 7.73 2.5
node 9621061 17.9 6.23 1
node 9621062 17.9 4.73 0.5
node 9621063 17.9 7.86 3.5
node 9621064 17.9 5.23 0.5
#node 9621065 17.9 8.46 4.54
#node 9621066 17.9 8.46 4
node 9621067 17.9 7.23 1.5
node 9621068 17.9 7.86 3
node 9621069 17.9 5.73 0.5
#node 9621070 17.9 7.73 2
node 9621071 17.9 6.73 1
#node 9621072 17.9 8.46 3.5
node 9621073 17.9 7.86 2.5
#node 9621074 17.9 8.46 3
node 9621075 17.9 6.23 0.5
#node 9621076 17.9 4.23 0
node 9621077 17.9 4.73 0
#node 9621078 17.9 7.73 1.5
node 9621079 17.9 7.23 1
node 9621080 17.9 5.23 0
#node 9621081 17.9 8.46 2.5
node 9621082 17.9 7.86 2
node 9621083 17.9 6.73 0.5
node 9621084 17.9 5.73 0
#node 9621085 17.9 8.46 2
node 9621086 17.9 6.23 0
#node 9621087 17.9 7.73 1
node 9621088 17.9 7.86 1.5
node 9621089 17.9 7.23 0.5
node 9621090 17.9 6.73 0
#node 9621091 17.9 8.46 1.5
node 9621092 17.9 7.86 1
#node 9621093 17.9 7.73 0.5
#node 9621094 17.9 7.23 0
#node 9621095 17.9 8.46 1
node 9621096 17.9 7.86 0.5
#node 9621097 17.9 7.73 0
#node 9621098 17.9 8.46 0.5
#node 9621099 17.9 7.86 0
#node 9621100 17.9 8.46 0

#X622
##node 9622001 17.9 4.23 7.55
node 9622002 17.9 4.73 7.55
##node 9622003 17.9 4.23 7.04
node 9622004 17.9 4.73 7.04
node 9622005 17.9 5.23 7.55
##node 9622006 17.9 4.23 6.54
node 9622007 17.9 5.23 7.04
node 9622008 17.9 4.73 6.54
node 9622009 17.9 5.23 6.54
node 9622010 17.9 5.73 7.55
##node 9622011 17.9 4.23 6.04
node 9622012 17.9 5.73 7.04
node 9622013 17.9 4.73 6.04
node 9622014 17.9 5.73 6.54
node 9622015 17.9 5.23 6.04
node 9622016 17.9 6.23 7.55
##node 9622017 17.9 4.23 5.54
node 9622018 17.9 6.23 7.04
node 9622019 17.9 4.73 5.54
node 9622020 17.9 5.73 6.04
node 9622021 17.9 6.23 6.54
node 9622022 17.9 5.23 5.54
node 9622023 17.9 6.73 7.55
node 9622024 17.9 6.23 6.04
node 9622025 17.9 5.73 5.54
##node 9622026 17.9 4.23 5.04
node 9622027 17.9 6.73 7.04
node 9622028 17.9 4.73 5.04
node 9622029 17.9 6.73 6.54
node 9622030 17.9 5.23 5.04
node 9622031 17.9 6.23 5.54
node 9622032 17.9 6.73 6.04
node 9622033 17.9 5.73 5.04
node 9622034 17.9 7.23 7.55
##node 9622035 17.9 4.23 4.54
node 9622036 17.9 7.23 7.04
##node 9622037 17.9 4.73 4.54
node 9622038 17.9 7.23 6.54
##node 9622039 17.9 5.23 4.54
node 9622040 17.9 6.73 5.54
node 9622041 17.9 6.23 5.04
node 9622042 17.9 7.23 6.04
##node 9622043 17.9 5.73 4.54
#node 9622044 17.9 7.73 7.55
#node 9622045 17.9 7.73 7.04
node 9622046 17.9 6.73 5.04
node 9622047 17.9 7.23 5.54
##node 9622048 17.9 6.23 4.54
```

```
#node   9622049 17.9   7.73   6.54
#node   9622050 17.9   7.73   6.04
node   9622051 17.9   7.23   5.04
##node  9622052 17.9   6.73   4.54
#node   9622053 17.9   7.86   7.55
node   9622054 17.9   7.86   7.04
#node   9622055 17.9   7.73   5.54
node   9622056 17.9   7.86   6.54
##node  9622057 17.9   8.46   7.55
##node  9622058 17.9   7.23   4.54
##node  9622059 17.9   8.46   7.04
node   9622060 17.9   7.86   6.04
#node   9622061 17.9   7.73   5.04
##node  9622062 17.9   8.46   6.54
node   9622063 17.9   7.86   5.54
##node  9622064 17.9   8.46   6.04
##node  9622065 17.9   7.73   4.54
##node  9622066 17.9   8.46   5.54
node   9622067 17.9   7.86   5.04
##node  9622068 17.9   8.46   5.04
##node  9622069 17.9   7.86   4.54
##node  9622070 17.9   8.46   4.54

#X623 (9823XXX)
#node   9823001 17.9   4.23   7.55
#node   9823002 17.9   4.73   7.55
#node   9823003 17.9   4.23   8.05
node   9823004 17.9   4.73   8.05
#node   9823005 17.9   5.23   7.55
#node   9823006 17.9   4.23   8.55
node   9823007 17.9   5.23   8.05
node   9823008 17.9   4.73   8.55
node   9823009 17.9   5.23   8.55
#node   9823010 17.9   5.73   7.55
#node   9823011 17.9   4.23   9.05
node   9823012 17.9   5.73   8.05
node   9823013 17.9   4.73   9.05
node   9823014 17.9   5.73   8.55
node   9823015 17.9   5.23   9.05
#node   9823016 17.9   6.23   7.55
#node   9823017 17.9   4.23   9.55
node   9823018 17.9   6.23   8.05
node   9823019 17.9   4.73   9.55
node   9823020 17.9   5.73   9.05
node   9823021 17.9   5.23   9.55
node   9823022 17.9   6.23   8.55
#node   9823023 17.9   6.73   7.55
node   9823024 17.9   5.73   9.55
#node   9823025 17.9   4.23   10.05
node   9823026 17.9   6.23   9.05
node   9823027 17.9   6.73   8.05
node   9823028 17.9   4.73   10.05
node   9823029 17.9   6.73   8.55
node   9823030 17.9   5.23   10.05
node   9823031 17.9   6.23   9.55
node   9823032 17.9   6.73   9.05
node   9823033 17.9   5.73   10.05
#node   9823034 17.9   7.23   7.55
#node   9823035 17.9   4.23   10.55
node   9823036 17.9   7.23   8.05
node   9823037 17.9   4.73   10.55
node   9823038 17.9   7.23   8.55
node   9823039 17.9   5.23   10.55
node   9823040 17.9   6.73   9.55
node   9823041 17.9   6.23   10.05
node   9823042 17.9   7.23   9.05
node   9823043 17.9   5.73   10.55
#node   9823044 17.9   7.73   7.55
#node   9823045 17.9   4.23   11.05
#node   9823046 17.9   7.73   8.05
node   9823047 17.9   6.73   10.05
node   9823048 17.9   4.73   11.05
node   9823049 17.9   7.23   9.55
node   9823050 17.9   6.23   10.55
#node   9823051 17.9   7.73   8.55
node   9823052 17.9   5.23   11.05
#node   9823053 17.9   7.73   9.05
node   9823054 17.9   5.73   11.05
node   9823055 17.9   7.23   10.05
node   9823056 17.9   6.73   10.55
#node   9823057 17.9   7.86   7.55
#node   9823058 17.9   4.23   11.55
node   9823059 17.9   7.86   8.05
#node   9823060 17.9   7.73   9.55
node   9823061 17.9   6.23   11.05
node   9823062 17.9   4.73   11.55
node   9823063 17.9   7.86   8.55
node   9823064 17.9   5.23   11.55
#node   9823065 17.9   4.23   11.74
node   9823066 17.9   4.73   11.74
#node   9823067 17.9   8.46   7.55
node   9823068 17.9   7.23   10.55
#node   9823069 17.9   8.46   8.05
node   9823070 17.9   7.86   9.05
node   9823071 17.9   5.73   11.55
#node   9823072 17.9   7.73   10.05
node   9823073 17.9   6.73   11.05
node   9823074 17.9   5.23   11.74
#node   9823075 17.9   8.46   8.55
node   9823076 17.9   5.73   11.74
node   9823077 17.9   7.86   9.55
node   9823078 17.9   6.23   11.55
#node   9823079 17.9   8.46   9.05
node   9823080 17.9   7.23   11.05
#node   9823081 17.9   7.73   10.55
node   9823082 17.9   6.23   11.74
#node   9823083 17.9   8.46   9.55
node   9823084 17.9   7.86   10.05
node   9823085 17.9   6.73   11.55
node   9823086 17.9   6.73   11.74
#node   9823087 17.9   8.46   10.05
#node   9823088 17.9   7.73   11.05
node   9823089 17.9   7.86   10.55
node   9823090 17.9   7.23   11.55
#node   9823091 17.9   7.23   11.74
#node   9823092 17.9   8.46   10.55
node   9823093 17.9   7.86   11.05
#node   9823094 17.9   7.73   11.55
#node   9823095 17.9   7.73   11.74
#node   9823096 17.9   8.46   11.05
node   9823097 17.9   7.86   11.55
#node   9823098 17.9   7.86   11.74
#node   9823099 17.9   8.46   11.55
#node   9823100 17.9   8.46   11.74

