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THE PERFORMANCE EVALUATION OF EXISTING PRECAST CONCRETE BUILDINGS (HOSPITALS) TO SEISMIC LATERAL LOAD

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SUMMARY

Here will be a summary, based on the result, assessment, discussions, and conclusions about the seismic performance precast reinforced concrete structures and analysis of the existing precast reinforced concrete from earthquake resistance.

And comparing the cast-in-site concrete structures with precast structure the resistance strength capacity, to recommend the building construction structures in high seismic regions.

The assessment of building performance from the past earthquake, there was a lot of failure characteristics which expose the precast reinforced concrete structures

Those technical testing observations have found many faults form the precast structures during the earthquake, moreover, the testing instrument exposes the lack of eurocode8- seismic resistance design code, which was a beam to column connections and walls joints were a very weak design. Moreover, the design of lateral force stiffness and mass were not proportional, and it makes torsional for large displacement between the stiffness of the lateral loads. Due to this fault, some precast structures can be collapsed during an earthquake.

However, buildings in high seismic regions should be designed to have the capacity to withstand the effects of an earthquake without collapse.

In order to figure out the resistance of buildings in those regions having high seismic, we have supposed to build one Hospital in Cuba.

Furthermore, the precast structure of the Hospital in Cuba which were investigated, involved with the cooperation and contribution engineers from Norway and Cuba more detail the characteristics, and plan design view and materials quality were assessed as it was weak and also has irregularity structures beam to column and walls joints connections which may expose for earthquake damage.

Based on seismic resistance assessments, the static loading numerical modelling, by using SAP2000 software for the x-y, x-z, y-z and 3d view numerical modelling of the hospital building analysed and investigated members of utility levels ratio of rigidity and flexibility at the joints of the walls and beam to column connections within significant effects overall behaviour of the structures.

Moreover, the precast understudy, the connection cannot be assumed rigid the option we have is as flexible and partial fixed connection beam to column connections and walls joints we assumed as Model_1 and was created Model_2 as Fixed connection representing as the case of cast-in-situ structure to compare the differences in terms of seismic performance.

Based on, the structural analysis we have used linear dynamic analysis instead of none liner analysis because of we have used the major axis instead of minor axis but the result of linear dynamic analysis Model_1 and Model_2 about the response spectrum analysis with computation of seismic demand in X-Y direction the result was done on a graph with their capacity levels results.

The numerical design Mdel_1 and Model_2 describe detail the lateral seismic demand displacement from response spectrum analysis and base reactions of shear forces from response spectrum comparing both the partially fixed connection(Model_1) and fixed connection (Model_2).

As, a result the Model_1, it has more displacement and less lateral force resistance during the earthquake In contrary to that, the Model_2 has small displacement and more and more resistance lateral force during an earthquake.

Based on the Evaluations result, the cast-in-situ structure meaning the fixed connection Model_2 is accepted to build in those regions having high seismic. As a result, we have decided on the Hospital in Cuba, which we explained in our design built by cast-in-situ concrete structures

According to the result of the assessments, one cannot recommend the precast reinforced structures in those regions which exposed to high seismic. This result may apply to those regions having low seismic because of the safety of construction buildings and economic advantages.

1 INTRODUCTION

This thesis describes the performance evaluation of existing precast reinforced concrete buildings such as hospitals to seismic lateral load.

Insignificance advances have been assessed about precast reinforced concrete in the seismic protection of structures, the assessment is before and after the earthquake happened to get more lesson to form for future better progressive technology and mechanisms of to save people's life from unexpected life disaster, the role of design precast reinforced concrete in the whole picture of seismic risk, defined as a combination of seismic hazard and vulnerability. The performance objectives and acceptance criteria is a critical revision in response to recognizing the urgent need to design, construct, evaluate, and maintain facilities with better damage control, and take own initiative for the preparation of platform of the buildings process and how the concepts and designs to construct in the construction aspects and the performance levels are an expression of the maximum desired extent of damage under a given level of seismic ground motion, thus standing for losses, and repairing costs due to structural and non-structural damage.

In general, the idea of precast reinforced concrete performance is a framework for more comprehensive performance-based seismic design and assessment approach with the introduction of jointed ductile systems which is based on unbonded ductile post-tensioning techniques, it can be useful for a damage control limit state regardless of the seismic intensity. (priestly et.al 1999).