#3rd Storey
#-------------------------------------
#X031
#node   9031001 0   7.86   4.54
node   9031002 0   8.36   4.54
#node   9031003 0   7.86   4
node   9031004 0   8.36   4
node   9031005 0   8.86   4.54
#node   9031006 0   7.86   3.5
node   9031007 0   8.86   4
node   9031008 0   8.36   3.5
node   9031009 0   8.86   3.5
node   9031010 0   9.36   4.54
#node   9031011 0   7.86   3
node   9031012 0   9.36   4
node   9031013 0   8.36   3
node   9031014 0   9.36   3.5
node   9031015 0   8.86   3
node   9031016 0   9.86   4.54
#node   9031017 0   7.86   2.5
node   9031018 0   9.86   4
node   9031019 0   8.36   2.5
node   9031020 0   9.36   3
node   9031021 0   9.86   3.5
node   9031022 0   8.86   2.5
node   9031023 0   10.36   4.54
node   9031024 0   9.86   3
node   9031025 0   9.36   2.5
#node   9031026 0   7.86   2
node   9031027 0   10.36   4
node   9031028 0   8.36   2
node   9031029 0   10.36   3.5
node   9031030 0   8.86   2
node   9031031 0   9.86   2.5
node   9031032 0   10.36   3
node   9031033 0   9.36   2
node   9031034 0   10.86   4.54
#node   9031035 0   7.86   1.5
node   9031036 0   10.86   4
node   9031037 0   8.36   1.5
node   9031038 0   10.86   3.5
node   9031039 0   8.86   1.5
node   9031040 0   10.36   2.5
node   9031041 0   9.86   2
node   9031042 0   10.86   3
node   9031043 0   9.36   1.5
#node   9031044 0   11.36   4.54
#node   9031045 0   7.86   1
#node   9031046 0   11.36   4
node   9031047 0   10.36   2
node   9031048 0   8.36   1
node   9031049 0   10.86   2.5
node   9031050 0   9.86   1.5
#node   9031051 0   11.36   3.5
node   9031052 0   8.86   1
#node   9031053 0   11.36   3
node   9031054 0   9.36   1
node   9031055 0   10.86   2
node   9031056 0   10.36   1.5
#node   9031057 0   11.48   4.54
node   9031058 0   11.48   4
#node   9031059 0   7.86   0.5
#node   9031060 0   11.36   2.5
node   9031061 0   9.86   1
node   9031062 0   8.36   0.5
node   9031063 0   11.48   3.5
node   9031064 0   8.86   0.5
#node   9031065 0   12.09   4.54
#node   9031066 0   12.09   4
node   9031067 0   10.86   1.5
node   9031068 0   11.48   3
node   9031069 0   9.36   0.5
#node   9031070 0   11.36   2
node   9031071 0   10.36   1
#node   9031072 0   12.09   3.5
node   9031073 0   11.48   2.5
#node   9031074 0   12.09   3
node   9031075 0   9.86   0.5
#node   9031076 0   7.86   0
node   9031077 0   8.36   0
#node   9031078 0   11.36   1.5
node   9031079 0   10.86   1
node   9031080 0   8.86   0
#node   9031081 0   12.09   2.5
node   9031082 0   11.48   2
node   9031083 0   10.36   0.5
node   9031084 0   9.36   0
#node   9031085 0   12.09   2
node   9031086 0   9.86   0
#node   9031087 0   11.36   1
node   9031088 0   11.48   1.5
node   9031089 0   10.86   0.5
node   9031090 0   10.36   0
#node   9031091 0   12.09   1.5
node   9031092 0   11.48   1
#node   9031093 0   11.36   0.5
#node   9031094 0   10.86   0
#node   9031095 0   12.09   1
node   9031096 0   11.48   0.5
#node   9031097 0   11.36   0
#node   9031098 0   12.09   0.5
#node   9031099 0   11.48   0
#node   9031100 0   12.09   0

#X032
#node   9032001 0   7.86   7.55
node   9032002 0   8.36   7.55
#node   9032003 0   7.86   7.04
node   9032004 0   8.36   7.04
node   9032005 0   8.86   7.55
#node   9032006 0   7.86   6.54
node   9032007 0   8.86   7.04
node   9032008 0   8.36   6.54
node   9032009 0   8.86   6.54
node   9032010 0   9.36   7.55
#node   9032011 0   7.86   6.04
node   9032012 0   9.36   7.04
node   9032013 0   8.36   6.04
node   9032014 0   9.36   6.54
node   9032015 0   8.86   6.04
node   9032016 0   9.86   7.55
#node   9032017 0   7.86   5.54
node   9032018 0   9.86   7.04
node   9032019 0   8.36   5.54
node   9032020 0   9.36   6.04
node   9032021 0   9.86   6.54
node   9032022 0   8.86   5.54
node   9032023 0   10.36   7.55
node   9032024 0   9.86   6.04
node   9032025 0   9.36   5.54
#node   9032026 0   7.86   5.04
node   9032027 0   10.36   7.04
node   9032028 0   8.36   5.04
node   9032029 0   10.36   6.54
node   9032030 0   8.86   5.04
node   9032031 0   9.86   5.54
node   9032032 0   10.36   6.04
node   9032033 0   9.36   5.04
node   9032034 0   10.86   7.55
#node   9032035 0   7.86   4.54
node   9032036 0   10.86   7.04
#node   9032037 0   8.36   4.54
node   9032038 0   10.86   6.54
#node   9032039 0   8.86   4.54
node   9032040 0   10.36   5.54
node   9032041 0   9.86   5.04
node   9032042 0   10.86   6.04
#node   9032043 0   9.36   4.54
#node   9032044 0   11.36   7.55
#node   9032045 0   11.36   7.04
node   9032046 0   10.36   5.04
node   9032047 0   10.86   5.54
#node   9032048 0   9.86   4.54
#node   9032049 0   11.36   6.54
#node   9032050 0   11.36   6.04
node   9032051 0   10.86   5.04
#node   9032052 0   10.36   4.54
```

```
#node 9032053 0 11.48 7.55
node 9032054 0 11.48 7.04
#node 9032055 0 11.36 5.54
node 9032056 0 11.48 6.54
#node 9032057 0 12.09 7.55
#node 9032058 0 10.86 4.54
#node 9032059 0 12.09 7.04
node 9032060 0 11.48 6.04
#node 9032061 0 11.36 5.04
#node 9032062 0 12.09 6.54
node 9032063 0 11.48 5.54
#node 9032064 0 12.09 6.04
#node 9032065 0 11.36 4.54
#node 9032066 0 12.09 5.54
node 9032067 0 11.48 5.04
#node 9032068 0 12.09 5.04
#node 9032069 0 11.48 4.54
#node 9032070 0 12.09 4.54

#X033
#node 9033001 0 7.86 7.55
#node 9033002 0 8.36 7.55
#node 9033003 0 7.86 8.05
node 9033004 0 8.36 8.05
#node 9033005 0 8.86 7.55
#node 9033006 0 7.86 8.55
node 9033007 0 8.86 8.05
node 9033008 0 8.36 8.55
node 9033009 0 8.86 8.55
#node 9033010 0 9.36 7.55
#node 9033011 0 7.86 9.05
node 9033012 0 9.36 8.05
node 9033013 0 8.36 9.05
node 9033014 0 9.36 8.55
node 9033015 0 8.86 9.05
#node 9033016 0 9.86 7.55
#node 9033017 0 7.86 9.55
node 9033018 0 9.86 8.05
node 9033019 0 8.36 9.55
node 9033020 0 9.36 9.05
node 9033021 0 8.86 9.55
node 9033022 0 9.86 8.55
#node 9033023 0 10.36 7.55
node 9033024 0 9.36 9.55
#node 9033025 0 7.86 10.05
node 9033026 0 9.86 9.05
node 9033027 0 10.36 8.05
node 9033028 0 8.36 10.05
node 9033029 0 10.36 8.55
node 9033030 0 8.86 10.05
node 9033031 0 9.86 9.55
node 9033032 0 10.36 9.05
node 9033033 0 9.36 10.05
#node 9033034 0 10.86 7.55
#node 9033035 0 7.86 10.55
node 9033036 0 10.86 8.05
node 9033037 0 8.36 10.55
node 9033038 0 10.86 8.55
node 9033039 0 8.86 10.55
node 9033040 0 10.36 9.55
node 9033041 0 9.86 10.05
node 9033042 0 10.86 9.05
node 9033043 0 9.36 10.55
#node 9033044 0 11.36 7.55
#node 9033045 0 7.86 11.05
#node 9033046 0 11.36 8.05
node 9033047 0 10.36 10.05
node 9033048 0 8.36 11.05
node 9033049 0 10.86 9.55
node 9033050 0 9.86 10.55
#node 9033051 0 11.36 8.55
node 9033052 0 8.86 11.05
#node 9033053 0 11.36 9.05
node 9033054 0 9.36 11.05
node 9033055 0 10.86 10.05
node 9033056 0 10.36 10.55
#node 9033057 0 11.48 7.55
#node 9033058 0 7.86 11.55
node 9033059 0 11.48 8.05
#node 9033060 0 11.36 9.55
node 9033061 0 9.86 11.05
node 9033062 0 8.36 11.55
node 9033063 0 11.48 8.55
node 9033064 0 8.86 11.55
#node 9033065 0 7.86 11.74
node 9033066 0 8.36 11.74
#node 9033067 0 12.09 7.55
node 9033068 0 10.86 10.55
#node 9033069 0 12.09 8.05
node 9033070 0 11.48 9.05
node 9033071 0 9.36 11.55
#node 9033072 0 11.36 10.05
node 9033073 0 10.36 11.05
node 9033074 0 8.86 11.74
#node 9033075 0 12.09 8.55
node 9033076 0 9.36 11.74
node 9033077 0 11.48 9.55
node 9033078 0 9.86 11.55
#node 9033079 0 12.09 9.05
node 9033080 0 10.86 11.05
#node 9033081 0 11.36 10.55
node 9033082 0 9.86 11.74
#node 9033083 0 12.09 9.55
node 9033084 0 11.48 10.05
node 9033085 0 10.36 11.55
node 9033086 0 10.36 11.74
#node 9033087 0 12.09 10.05
#node 9033088 0 11.36 11.05
node 9033089 0 11.48 10.55
node 9033090 0 10.86 11.55
#node 9033091 0 10.86 11.74
#node 9033092 0 12.09 10.55
node 9033093 0 11.48 11.05
#node 9033094 0 11.36 11.55
#node 9033095 0 11.36 11.74
#node 9033096 0 12.09 11.05
node 9033097 0 11.48 11.55
#node 9033098 0 11.48 11.74
#node 9033099 0 12.09 11.55
#node 9033100 0 12.09 11.74

#X631
#node 9631001 17.9 7.86 4.54
node 9631002 17.9 8.36 4.54
#node 9631003 17.9 7.86 4
node 9631004 17.9 8.36 4
node 9631005 17.9 8.86 4.54
#node 9631006 17.9 7.86 3.5
node 9631007 17.9 8.86 4
node 9631008 17.9 8.36 3.5
node 9631009 17.9 8.86 3.5
node 9631010 17.9 9.36 4.54
#node 9631011 17.9 7.86 3
node 9631012 17.9 9.36 4
node 9631013 17.9 8.36 3
node 9631014 17.9 9.36 3.5
node 9631015 17.9 8.86 3
node 9631016 17.9 9.86 4.54
#node 9631017 17.9 7.86 2.5
node 9631018 17.9 9.86 4
node 9631019 17.9 8.36 2.5
node 9631020 17.9 9.36 3
node 9631021 17.9 9.86 3.5
node 9631022 17.9 8.86 2.5
node 9631023 17.9 10.36 4.54
node 9631024 17.9 9.86 3
node 9631025 17.9 9.36 2.5
#node 9631026 17.9 7.86 2
node 9631027 17.9 10.36 4
node 9631028 17.9 8.36 2
node 9631029 17.9 10.36 3.5
node 9631030 17.9 8.86 2
node 9631031 17.9 9.86 2.5
node 9631032 17.9 10.36 3
node 9631033 17.9 9.36 2
node 9631034 17.9 10.86 4.54
#node 9631035 17.9 7.86 1.5
node 9631036 17.9 10.86 4
node 9631037 17.9 8.36 1.5
node 9631038 17.9 10.86 3.5
node 9631039 17.9 8.86 1.5
node 9631040 17.9 10.36 2.5
node 9631041 17.9 9.86 2
node 9631042 17.9 10.86 3
node 9631043 17.9 9.36 1.5
#node 9631044 17.9 11.36 4.54
#node 9631045 17.9 7.86 1
#node 9631046 17.9 11.36 4
node 9631047 17.9 10.36 2
node 9631048 17.9 8.36 1
node 9631049 17.9 10.86 2.5
node 9631050 17.9 9.86 1.5
#node 9631051 17.9 11.36 3.5
node 9631052 17.9 8.86 1
#node 9631053 17.9 11.36 3
node 9631054 17.9 9.36 1
node 9631055 17.9 10.86 2
node 9631056 17.9 10.36 1.5
#node 9631057 17.9 11.86 4.54
node 9631058 17.9 11.46 4
#node 9631059 17.9 7.86 0.5
#node 9631060 17.9 11.36 2.5
node 9631061 17.9 9.86 1
node 9631062 17.9 8.36 0.5
node 9631063 17.9 11.46 3.5
node 9631064 17.9 8.86 0.5
#node 9631065 17.9 12.09 4.54
#node 9631066 17.9 12.09 4
node 9631067 17.9 10.86 1.5
node 9631068 17.9 11.46 3
node 9631069 17.9 9.36 0.5
#node 9631070 17.9 11.36 2
node 9631071 17.9 10.36 1
#node 9631072 17.9 12.09 3.5
node 9631073 17.9 11.46 2.5
#node 9631074 17.9 12.09 3
node 9631075 17.9 9.86 0.5
#node 9631076 17.9 7.86 0
node 9631077 17.9 8.36 0
#node 9631078 17.9 11.36 1.5
node 9631079 17.9 10.86 1
node 9631080 17.9 8.86 0
#node 9631081 17.9 12.09 2.5
node 9631082 17.9 11.46 2
node 9631083 17.9 10.36 0.5
node 9631084 17.9 9.36 0
#node 9631085 17.9 12.09 2
node 9631086 17.9 9.86 0
#node 9631087 17.9 11.36 1
node 9631088 17.9 11.46 1.5
node 9631089 17.9 10.86 0.5
node 9631090 17.9 10.36 0
#node 9631091 17.9 12.09 1.5
node 9631092 17.9 11.46 1
#node 9631093 17.9 11.36 0.5
#node 9631094 17.9 10.86 0
#node 9631095 17.9 12.09 1
node 9631096 17.9 11.46 0.5
#node 9631097 17.9 11.36 0
#node 9631098 17.9 12.09 0.5
#node 9631099 17.9 11.86 0
#node 9631100 17.9 12.09 0

#X632
#node 9632001 17.9 7.86 7.55
node 9632002 17.9 8.36 7.55
#node 9632003 17.9 7.86 7.04
node 9632004 17.9 8.36 7.04
node 9632005 17.9 8.86 7.55
#node 9632006 17.9 7.86 6.54
node 9632007 17.9 8.86 7.04
node 9632008 17.9 8.36 6.54
node 9632009 17.9 8.86 6.54
node 9632010 17.9 9.36 7.55
#node 9632011 17.9 7.86 6.04
node 9632012 17.9 9.36 7.04
node 9632013 17.9 8.36 6.04
node 9632014 17.9 9.36 6.54
node 9632015 17.9 8.86 6.04
node 9632016 17.9 9.86 7.55
#node 9632017 17.9 7.86 5.54
node 9632018 17.9 9.86 7.04
node 9632019 17.9 8.36 5.54
node 9632020 17.9 9.36 6.04
node 9632021 17.9 9.86 6.54
node 9632022 17.9 8.86 5.54
node 9632023 17.9 10.36 7.55
node 9632024 17.9 9.86 6.04
node 9632025 17.9 9.36 5.54
#node 9632026 17.9 7.86 5.04
node 9632027 17.9 10.36 7.04
node 9632028 17.9 8.36 5.04
node 9632029 17.9 10.36 6.54
node 9632030 17.9 8.86 5.04
node 9632031 17.9 9.86 5.54
node 9632032 17.9 10.36 6.04
node 9632033 17.9 9.36 5.04
node 9632034 17.9 10.86 7.55
#node 9632035 17.9 7.86 4.54
node 9632036 17.9 10.86 7.04
#node 9632037 17.9 8.36 4.54
node 9632038 17.9 10.86 6.54
#node 9632039 17.9 8.86 4.54
node 9632040 17.9 10.36 5.54
node 9632041 17.9 9.86 5.04
node 9632042 17.9 10.86 6.04
#node 9632043 17.9 9.36 4.54
#node 9632044 17.9 11.36 7.55
#node 9632045 17.9 11.36 7.04
node 9632046 17.9 10.36 5.04
node 9632047 17.9 10.86 5.54
#node 9632048 17.9 9.86 4.54
#node 9632049 17.9 11.36 6.54
#node 9632050 17.9 11.36 6.04
node 9632051 17.9 10.86 5.04
#node 9632052 17.9 10.36 4.54
#node 9632053 17.9 11.49 7.55
node 9632054 17.9 11.49 7.04
#node 9632055 17.9 11.36 5.54
node 9632056 17.9 11.49 6.54
#node 9632057 17.9 12.09 7.55
#node 9632058 17.9 10.86 4.54
```

```
#node   9632059 17.9   12.09   7.04
node   9632060 17.9   11.49   6.04
#node   9632061 17.9   11.36   5.04
#node   9632062 17.9   12.09   6.54
node   9632063 17.9   11.49   5.54
#node   9632064 17.9   12.09   6.04
#node   9632065 17.9   11.36   4.54
#node   9632066 17.9   12.09   5.54
node   9632067 17.9   11.49   5.04
#node   9632068 17.9   12.09   5.04
#node   9632069 17.9   11.49   4.54
#node   9632070 17.9   12.09   4.54

#X633
#node   9633001 17.9   7.86   7.55
#node   9633002 17.9   8.36   7.55
#node   9633003 17.9   7.86   8.05
node   9633004 17.9   8.36   8.05
#node   9633005 17.9   8.86   7.55
#node   9633006 17.9   7.86   8.55
node   9633007 17.9   8.86   8.05
node   9633008 17.9   8.36   8.55
node   9633009 17.9   8.86   8.55
#node   9633010 17.9   9.36   7.55
#node   9633011 17.9   7.86   9.05
node   9633012 17.9   9.36   8.05
node   9633013 17.9   8.36   9.05
node   9633014 17.9   9.36   8.55
node   9633015 17.9   8.86   9.05
#node   9633016 17.9   9.86   7.55
#node   9633017 17.9   7.86   9.55
node   9633018 17.9   9.86   8.05
node   9633019 17.9   8.36   9.55
node   9633020 17.9   9.36   9.05
node   9633021 17.9   8.86   9.55
node   9633022 17.9   9.86   8.55
#node   9633023 17.9   10.36   7.55
node   9633024 17.9   9.36   9.55
#node   9633025 17.9   7.86   10.05
node   9633026 17.9   9.86   9.05
node   9633027 17.9   10.36   8.05
node   9633028 17.9   8.36   10.05
node   9633029 17.9   10.36   8.55
node   9633030 17.9   8.86   10.05
node   9633031 17.9   9.86   9.55
node   9633032 17.9   10.36   9.05
node   9633033 17.9   9.36   10.05
#node   9633034 17.9   10.86   7.55
#node   9633035 17.9   7.86   10.55
node   9633036 17.9   10.86   8.05
node   9633037 17.9   8.36   10.55
node   9633038 17.9   10.86   8.55
node   9633039 17.9   8.86   10.55
node   9633040 17.9   10.36   9.55
node   9633041 17.9   9.86   10.05
node   9633042 17.9   10.86   9.05
node   9633043 17.9   9.36   10.55
#node   9633044 17.9   11.36   7.55
#node   9633045 17.9   7.86   11.05
#node   9633046 17.9   11.36   8.05
node   9633047 17.9   10.36   10.05
node   9633048 17.9   8.36   11.05
node   9633049 17.9   10.86   9.55
node   9633050 17.9   9.86   10.55
#node   9633051 17.9   11.36   8.55
node   9633052 17.9   8.86   11.05
#node   9633053 17.9   11.36   9.05
node   9633054 17.9   9.36   11.05
node   9633055 17.9   10.86   10.05
node   9633056 17.9   10.36   10.55
#node   9633057 17.9   11.49   7.55
#node   9633058 17.9   7.86   11.55
node   9633059 17.9   11.49   8.05
#node   9633060 17.9   11.36   9.55
node   9633061 17.9   9.86   11.05
node   9633062 17.9   8.36   11.55
node   9633063 17.9   11.49   8.55
node   9633064 17.9   8.86   11.55
#node   9633065 17.9   7.86   11.74
node   9633066 17.9   8.36   11.74
#node   9633067 17.9   12.09   7.55
node   9633068 17.9   10.86   10.55
#node   9633069 17.9   12.09   8.05
node   9633070 17.9   11.49   9.05
node   9633071 17.9   9.36   11.55
#node   9633072 17.9   11.36   10.05
node   9633073 17.9   10.36   11.05
node   9633074 17.9   8.86   11.74
#node   9633075 17.9   12.09   8.55
node   9633076 17.9   9.36   11.74
node   9633077 17.9   11.49   9.55
node   9633078 17.9   9.86   11.55
#node   9633079 17.9   12.09   9.05
node   9633080 17.9   10.86   11.05
#node   9633081 17.9   11.36   10.55
node   9633082 17.9   9.86   11.74
#node   9633083 17.9   12.09   9.55
node   9633084 17.9   11.49   10.05
node   9633085 17.9   10.36   11.55
node   9633086 17.9   10.36   11.74
#node   9633087 17.9   12.09   10.05
#node   9633088 17.9   11.36   11.05
node   9633089 17.9   11.49   10.55
node   9633090 17.9   10.86   11.55
#node   9633091 17.9   10.86   11.74
#node   9633092 17.9   12.09   10.55
node   9633093 17.9   11.49   11.05
#node   9633094 17.9   11.36   11.55
#node   9633095 17.9   11.36   11.74
#node   9633096 17.9   12.09   11.05
node   9633097 17.9   11.49   11.55