A further assessment has been argued by using many approaches, such as the design philosophy of the structures which evaluates to get the conceptual and arguments, why socio-economical losses due to the earthquake, the weakness of the structural stiffness, lack of the knowledge of seismic resistance design code, the joints and the overlay structures were not having well designed with the knowledge of resistance seismic code, those skilled peoples on construction site workers and design engineers were not significant for construction analysis based on the fact that the characteristics of seismic design.

Most of the evaluations which are in chapter two explanations, based on for each picture assessment about the disaster and the weak design which is assessed about, before and after the earthquake and more detail lesson the design failure of the structure by using test apparatus and by comparing the design code of each country and euro to get more detail assessment.

Th**e** Model of design software, which **is** SAP2000 are used to get for more detail assessments, where the fault of the design was and all loads of the construction experimented and analysed with the results feedback in the rest chapters.

In general, all I explained in this thesis based on references, the subject teacher school notice and the one who is working at an earthquake research institute detail on the subject as advisers.

I think this thesis may have good knowledge of assessment to get why the precast reinforced structure exposed for disaster instead of technological advantage. So even if the disadvantage and advantage of precast reinforced concrete I tried to assess in this thesis but for further technological innovation I recommend for those countries having low Magnitudes of the earth, they may not expose them for seismic disaster if they are using the design resistance of seismic code, the precast reinforced concrete is more advantageous to consume economically, time and skilled peoples, because of, it is more safety, moderate and easy facilitated

2 LITERATURE REVIEW

In this literature study, we are looking deeply about the performance evaluation of existing precast concrete buildings (hospitals) seismic lateral load how it behaves in different categories, such as the seismic performance reinforced concrete structures, precast reinforced structures, existing precast reinforcement from the earthquake, description of the design, causes, summary and assessments and recommendations explained because of to know in assessment either the designer used the seismic code or not and what is the advantage and disadvantage of precast reinforced concrete before and after the earthquake and why it is exposed for seismic.

2.1 Seismic Performance Precast Reinforced Concrete structures

The precast reinforced concrete structure in seismic performance was constructed and evaluated under static reversed cyclic of lateral loading. One unit was code compliant conventionally reinforced specimen, designed to emulate the behaviour of a ductile cast-in-place concrete wall. The other unit was part of a precast partially prestressed system that incorporated post-tensioned unbonded carbon fibre tendons and steel fibre reinforced concrete. The energy dissipation devices were provided in the latter unit in the form of low yield strength tapered longitudinal reinforcement, acting as a fuse connection between the wall panel and the foundation beam. The conventional precast reinforced wall performed very well in terms of the ductility capacity and energy absorption capability (Holden et al. 2003).

2.1.1 Precast Reinforced Concrete structures

Precast reinforced concrete can be manufactured, fabricated by both, a manual and an industrial factory, which is by casting of reinforced concrete in a reusable form, and cured in a controlled environment, transported to a construction site and lift for using by instrument and it doesn't need too much formwork, like existing reinforced concrete it saves much economical and also it can be used by a few numbers of skilled peoples. In contrast, standard concrete is poured into site-specific forms and cured on sites under a given curing date(Manual et.al, 2004).

Figure2-1:an example of reinforced Concrete Slab Precast RC
on the site source by my camera from work site

Figure 2-2 it is an example of the reinforced concreate beam
precast RC (source by my camera from work site)

2.1.2 Existing precast reinforcement from earthquake

The Seismic Performance of Precast Reinforced Concrete Buildings exists, there were two earthquakes with magnitudes of 5.8 and 5.9 in Northern Italy at Emilia. The failure of the building during the earthquake was registered from the journal notes the seismic vulnerability of precast structures. The damage was caused by both the connection of the systems and the loss of support of the horizontal structural elements, due to the failure of friction beam-to-column and roof-to-beam connections, and the collapse of the cladding panels, due to the failure of the panel- to-structure connections(Magliulo.et.al, 2008)

It is recommended that the future constructions, either buildings or any civil structure projects, consider the risk of seismic hazards, to protect the elements of the structure from being damaged. Peak ground acceleration and the ductility class values should be considered in analysis and design.