#4th Storey
#-------------------------------------

#X041
#node   9041001 0   11.48   4.54
node   9041002 0   11.98   4.54
#node   9041003 0   11.48   4
node   9041004 0   11.98   4
node   9041005 0   12.48   4.54
#node   9041006 0   11.48   3.5
node   9041007 0   12.48   4
node   9041008 0   11.98   3.5
node   9041009 0   12.48   3.5
node   9041010 0   12.98   4.54
#node   9041011 0   11.48   3
node   9041012 0   12.98   4
node   9041013 0   11.98   3
node   9041014 0   12.98   3.5
node   9041015 0   12.48   3
node   9041016 0   13.48   4.54
#node   9041017 0   11.48   2.5
node   9041018 0   13.48   4
node   9041019 0   11.98   2.5
node   9041020 0   12.98   3
node   9041021 0   13.48   3.5
node   9041022 0   12.48   2.5
node   9041023 0   13.98   4.54
node   9041024 0   13.48   3
node   9041025 0   12.98   2.5
#node   9041026 0   11.48   2
node   9041027 0   13.98   4
node   9041028 0   11.98   2
node   9041029 0   13.98   3.5
node   9041030 0   12.48   2
node   9041031 0   13.48   2.5
node   9041032 0   13.98   3
node   9041033 0   12.98   2
#node   9041034 0   14.48   4.54
#node   9041035 0   11.48   1.5
node   9041036 0   14.48   4
node   9041037 0   11.98   1.5
node   9041038 0   14.48   3.5
node   9041039 0   12.48   1.5
node   9041040 0   13.98   2.5
node   9041041 0   13.48   2
node   9041042 0   14.48   3
node   9041043 0   12.98   1.5
#node   9041044 0   14.62   4.54
#node   9041045 0   11.48   1
#node   9041046 0   14.62   4
node   9041047 0   13.98   2
node   9041048 0   11.98   1
node   9041049 0   14.48   2.5
node   9041050 0   13.48   1.5
#node   9041051 0   14.62   3.5
node   9041052 0   12.48   1
#node   9041053 0   14.62   3
node   9041054 0   12.98   1
node   9041055 0   14.48   2
node   9041056 0   13.98   1.5
#node   9041057 0   15.48   4.54
#node   9041058 0   15.48   4
#node   9041059 0   11.48   0.5
#node   9041060 0   14.62   2.5
node   9041061 0   13.48   1
node   9041062 0   11.98   0.5
#node   9041063 0   15.48   3.5
node   9041064 0   12.48   0.5
#node   9041065 0   15.71   4.54
#node   9041066 0   15.71   4
node   9041067 0   14.48   1.5
#node   9041068 0   15.48   3
node   9041069 0   12.98   0.5
#node   9041070 0   14.62   2
node   9041071 0   13.98   1
#node   9041072 0   15.71   3.5
#node   9041073 0   15.48   2.5
#node   9041074 0   15.71   3
node   9041075 0   13.48   0.5
#node   9041076 0   11.48   0
node   9041077 0   11.98   0
#node   9041078 0   14.62   1.5
node   9041079 0   14.48   1
node   9041080 0   12.48   0
#node   9041081 0   15.71   2.5
#node   9041082 0   15.48   2
node   9041083 0   13.98   0.5
node   9041084 0   12.98   0
#node   9041085 0   15.71   2
node   9041086 0   13.48   0
#node   9041087 0   14.62   1
#node   9041088 0   15.48   1.5
node   9041089 0   14.48   0.5

#X042
#node   9042001 0   11.48   7.55
node   9042002 0   11.98   7.55
#node   9042003 0   11.48   7.04
node   9042004 0   11.98   7.04
node   9042005 0   12.48   7.55
#node   9042006 0   11.48   6.54
node   9042007 0   12.48   7.04
node   9042008 0   11.98   6.54
node   9042009 0   12.48   6.54
node   9042010 0   12.98   7.55
#node   9042011 0   11.48   6.04
node   9042012 0   12.98   7.04
node   9042013 0   11.98   6.04
node   9042014 0   12.98   6.54
node   9042015 0   12.48   6.04
node   9042016 0   13.48   7.55
#node   9042017 0   11.48   5.54
node   9042018 0   13.48   7.04
node   9042019 0   11.98   5.54
node   9042020 0   12.98   6.04
node   9042021 0   13.48   6.54
node   9042022 0   12.48   5.54
node   9042023 0   13.98   7.55
node   9042024 0   13.48   6.04
node   9042025 0   12.98   5.54
#node   9042026 0   11.48   5.04
node   9042027 0   13.98   7.04
node   9042028 0   11.98   5.04
node   9042029 0   13.98   6.54
node   9042030 0   12.48   5.04
node   9042031 0   13.48   5.54
node   9042032 0   13.98   6.04
node   9042033 0   12.98   5.04
#node   9042034 0   14.48   7.55
#node   9042035 0   11.48   4.54
node   9042036 0   14.48   7.04
#node   9042037 0   11.98   4.54
node   9042038 0   14.48   6.54
#node   9042039 0   12.48   4.54
node   9042040 0   13.98   5.54
node   9042041 0   13.48   5.04
node   9042042 0   14.48   6.04
#node   9042043 0   12.98   4.54
#node   9042044 0   14.62   7.55
#node   9042045 0   14.62   7.04
node   9042046 0   13.98   5.04
node   9042047 0   14.48   5.54
#node   9042048 0   13.48   4.54
#node   9042049 0   14.62   6.54
#node   9042050 0   14.62   6.04
node   9042051 0   14.48   5.04

#X043 (9034XXX)
#node   9043001 0   11.48   7.55
#node   9043002 0   11.98   7.55
#node   9043003 0   11.48   8.05
node   9043004 0   11.98   8.05
#node   9043005 0   12.48   7.55
#node   9043006 0   11.48   8.55
node   9043007 0   12.48   8.05
node   9043008 0   11.98   8.55
node   9043009 0   12.48   8.55
#node   9043010 0   12.98   7.55
#node   9043011 0   11.48   9.05
node   9043012 0   12.98   8.05
node   9043013 0   11.98   9.05
node   9043014 0   12.98   8.55
node   9043015 0   12.48   9.05
#node   9043016 0   13.48   7.55
node   9043018 0   13.48   8.05
node   9043019 0   11.98   9.55
node   9043020 0   12.98   9.05
node   9043021 0   12.48   9.55
node   9043022 0   13.48   8.55
node   9043024 0   12.98   9.55
```

```
node 9043026 0 13.48 9.05
node 9043027 0 13.98 8.05
node 9043028 0 11.98 10.05
node 9043029 0 13.98 8.55
node 9043030 0 12.48 10.05
node 9043031 0 13.48 9.55
node 9043032 0 13.98 9.05
node 9043033 0 12.98 10.05
node 9043036 0 14.48 8.05
node 9043037 0 11.98 10.55
node 9043038 0 14.48 8.55
node 9043039 0 12.48 10.55
node 9043040 0 13.98 9.55
node 9043041 0 13.48 10.05
node 9043042 0 14.48 9.05
node 9043043 0 12.98 10.55
node 9043047 0 13.98 10.05
node 9043048 0 11.98 11.05
node 9043049 0 14.48 9.55
node 9043050 0 13.48 10.55
node 9043052 0 12.48 11.05
node 9043054 0 12.98 11.05
node 9043055 0 14.48 10.05
node 9043056 0 13.98 10.55
node 9043061 0 13.48 11.05
node 9043062 0 11.98 11.55
node 9043064 0 12.48 11.55
node 9043066 0 11.98 11.74
node 9043068 0 14.48 10.55
node 9043071 0 12.98 11.55
node 9043073 0 13.98 11.05
node 9043074 0 12.48 11.74
node 9043076 0 12.98 11.74
node 9043078 0 13.48 11.55
node 9043080 0 14.48 11.05
node 9043082 0 13.48 11.74
node 9043085 0 13.98 11.55
node 9043090 0 14.48 11.55

#X641
node 9641004 17.9 11.98 4
node 9641007 17.9 12.48 4
node 9641008 17.9 11.98 3.5
node 9641009 17.9 12.48 3.5
node 9641012 17.9 12.98 4
node 9641013 17.9 11.98 3
node 9641014 17.9 12.98 3.5
node 9641015 17.9 12.48 3
node 9641018 17.9 13.48 4
node 9641019 17.9 11.98 2.5
node 9641020 17.9 12.98 3
node 9641021 17.9 13.48 3.5
node 9641022 17.9 12.48 2.5
node 9641024 17.9 13.48 3
node 9641025 17.9 12.98 2.5
node 9641027 17.9 13.98 4
node 9641028 17.9 11.98 2
node 9641029 17.9 13.98 3.5
node 9641030 17.9 12.48 2
node 9641031 17.9 13.48 2.5
node 9641032 17.9 13.98 3
node 9641033 17.9 12.98 2
node 9641036 17.9 14.48 4
node 9641037 17.9 11.98 1.5
node 9641038 17.9 14.48 3.5
node 9641039 17.9 12.48 1.5
node 9641040 17.9 13.98 2.5
node 9641041 17.9 13.48 2
node 9641042 17.9 14.48 3
node 9641043 17.9 12.98 1.5
node 9641047 17.9 13.98 2
node 9641048 17.9 11.98 1
node 9641049 17.9 14.48 2.5
node 9641050 17.9 13.48 1.5
node 9641052 17.9 12.48 1
node 9641054 17.9 12.98 1
node 9641055 17.9 14.48 2
node 9641056 17.9 13.98 1.5
node 9641061 17.9 13.48 1
node 9641062 17.9 11.98 0.5
node 9641064 17.9 12.48 0.5
node 9641067 17.9 14.48 1.5
node 9641069 17.9 12.98 0.5
node 9641071 17.9 13.98 1
node 9641075 17.9 13.48 0.5
node 9641077 17.9 11.98 0
node 9641079 17.9 14.48 1
node 9641080 17.9 12.48 0
node 9641083 17.9 13.98 0.5
node 9641084 17.9 12.98 0
node 9641086 17.9 13.48 0
node 9641089 17.9 14.48 0.5

#X642
```

```
node 9642004 17.9 11.98 7.04
node 9642007 17.9 12.48 7.04
node 9642008 17.9 11.98 6.54
node 9642009 17.9 12.48 6.54
node 9642012 17.9 12.98 7.04
node 9642013 17.9 11.98 6.04
node 9642014 17.9 12.98 6.54
node 9642015 17.9 12.48 6.04
node 9642018 17.9 13.48 7.04
node 9642019 17.9 11.98 5.54
node 9642020 17.9 12.98 6.04
node 9642021 17.9 13.48 6.54
node 9642022 17.9 12.48 5.54
node 9642024 17.9 13.48 6.04
node 9642025 17.9 12.98 5.54
node 9642027 17.9 13.98 7.04
node 9642028 17.9 11.98 5.04
node 9642029 17.9 13.98 6.54
node 9642030 17.9 12.48 5.04
node 9642031 17.9 13.48 5.54
node 9642032 17.9 13.98 6.04
node 9642033 17.9 12.98 5.04
node 9642036 17.9 14.48 7.04
node 9642037 17.9 11.98 4.54
node 9642038 17.9 14.48 6.54
node 9642039 17.9 12.48 4.54
node 9642040 17.9 13.98 5.54
node 9642041 17.9 13.48 5.04
node 9642042 17.9 14.48 6.04
node 9642043 17.9 12.98 4.54
node 9642046 17.9 13.98 5.04
node 9642047 17.9 14.48 5.54
node 9642048 17.9 13.48 4.54
node 9642051 17.9 14.48 5.04
node 9642052 17.9 13.98 4.54

#X643
node 9643002 17.9 11.98 7.55
node 9643004 17.9 11.98 8.05
node 9643005 17.9 12.48 7.55
node 9643007 17.9 12.48 8.05
node 9643008 17.9 11.98 8.55
node 9643009 17.9 12.48 8.55
node 9643010 17.9 12.98 7.55
node 9643012 17.9 12.98 8.05
node 9643013 17.9 11.98 9.05
node 9643014 17.9 12.98 8.55
node 9643015 17.9 12.48 9.05
node 9643016 17.9 13.48 7.55
node 9643018 17.9 13.48 8.05
node 9643019 17.9 11.98 9.55
node 9643020 17.9 12.98 9.05
node 9643021 17.9 12.48 9.55
node 9643022 17.9 13.48 8.55
node 9643023 17.9 13.98 7.55
node 9643024 17.9 12.98 9.55
node 9643026 17.9 13.48 9.05
node 9643027 17.9 13.98 8.05
node 9643028 17.9 11.98 10.05
node 9643029 17.9 13.98 8.55
node 9643030 17.9 12.48 10.05
node 9643031 17.9 13.48 9.55
node 9643032 17.9 13.98 9.05
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node 9643036 17.9 14.48 8.05
node 9643037 17.9 11.98 10.55
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node 9643039 17.9 12.48 10.55
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node 9643041 17.9 13.48 10.05
node 9643042 17.9 14.48 9.05
node 9643043 17.9 12.98 10.55
node 9643047 17.9 13.98 10.05
node 9643048 17.9 11.98 11.05
node 9643049 17.9 14.48 9.55
node 9643050 17.9 13.48 10.55
node 9643052 17.9 12.48 11.05
node 9643054 17.9 12.98 11.05
node 9643055 17.9 14.48 10.05
node 9643056 17.9 13.98 10.55
node 9643061 17.9 13.48 11.05
node 9643062 17.9 11.98 11.55
node 9643064 17.9 12.48 11.55
node 9643066 17.9 11.98 11.74
node 9643068 17.9 14.48 10.55
node 9643071 17.9 12.98 11.55
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node 9643078 17.9 13.48 11.55
node 9643080 17.9 14.48 11.05
node 9643082 17.9 13.48 11.74
node 9643085 17.9 13.98 11.55
node 9643090 17.9 14.48 11.55
```

```
########################################
#Shell Element
########################################
#---------------------------
#node 999X; X:Numero Elemento
#Ejemplo: element ShellMITC4 1000 133 11 230 229 1

#1st Floor
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#X602
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#1st Floor
#Lateral (X0)
#X021


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#3rd Storey
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9042004 9032054 9032056 1
element ShellMITC4 904249 9041002
9042028 9042030 9041005 1

#X043
element ShellMITC4 984307 9043085 529
522 9043090 1
element ShellMITC4 984318 9043073
9043085 9043090 9043080 1
element ShellMITC4 984319 9043056
9043073 9043080 9043068 1
element ShellMITC4 984346 9043047
9043056 9043068 9043055 1
element ShellMITC4 984345 9043040
9043047 9043055 9043049 1
element ShellMITC4 984344 9043040
9043049 9043042 9043032 1
element ShellMITC4 984343 9043032
9043042 9043038 9043029 1
element ShellMITC4 984342 9043036
9043027 9043029 9043038 1
element ShellMITC4 984341 9043027
9043036 515 9042023 1

element ShellMITC4 904308 529 9043085
9043078 9043082 1
element ShellMITC4 904317 9043061
9043078 9043085 9043073 1
element ShellMITC4 904347 9043050
9043061 9043073 9043056 1
element ShellMITC4 904348 9043041
9043050 9043056 9043047 1
element ShellMITC4 904349 9043031
9043041 9043047 9043040 1
element ShellMITC4 904350 9043026
9043031 9043040 9043032 1
element ShellMITC4 904351 9043026
9043032 9043029 9043022 1
element ShellMITC4 904352 9043027
9043018 9043022 9043029 1
element ShellMITC4 904353 9043018
9043027 9042023 9042016 1

element ShellMITC4 904309 9043076
9043082 9043078 9043071 1
element ShellMITC4 904316 9043071
9043078 9043061 9043054 1
element ShellMITC4 904354 9043043
9043054 9043061 9043050 1
element ShellMITC4 904355 9043033
9043043 9043050 9043041 1
element ShellMITC4 904356 9043024
9043033 9043041 9043031 1
element ShellMITC4 904357 9043020
9043024 9043031 9043026 1
element ShellMITC4 904358 9043014
9043020 9043026 9043022 1
element ShellMITC4 904359 9043018
9043012 9043014 9043022 1
element ShellMITC4 904360 9043012
9043018 9042016 9042010 1

element ShellMITC4 904310 9043064
9043074 9043076 9043071 1
element ShellMITC4 904315 9043052
9043064 9043071 9043054 1
element ShellMITC4 904361 9043039
9043052 9043054 9043043 1
element ShellMITC4 904362 9043030
9043039 9043043 9043033 1
element ShellMITC4 904363 9043021
9043030 9043033 9043024 1
element ShellMITC4 904364 9043015
9043021 9043024 9043020 1
element ShellMITC4 904365 9043009
9043015 9043020 9043014 1
element ShellMITC4 904366 9043007
9043009 9043014 9043012 1
element ShellMITC4 904367 9042005
9043007 9043012 9042010 1

element ShellMITC4 904311 9043062
9043066 9043074 9043064 1
element ShellMITC4 904314 9043052
9043048 9043062 9043064 1
element ShellMITC4 904370 9043037
9043048 9043052 9043039 1
element ShellMITC4 904372 9043028
9043037 9043039 9043030 1
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9043028 9043030 9043021 1
element ShellMITC4 904376 9043013
9043019 9043021 9043015 1
element ShellMITC4 904378 9043013
9043015 9043009 9043008 1
element ShellMITC4 904369 9043008
9043009 9043007 9043004 1
element ShellMITC4 904368 9043004
9043007 9042005 9042002 1

element ShellMITC4 904313 9033093
9033097 9043062 9043048 1
element ShellMITC4 904371 9043037
9033089 9033093 9043048 1
element ShellMITC4 904373 9033084
9033089 9043037 9043028 1
element ShellMITC4 904375 9043019
9033077 9033084 9043028 1
element ShellMITC4 904377 9033070
9033077 9043019 9043013 1
element ShellMITC4 904381 9033063
9033070 9043013 9043008 1
element ShellMITC4 904380 9043004
9033059 9033063 9043008 1
element ShellMITC4 904379 415 9033059
9043004 9042002 1

#X641
element ShellMITC4 964160 9641027
9642052 514 9641036 1
element ShellMITC4 964161 9641029
9641027 9641036 9641038 1
element ShellMITC4 964162 9641032
9641029 9641038 9641042 1
element ShellMITC4 964163 9641040
9641032 9641042 9641049 1
element ShellMITC4 964150 9641040
9641049 9641055 9641047 1
element ShellMITC4 964149 9641047
9641055 9641067 9641056 1
element ShellMITC4 964148 9641056
9641067 9641079 9641071 1
element ShellMITC4 964147 9641071
9641079 9641089 9641083 1
element ShellMITC4 964146 9641083
9641089 57 5263 1