In the meantime, the results may help the structural and economic advantages from precast reinforced concrete. Precast reinforced concrete behaves monolithically with enough strength, stiffness, ductility, and durability to resist seismic loadings and forces (Magliulo.et.al, 2008)

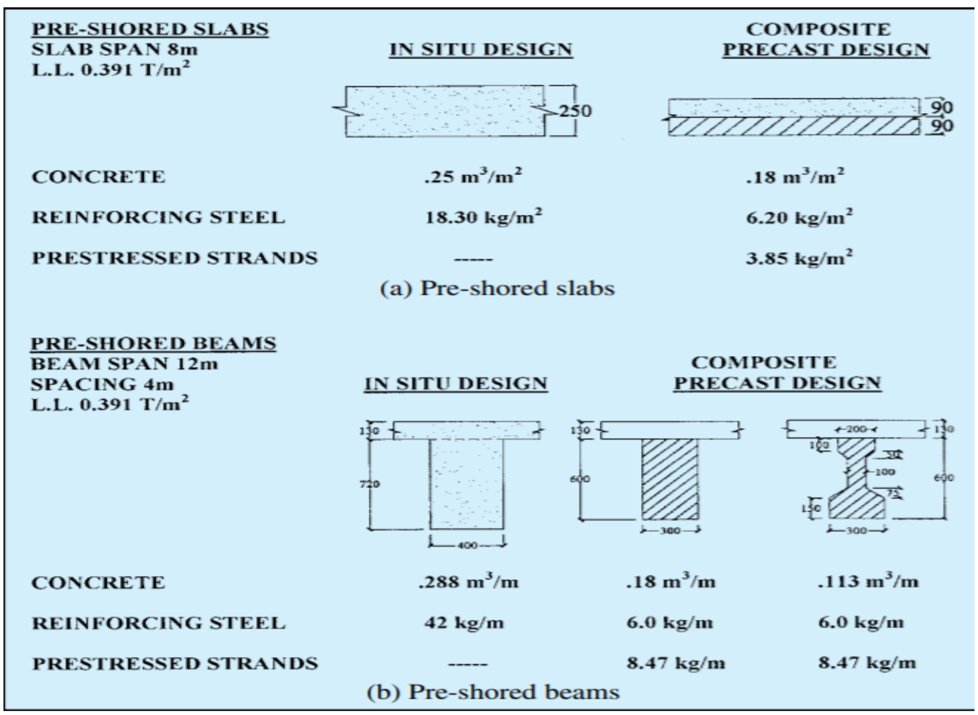


Figure 2-3: it shows material saving using precast concrete (Yee, &Alfred, 2001)

The precast units can be integrated vertically(longitudinal) and horizontally (latitudinal) to form the building frames in a monolithic manner. Precast or prestressed concrete for building construction is designed to resist seismic activity (Yee & Alfred, 2001)

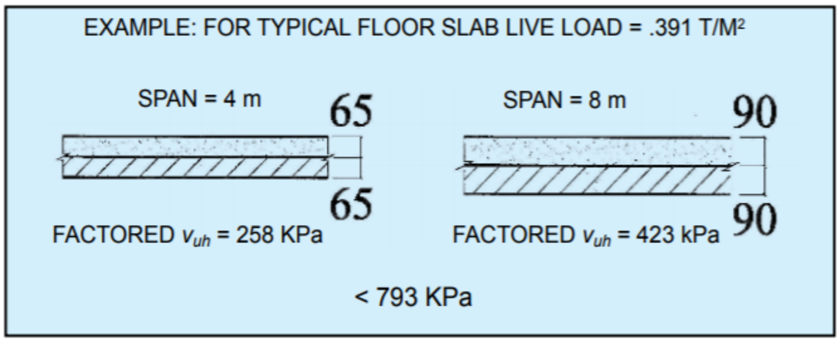


Figure 2-4 it shows the horizontal shear stress calculation for a composite
Slab under ordinary loading conditions. (Yee, 2001)

The shear stress calculation was designed with the knowledge of resisting seismic before the precast fabricated. It is designed according to the design materials Eurocode 8: EN1998: Design of Structures for Earthquake Resistance.

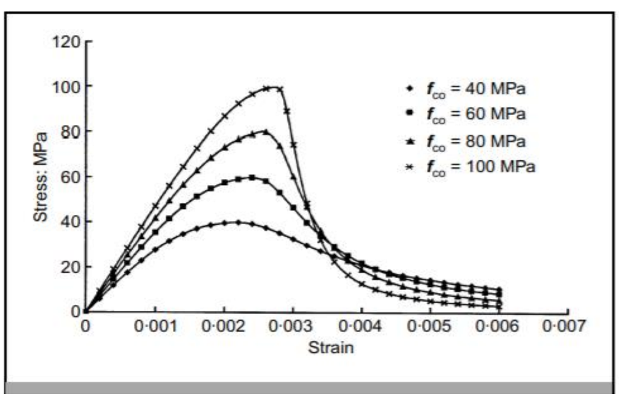


Figure2-5 it shows the stress strain curves of concrete (Eurocode 2: steel structures)

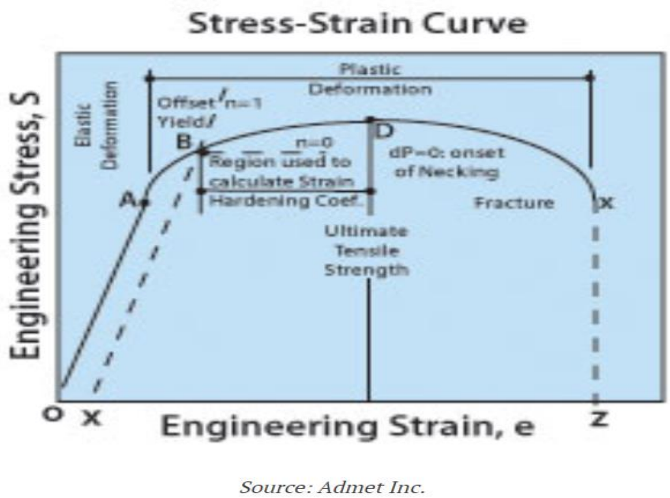


Figure 2-6 it shows the stress and strain curves of reinforce ductility yield (Source: - Admet Inc.)

In the higher strain rates hurt the ductility of materials, meaning that elongation values decrease as the strain rate increases.

The model of the precast is designed depending on the assessment of structural calculation, ductility of the materials. That means if the design is not well measured and calculated, its structural materials may not fit at the joint and it may cause the joint linkages and the structures to be easily damaged. This can cause an economic disaster in both the low and high seismic regions.

The prefabricated reinforced concrete should have been assessed before fabrication to ensure proper ductility and stiffness. If we use those reinforced materials without checking the ductility and stiffness it may cause a disaster for all construction-buildings. (Yee, 2001)

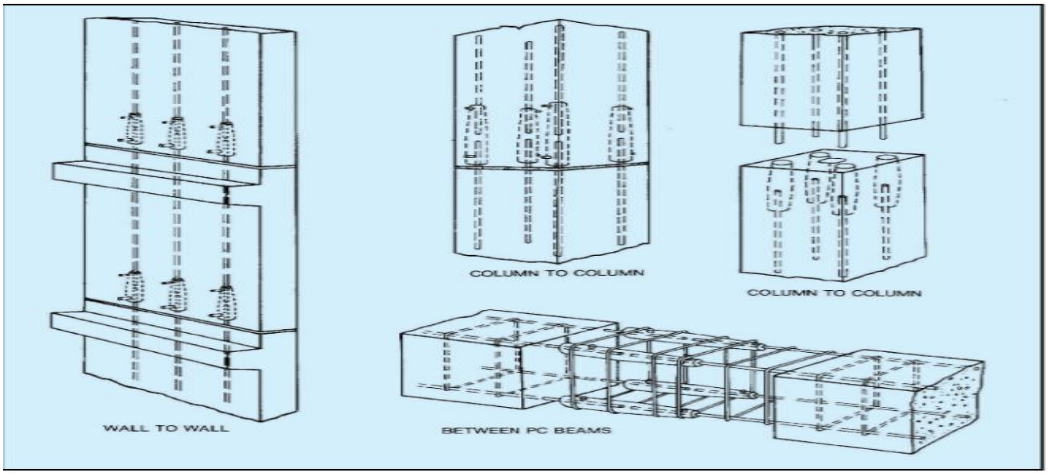


Figure 2-7 it shows the arrangement of in different precast concrete connection (Yee, 2001)

During the Connection of precast reinforced concrete, the joints should be considered the stiffness is as the centre of the mass of the exerted materials, and others supporting elbows should have at the joint, to hold the exerted precast. So, the connection of precast will get more strength, and the forces at the joint may not disappear from each other