element ShellMITC4 964137 9641018
9642048 9642052 9641027 1
element ShellMITC4 964138 9641021
9641018 9641027 9641029 1
element ShellMITC4 964139 9641024
9641021 9641029 9641032 1
element ShellMITC4 964140 9641031
9641024 9641032 9641040 1
element ShellMITC4 964141 9641041
9641031 9641040 9641047 1
element ShellMITC4 964142 9641041
9641047 9641056 9641050 1
element ShellMITC4 964143 9641050
9641056 9641071 9641061 1
element ShellMITC4 964144 9641061
9641071 9641083 9641075 1
element ShellMITC4 964145 9641075
9641083 5263 9641086 1

```
element ShellMITC4  964136  9641012
9642043 9642048 9641018 1
element ShellMITC4  964135  9641014
9641012 9641018 9641021 1
element ShellMITC4  964134  9641020
9641014 9641021 9641024 1
element ShellMITC4  964133  9641025
9641020 9641024 9641031 1
element ShellMITC4  964132  9641033
9641025 9641031 9641041 1
element ShellMITC4  964131  9641043
9641033 9641041 9641050 1
element ShellMITC4  964130  9641043
9641050 9641061 9641054 1
element ShellMITC4  964128  9641054
9641061 9641075 9641069 1
element ShellMITC4  964129  9641069
9641075 9641086 9641084 1

element ShellMITC4  964120  9641007
9642039 9642043 9641012 1
element ShellMITC4  964121  9641009
9641007 9641012 9641014 1
element ShellMITC4  964122  9641015
9641009 9641014 9641020 1
element ShellMITC4  964123  9641022
9641015 9641020 9641025 1
element ShellMITC4  964124  9641030
9641022 9641025 9641033 1
element ShellMITC4  964125  9641039
9641030 9641033 9641043 1
element ShellMITC4  964126  9641052
9641039 9641043 9641054 1
element ShellMITC4  964127  9641052
9641054 9641069 9641064 1
element ShellMITC4  964115  9641064
9641069 9641084 9641080 1

element ShellMITC4  964104  9642039
9641007 9641004 9642037 1
element ShellMITC4  964105  9641008
9641004 9641007 9641009 1
element ShellMITC4  964106 9641009
9641015 9641013 9641008 1
element ShellMITC4  964107 9641015
9641022 9641019 9641013 1
element ShellMITC4  964119 9641022
9641030 9641028 9641019 1
element ShellMITC4  964118  9641037
9641028 9641030 9641039 1
element ShellMITC4  964117  9641048
9641037 9641039 9641052 1
element ShellMITC4  964116  9641062
9641048 9641052 9641064 1
element ShellMITC4  964114  9641062
9641064 9641080 9641077 1

element ShellMITC4  964182  9643002
9642004 9632054 421 1
element ShellMITC4  964102  9631063
9631058 9641004 9641008 1
element ShellMITC4  964103  9631068
9631063 9641008 9641013 1
element ShellMITC4  964108  9631073
9631068 9641013 9641019 1
element ShellMITC4  964109  9631082
9631073 9641019 9641028 1
element ShellMITC4  964110  9631088
9631082 9641028 9641037 1
element ShellMITC4  964111  9631092
9631088 9641037 9641048 1
element ShellMITC4  964112  9631096
9631092 9641048 9641062 1
element ShellMITC4  964113  9642028
9642037 414 9632067 1

#X642
element ShellMITC4  964213  9643023 521
9642036 9642027 1
element ShellMITC4  964212  9642027
9642036 9642038 9642029 1
element ShellMITC4  964211  9642042
9642032 9642029 9642038 1
element ShellMITC4  964209  9642040
9642032 9642042 9642047 1
element ShellMITC4  964210  9642051
9642046 9642040 9642047 1
element ShellMITC4  964221  9642052
9642046 9642051 514 1

element ShellMITC4  964237  9642018
9643016 9643023 9642027 1
element ShellMITC4  964236  9642021
9642018 9642027 9642029 1
element ShellMITC4  964235  9642032
9642024 9642021 9642029 1
element ShellMITC4  964255  9642031
9642024 9642032 9642040 1
element ShellMITC4  964222  9642046
9642041 9642031 9642040 1
element ShellMITC4  964223  9642041
9642046 9642052 9642048 1

element ShellMITC4  964238  9642012
9643010 9643016 9642018 1
element ShellMITC4  964239  9642014
9642012 9642018 9642021 1
element ShellMITC4  964240  9642014
9642021 9642024 9642020 1
element ShellMITC4  964207  9642020
9642024 9642031 9642025 1
element ShellMITC4  964224  9642025
9642031 9642041 9642033 1
element ShellMITC4  964225  9642033
9642041 9642048 9642043 1

element ShellMITC4  964243  9642007
9643005 9643010 9642012 1
element ShellMITC4  964242  9642009
9642007 9642012 9642014 1
element ShellMITC4  964241  9642015
9642009 9642014 9642020 1
element ShellMITC4  964208  9642015
9642020 9642025 9642022 1
element ShellMITC4  964227  9642022
9642025 9642033 9642030 1
element ShellMITC4  964226  9642030
9642033 9642043 9642039 1

element ShellMITC4  964244  9642004
9643002 9643005 9642007 1
element ShellMITC4  964245  9642008
9642004 9642007 9642009 1
element ShellMITC4  964246  9642013
9642008 9642009 9642015 1
element ShellMITC4  964247  9642019
9642013 9642015 9642022 1
element ShellMITC4  964228  9642019
9642022 9642030 9642028 1
element ShellMITC4  964248  9642028
9642030 9642039 9642037 1

element ShellMITC4  964254  414 9642037
9641004 9631058 1
element ShellMITC4  964253  9632056
9632054 9642004 9642008 1
element ShellMITC4  964252  9632060
9632056 9642008 9642013 1
element ShellMITC4  964251  9632063
9632060 9642013 9642019 1
element ShellMITC4  964250  9632067
9632063 9642019 9642028 1
element ShellMITC4  964249  9641077
9641062 9631096 47  1

#X643
element ShellMITC4  964307  9643085
5240    528 9643090 1
element ShellMITC4  964318  9643073
9643085 9643090 9643080 1
element ShellMITC4  964319  9643056
9643073 9643080 9643068 1
element ShellMITC4  964346  9643047
9643056 9643068 9643055 1
element ShellMITC4  964345  9643040
9643047 9643055 9643049 1
element ShellMITC4  964344  9643040
9643049 9643042 9643032 1
element ShellMITC4  964343  9643032
9643042 9643038 9643029 1
element ShellMITC4  964342  9643036
9643027 9643029 9643038 1
element ShellMITC4  964341  9643027
9643036 521 9643023 1

element ShellMITC4  964308  5240
9643085 9643078 9643082 1
element ShellMITC4  964317  9643061
9643078 9643085 9643073 1
element ShellMITC4  964347  9643050
9643061 9643073 9643056 1
element ShellMITC4  964348  9643041
9643050 9643056 9643047 1
element ShellMITC4  964349  9643031
9643041 9643047 9643040 1
element ShellMITC4  964350  9643026
9643031 9643040 9643032 1
element ShellMITC4  964351  9643026
9643032 9643029 9643022 1
element ShellMITC4  964352  9643027
9643018 9643022 9643029 1
element ShellMITC4  964353  9643018
9643027 9643023 9643016 1

element ShellMITC4  964309  9643076
9643082 9643078 9643071 1
element ShellMITC4  964316  9643071
9643078 9643061 9643054 1
element ShellMITC4  964354  9643043
9643054 9643061 9643050 1
element ShellMITC4  964355  9643033
9643043 9643050 9643041 1
element ShellMITC4  964356  9643024
9643033 9643041 9643031 1
element ShellMITC4  964357  9643020
9643024 9643031 9643026 1
element ShellMITC4  964358  9643014
9643020 9643026 9643022 1
element ShellMITC4  964359  9643018
9643012 9643014 9643022 1
element ShellMITC4  964360  9643012
9643018 9643016 9643010 1

element ShellMITC4  964310  9643064
9643074 9643076 9643071 1
element ShellMITC4  964315  9643052
9643064 9643071 9643054 1
element ShellMITC4  964361  9643039
9643052 9643054 9643043 1
element ShellMITC4  964362  9643030
9643039 9643043 9643033 1
element ShellMITC4  964363  9643021
9643030 9643033 9643024 1
element ShellMITC4  964364  9643015
9643021 9643024 9643020 1
element ShellMITC4  964365  9643009
9643015 9643020 9643014 1
element ShellMITC4  964366  9643007
9643009 9643014 9643012 1
element ShellMITC4  964367  9643005
9643007 9643012 9643010 1

element ShellMITC4  964311  9643062
9643066 9643074 9643064 1
element ShellMITC4  964314  9643052
9643048 9643062 9643064 1
element ShellMITC4  964370  9643037
9643048 9643052 9643039 1
element ShellMITC4  964372  9643028
9643037 9643039 9643030 1
element ShellMITC4  964374  9643019
9643028 9643030 9643021 1
element ShellMITC4  964376  9643013
9643019 9643021 9643015 1
element ShellMITC4  964378  9643013
9643015 9643009 9643008 1
element ShellMITC4  964369  9643008
9643009 9643007 9643004 1
element ShellMITC4  964368  9643004
9643007 9643005 9643002 1

element ShellMITC4  964312  9043066
9043062 9033097 422 1
element ShellMITC4  964313  9633093
9633097 9643062 9643048 1
element ShellMITC4  964371  9643037
9633089 9633093 9643048 1
element ShellMITC4  964373  9633084
9633089 9643037 9643028 1
element ShellMITC4  964375  9643019
9633077 9633084 9643028 1
element ShellMITC4  964377  9633070
9633077 9643019 9643013 1
element ShellMITC4  964381  9633063
9633070 9643013 9643008 1
element ShellMITC4  964380  9643004
9633059 9633063 9643008 1
element ShellMITC4  964379  9033066
9033062 9623097 322 1

############
#Back Shell

#1er Piso
element ShellMITC4  22560049 9101077
2256162 133 11 1
element ShellMITC4  2256004 2256163
9101080 9101077 2256162 1
element ShellMITC4  2256006 2256164
9101084 9101080 2256163 1
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element ShellMITC4 2256008 2256166 9101086 9101084 2256164 1
element ShellMITC4 2256010 2256168 9101090 9101086 2256166 1
element ShellMITC4 2256012 2256171 9101094 9101090 2256168 1
element ShellMITC4 2256014 9101094 230 229 2256171 1

element ShellMITC4 2256423 17 140 2256008 9601077 1
element ShellMITC4 2256003 9601077 9601080 2256009 2256008 1
element ShellMITC4 2256005 9601080 9601084 2256010 2256009 1
element ShellMITC4 2256007 9601084 9601086 2256012 2256010 1
element ShellMITC4 2256009 9601086 9601090 2256014 2256012 1
element ShellMITC4 2256011 9601090 9601094 2256015 2256014 1
element ShellMITC4 2256013 9601094 245 244 2256015 1

#2do Piso
element ShellMITC4 225601899 2256180 9021077 21 248 1
element ShellMITC4 2256020 2256180 2256184 9021080 9021077 1
element ShellMITC4 2256022 2256184 2256186 9021084 9021080 1
element ShellMITC4 2256024 2256186 2256189 9021086 9021084 1
element ShellMITC4 2256026 2256189 2256192 9021090 9021086 1
element ShellMITC4 2256017 27 9621077 2256024 247 1
element ShellMITC4 2256019 9621077 9621080 2256028 2256024 1
element ShellMITC4 2256021 2256028 2256030 9621084 9621080 1
element ShellMITC4 2256023 9621084 9621086 2256031 2256030 1
element ShellMITC4 2256025 9621086 9621090 2256035 2256031 1
element ShellMITC4 2256027 9621090 3263 3262 2256035 1
element ShellMITC4 2256029 3241 3242 9021090 2256192 1
element ShellMITC4 2256146 4242 2256228 9031090 4241 1

#3er Piso
element ShellMITC4 2256031 31 3243 2256206 9031077 1
element ShellMITC4 2256033 2256206 2256210 9031080 9031077 1
element ShellMITC4 2256035 2256210 2256216 9031084 9031080 1
element ShellMITC4 2256037 2256216 2256221 9031086 9031084 1
element ShellMITC4 2256039 2256221 2256228 9031090 9031086 1
element ShellMITC4 2256041 5242 5241 9041086 2256249 1
element ShellMITC4 2256081 2256239 9041077 41 4243 1

#4to Piso
element ShellMITC4 2256047 2256239 2256241 9041080 9041077 1
element ShellMITC4 2256049 2256241 2256245 9041084 9041080 1
element ShellMITC4 2256051 2256245 2256249 9041086 9041084 1

element ShellMITC4 2256046 47 9641077 2256097 4261 1
element ShellMITC4 2256048 9641077 9641080 2256104 2256097 1
element ShellMITC4 2256050 9641080 9641084 2256116 2256104 1
element ShellMITC4 2256052 9641084 9641086 2256125 2256116 1
element ShellMITC4 2256054 5262 5263 9641086 2256125 1

############################
#Front Shell

#1st Storey
element ShellMITC4 2257003 2257110 2257112 9103066 9103074 1
element ShellMITC4 2257005 2257110 2257108 9103076 9103074 1
element ShellMITC4 2257007 2257108 2257106 9103082 9103076 1
element ShellMITC4 2257009 2257106 2257104 9103086 9103082 1
element ShellMITC4 2257011 2257104 2257102 9103091 9103086 1

element ShellMITC4 2257002 128 153 2257056 9603066 1
element ShellMITC4 2257004 9603066 9603074 2257054 2257056 1
element ShellMITC4 2257006 9603074 9603076 2257052 2257054 1
element ShellMITC4 2257008 9603076 9603082 2257050 2257052 1
element ShellMITC4 2257010 2257050 2257048 9603086 9603082 1
element ShellMITC4 2257012 9603086 9603091 2257046 2257048 1
element ShellMITC4 2257014 9603091 284 282 2257046 1

#2nd Storey
element ShellMITC4 2257020 9623066 9623074 2257093 2257095 1
element ShellMITC4 2257022 9623074 2257093 2257091 9623076 1
element ShellMITC4 2257024 9623076 2257091 2257089 9623082 1
element ShellMITC4 9623086 9623086 2257087 2257089 9623082 1

element ShellMITC4 2257017 283 228 9823066 2257040 1
element ShellMITC4 2257019 2257040 9823066 9823074 2257038 1
element ShellMITC4 2257021 2257038 9823074 9823076 2257036 1
element ShellMITC4 2257023 2257036 9823076 9823082 2257034 1
element ShellMITC4 2257025 2257034 9823082 9823086 2257032 1
element ShellMITC4 2257027 2257032 3239 3240 9823086 1

#3rd Storey
element ShellMITC4 2257032 9033074 9033066 2257079 2257077 1
element ShellMITC4 2257036 9033074 2257077 2257074 9033076 1
element ShellMITC4 2257038 9033076 2257074 2257071 9033082 1
element ShellMITC4 2257040 9033082 2257071 2257067 9033086 1

element ShellMITC4 2257031 3238 328 9633066 2257026 1
element ShellMITC4 2257033 2257026 9633066 9633074 2257024 1
element ShellMITC4 2257035 2257024 9633074 9633076 2257022 1
element ShellMITC4 2257037 2257022 9633076 9633082 2257020 1
element ShellMITC4 2257039 2257020 9633082 9633086 2257018 1
element ShellMITC4 2257041 2257018 4239 4240 9633086 1

#4th Storey
element ShellMITC4 2257045 9043066 2257064 2257063 9043074 1
element ShellMITC4 2257044 2257063 2257062 9043076 9043074 1
element ShellMITC4 2257043 9043076 2257062 2257061 9043082 1

element ShellMITC4 2257049 9643066 428 4238 2257012 1
element ShellMITC4 2257048 9643066 9643074 2257010 2257012 1
element ShellMITC4 2257047 2257010 9643074 9643076 2257008 1
element ShellMITC4 2257050 9643076 9643082 2257007 2257008 1
element ShellMITC4 2257051 2257007 9643082 5240 5239 1

#First Storey
#groundfloor
element ShellMITC4 813 130 132 904 902 1

#Back FACADE
element ShellMITC4 815 134 12 231 232 1
element ShellMITC4 816 229 230 21 248 1
element ShellMITC4 817 136 135 233 234 1
element ShellMITC4 818 232 231 22 141 1
element ShellMITC4 819 234 236 249 233 1
element ShellMITC4 820 237 234 236 24 1
element ShellMITC4 821 238 237 24 239 1
element ShellMITC4 822 138 137 238 241 1
element ShellMITC4 823 250 241 238 239 1
element ShellMITC4 824 16 139 242 243 1
element ShellMITC4 825 243 242 246 26 1
element ShellMITC4 827 245 244 247 27 1
element ShellMITC4 828 232 141 23 235 1
element ShellMITC4 829 240 25 246 242 1
element ShellMITC4 830 244 243 26 247 1
element ShellMITC4 831 231 229 248 22 1
element ShellMITC4 832 25 240 241 250 1
element ShellMITC4 833 233 235 23 249 1

#Front Facade
element ShellMITC4 835 251 252 253 222 1
element ShellMITC4 836 254 255 223 256 1
element ShellMITC4 837 143 123 255 254 1
element ShellMITC4 838 252 254 256 253 1
element ShellMITC4 839 223 258 257 255 1
element ShellMITC4 840 255 257 144 123 1
element ShellMITC4 841 145 124 260 259 1
element ShellMITC4 842 259 260 224 262 1
element ShellMITC4 843 259 262 258 257 1
element ShellMITC4 844 124 146 263 260 1
element ShellMITC4 845 260 263 264 224 1
element ShellMITC4 846 147 125 267 265 1
element ShellMITC4 847 265 267 225 266 1
element ShellMITC4 848 265 266 264 263 1
element ShellMITC4 849 125 148 270 267 1
element ShellMITC4 850 267 270 269 225 1
element ShellMITC4 851 149 126 272 271 1
element ShellMITC4 852 271 272 226 273 1
element ShellMITC4 853 271 273 269 270 1
element ShellMITC4 854 126 150 274 272 1
element ShellMITC4 855 272 274 275 226 1
element ShellMITC4 856 151 127 279 277 1
element ShellMITC4 857 277 279 227 278 1
element ShellMITC4 858 277 278 275 274 1
element ShellMITC4 859 127 152 280 279 1
element ShellMITC4 860 279 280 281 227 1
element ShellMITC4 862 282 284 228 283 1
element ShellMITC4 863 282 283 281 280 1

#2nd Storey
#Front Facade
element ShellMITC4 871 329 3210 3211 322 1
element ShellMITC4 872 3210 3211 3213 3212 1
element ShellMITC4 873 3213 323 3214 3212 1
element ShellMITC4 874 256 223 3214 3212 1
element ShellMITC4 875 3214 3215 258 223 1
element ShellMITC4 876 3214 3215 3216 323 1
element ShellMITC4 877 3215 3217 3218 3216 1
element ShellMITC4 878 3217 3219 324 3218 1
element ShellMITC4 879 262 224 3219 3217 1
element ShellMITC4 880 224 264 3220 3219 1
element ShellMITC4 881 3220 3221 324 3219 1
element ShellMITC4 882 3220 3222 3223 3221 1
element ShellMITC4 883 3222 3224 325 3223 1
element ShellMITC4 884 266 225 3224 3222 1
element ShellMITC4 885 3224 3227 3226 325 1
element ShellMITC4 886 225 269 3227 3224 1
element ShellMITC4 887 3227 3229 3228 3226 1
element ShellMITC4 888 3229 3230 326 3228 1
element ShellMITC4 889 273 226 3230 3229 1
element ShellMITC4 890 3230 3232 3231 326 1

```
element ShellMITC4 891 226 275 3232
3230 1
element ShellMITC4 892 3231 3232 3234
3233 1
element ShellMITC4 893 3233 327 3235
3234 1
element ShellMITC4 894 3234 3235 227
278 1
element ShellMITC4 895 327 3236 3237
3235 1
element ShellMITC4 896 227 281 3237
3235 1
element ShellMITC4 897 3237 3236 3238
3239 1
element ShellMITC4 898 3239 3240 328
3238 1

#2nd Storey (Back FACADE)
element ShellMITC4 8949 3243 3241 3242
31 1
element ShellMITC4 8950 3244 3241 3243
32 1
element ShellMITC4 8951 32 3244 3245
3246 1
element ShellMITC4 8952 3245 3244 22
141 1
element ShellMITC4 8953 33 3247 3245
3246 1
element ShellMITC4 8954 3248 33 3247
3249 1
element ShellMITC4 8955 3250 3248 3249
3251 1
element ShellMITC4 8956 3251 3249 249
236 1
element ShellMITC4 8957 34 3250 3251
3252 1
element ShellMITC4 8958 3253 34 3252
3254 1
element ShellMITC4 8959 3256 3254 3253
3255 1
element ShellMITC4 8960 3256 3254 239
250 1
element ShellMITC4 8961 3256 3255 35
3257 1
element ShellMITC4 8962 3258 35 3257
3259 1
element ShellMITC4 8963 3260 36 3258
3259 1
element ShellMITC4 8964 3260 3259 246
26 1
element ShellMITC4 8965 3262 3261 36
3260 1
element ShellMITC4 8966 37 3263 3262
3261 1

#3rd Storey
#Front Facade
element ShellMITC4 8917 429 4210 4211
422 1
element ShellMITC4 8918 4210 4211 4212
4213 1
element ShellMITC4 8919 4213 4214 423
4212 1
element ShellMITC4 8920 3213 323 4214
4213 1
element ShellMITC4 8921 423 4215 4216
4214 1
element ShellMITC4 8922 4214 4216 3216
323 1
element ShellMITC4 8923 4215 4217 4218
4216 1
element ShellMITC4 8924 4218 4219 424
4217 1
element ShellMITC4 8925 3218 4218 4219
324 1
element ShellMITC4 8926 424 4220 4221
4219 1
element ShellMITC4 8927 324 3221 4221
4219 1
element ShellMITC4 8928 4221 4220 4222
4223 1
element ShellMITC4 8930 4223 4224 425
4222 1
element ShellMITC4 8932 325 4224 4223
3223 1
element ShellMITC4 8933 4224 425 4226
4227 1
element ShellMITC4 8934 325 4224 4227
3226 1
element ShellMITC4 8935 4227 4229 4228
4226 1
element ShellMITC4 8936 4229 4230 426
4228 1
element ShellMITC4 8937 4229 4230 326
3228 1
element ShellMITC4 8938 4230 426 4231
4232 1
element ShellMITC4 8939 326 3231 4232
4230 1
element ShellMITC4 8940 4232 4231 4233
4234 1
element ShellMITC4 8941 4234 4235 427
4233 1
element ShellMITC4 8943 4235 427 4236
4237 1
element ShellMITC4 8944 327 3236 4237
4235 1
element ShellMITC4 8945 4237 4236 4238
4239 1
element ShellMITC4 8946 4239 4238 428
4240 1

#3rd Storey (Back FACADE)
element ShellMITC4 8969 4243 41 4241
4242 1
element ShellMITC4 8970 42 4244 4242
4243 1
element ShellMITC4 8971 42 4244 4245
4246 1
element ShellMITC4 8972 4245 4244 32
3246 1
element ShellMITC4 8973 43 4247 4245
4246 1
element ShellMITC4 8974 4248 43 4247
4249 1
element ShellMITC4 8975 4250 4248 4249
4251 1
element ShellMITC4 8976 3250 3248 4249
4251 1
element ShellMITC4 8977 44 4250 4251
4252 1
element ShellMITC4 8978 4253 44 4252
4254 1
element ShellMITC4 8979 4256 4254 4253
4255 1
element ShellMITC4 8980 4256 4254 3253
3255 1
element ShellMITC4 8981 4256 4255 45
4257 1
element ShellMITC4 8982 4258 45 4257
4259 1
element ShellMITC4 8983 4260 46 4258
4259 1
element ShellMITC4 8984 4260 4259 3258
36 1
element ShellMITC4 8985 4262 4261 46
4260 1
element ShellMITC4 8986 47 4263 4262
4261 1

#4th Storey (Front Facade)
element ShellMITC4 8994 522 5211 5210
529 1
element ShellMITC4 8996 5210 5213 5212
5211 1
element ShellMITC4 8997 5213 5214 523
5212 1
element ShellMITC4 8998 4212 423 5214
5213 1
element ShellMITC4 8999 523 5215 5216
5214 1
element ShellMITC4 89910 5214 5216 4215
423 1
element ShellMITC4 89911 5215 5217 5218
5216 1
element ShellMITC4 89912 5218 5219 524
5217 1
element ShellMITC4 89913 4217 5218 5219
424 1
element ShellMITC4 89914 524 5220 5221
5219 1
element ShellMITC4 89915 424 4220 5221
5219 1
element ShellMITC4 89916 5221 5220 5222
5223 1
element ShellMITC4 89917 5222 525 5224
5223 1
element ShellMITC4 89918 4222 425 5224
5223 1
element ShellMITC4 89919 425 4226 5227
5224 1
element ShellMITC4 89920 525 5225 5227
5224 1
element ShellMITC4 89921 5225 5227 5229
5228 1
element ShellMITC4 89922 5228 5229 5230
526 1
element ShellMITC4 89924 5229 5230 426
4228 1
element ShellMITC4 89925 526 5230 5232
5231 1
element ShellMITC4 89926 5230 426 4231
5232 1
element ShellMITC4 89927 5231 5232 5234
5233 1
element ShellMITC4 89928 5233 5234 5235
527 1
element ShellMITC4 89929 5234 5235 427
4233 1
element ShellMITC4 89930 4234 4235 327
3233 1
element ShellMITC4 89931 5235 527 5236
5237 1
element ShellMITC4 89933 427 4236 5237
5235 1
element ShellMITC4 89934 5236 5237 5239
5238 1
element ShellMITC4 89935 5238 5239 5240
528 1

#4th Storey (Back FACADE)
element ShellMITC4 89938 5242 5241 51
5243 1
element ShellMITC4 89939 5244 5242 5243
52 1
element ShellMITC4 89940 52 5244 5245
5246 1
element ShellMITC4 89941 4246 42 5244
5245 1
element ShellMITC4 89942 53 5246 5245
5247 1
element ShellMITC4 89943 5248 53 5247
5249 1
element ShellMITC4 89944 5250 5248 5249
5251 1
element ShellMITC4 89945 5251 5249 4248
4250 1
element ShellMITC4 89946 54 5250 5251
5252 1
element ShellMITC4 89947 5253 54 5252
5254 1
element ShellMITC4 89948 5256 5254 5253
5255 1
element ShellMITC4 89949 5256 5254 4253
4255 1
element ShellMITC4 89950 5256 5255 55
5257 1
element ShellMITC4 89951 5258 55 5257
5259 1
element ShellMITC4 89952 5260 56 5258
5259 1
element ShellMITC4 89953 5260 5259 4258
46 1
element ShellMITC4 89954 5262 5261 56
5260 1
element ShellMITC4 89955 57 5263 5262
5261 1

puts "Shell Ok"

####################################
####################################
###
## define SAWS material parameters
####################################
####################################
###
## adjusted to fit global response
## see page 12 simplified seismic analysis
of woodframe structures (Folz)

set K0 3970

set F0     7 ;     # intercept strength of the
shear wall spring element or the asymtotic
line to the envelope curve F0>FI>0
set FI     4.5 ;     # intercept strength of the
spring element for the pinching branch of
the hysteretic curve (FI>0)
set DU    0.035 ;     # spring element
displacement at ultimate load (DU>0)
set S0    500 ;     # initial stiffness of the
shear wall spring element (S0>0)
set R1     0.028 ;     # stiffness ratio of the
asymptotic line to the spring element
envelope curve. The slope of the line is
R1,S0 (0<R1<1.0)
set R2    -0.000000001 ; # stiffness ratio of
the descending branch of the spring
element envelope curve. The slope of this
line is R2 S0 (R2<0)
```

```
set R3      0.49 ;       # stiffness ratio of the
unloading branch of the spring element
envelope curve. The slope of this line is R3
S0 (R3 1)
set R4    0.08 ;         # stiffness ratio of the
pinching branch for the spring element. The
slope of this line is R4 S0 (R4>0)
set alph    0.8 ;        # stiffness degradation
parameter for the shear wall spring element
(ALPHA>0)
set beta    1 ;          # stiffness degredation
parameter for the spring element (BETA>0)

uniaxialMaterial SAWS 30 $F0 $FI $DU $S0
$R1 $R2 $R3 $R4 $alph $beta;  # Model

uniaxialMaterial Elastic 77 100000000000
section Aggregator 777 30 P 77 Vy 77 Vz
77 My 77 Mz 77 T

#element dispBeamColumn $eleTag $iNode
$jNode $numIntgrPts $secTag $transfTag
<-mass $massDens> <-cMass> <-
integration $intType>

#partition
element dispBeamColumn  749 53231
53232 2 777 04;
element dispBeamColumn  750 53331
53332 2 777 04;
element dispBeamColumn  751 53431
53432 2 777 04;

#staircase
element dispBeamColumn  752 933 934 2
777 04;
element dispBeamColumn  753 935 936 2
777 04;
element dispBeamColumn  754 937 938 2
777 04;

element dispBeamColumn  755 939 940 2
777 04;
element dispBeamColumn  756 941 942 2
777 04;
element dispBeamColumn  757 943 944 2
777 04;

###################################
###################################
###
# Roof Loads
###################################
###################################
###

# apply point load on top nodes (vertical
pre-compression load)
set Vload -900
pattern Plain 1 Linear { ;
    foreach node {51 52 53 54 55 56 57 522
523 524 525 526 527 528} {
   load $node 0.0 $Vload 0.0 0.0 0.0 0.0}
#}

puts "Model Ready"
#DisplayModel3D DeformedShape

#source eigenvalues.tcl
puts "oi modos"

###################################
###################################
###
# Gravity Analysis Parameters -- load-
controlled static analysis
###################################
###################################
###

set Tol 1.0e-10;           # convergence
tolerance for test
constraints Plain;         # how it handles
boundary conditions
numberer Plain;            # renumber dof's to
minimize band-width (optimization), if you
want to
system BandGeneral;        # how to store
and solve the system of equations in the
analysis
test NormDispIncr $Tol 18 ; # determine if
convergence has been achieved at the end
of an iteration step
algorithm Newton;          # use Newton's
solution algorithm: updates tangent stiffness
at every iteration
set NstepGravity 10;       # apply gravity in
10 steps
set DGravity [expr 1./$NstepGravity];   # first
load increment;
integrator LoadControl $DGravity;      #
determine the next time step for an analysis
analysis Static;           # define type of
analysis static or transient
analyze $NstepGravity;     # apply gravity
# -------------------------------------------------
maintain constant gravity loads and reset
time to zero
loadConst -time 0.0

puts "Gravity Load OK"

# -------------------------------------------------
maintain constant gravity loads and reset
time to zero

###################################
###################################
###
# Define RECORDERS
###################################
###################################
###

recorder Node -file $dataDir/Top_DispZ.TXT
-node 21 31 41 51 -dof 1 disp;             #
displacements of free nodes on Z1 Axis
recorder Node -file
$dataDir/Base_Shear.TXT -node 11 18 115
122 12 19 116 123 13 110 117 124 14 131
118 125 15 112 119 126 16 113 120 127 17
114 121 128 -dof 1 reaction;         # support
reaction base floor on Z1 Axis

###################################
###################################
###
# Select ANALYSIS TYPE
###################################
###################################
###

source Pushover_horiz.tcl
#source Cyclic_horiz.tcl
```