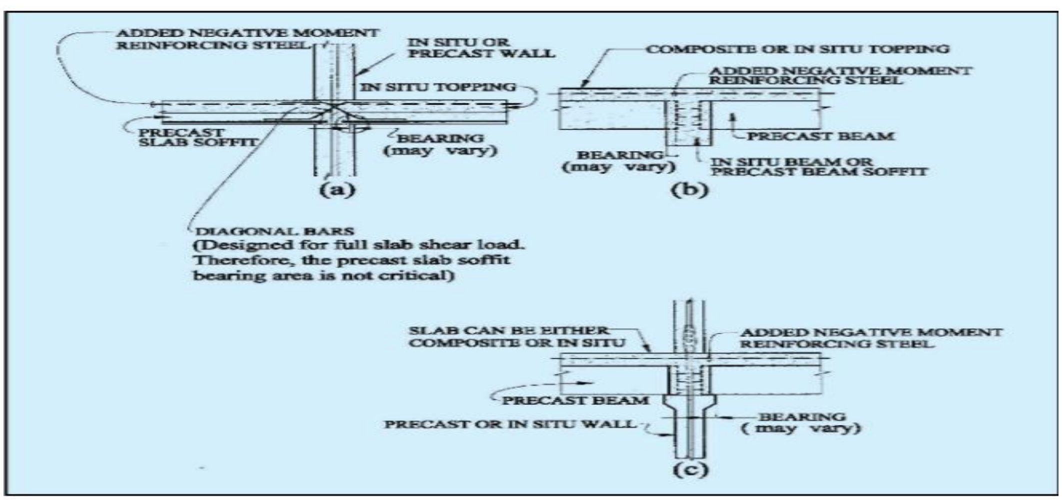
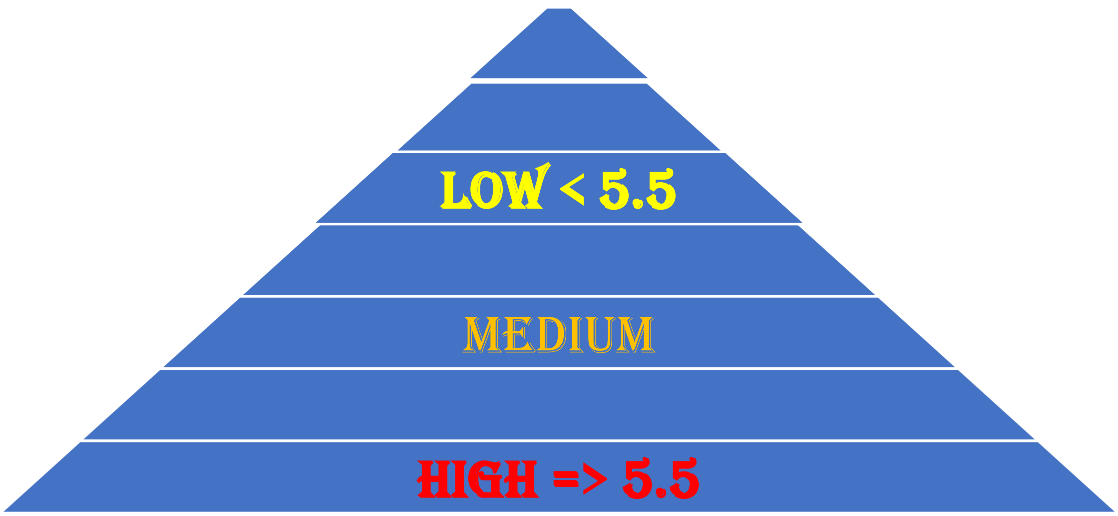


Figure 2-8 it shows the example of precast reinforced concrete connection. (Yee, 2001)

According to journal explanation, the assessment was in different test materials of the strength, ductility, stiffness of the joint, and the calculation of precast reinforced concrete, economically without costing high to design resisting seismic. The aim of the evaluation and prediction assessed for many years was, as it resists against seismic hazardous, still active, and functioning the journal notes (Yee, & Alfred,2001)

2.2 Description of the design:

The design description of Precast Reinforced Concrete in a different region of the world at low, medium, and high seismic. It is dependence on. the Magnitude of the Earth.



In those regions of low seismicity post-tensioning (PT) concrete is suitable, it is confirmed that after several experimental tests, the lateral drift demand is small and so extensive damage to the wall toe can be avoided.

According to the journal for buildings which is in a region of low seismicity, the flexural strength can be used and easily designed the wall, compressive strain over 0.003 may be more suitable for (PT) walls. The Test resulted and finite analysis was used to quantify the strain in the wall toe and develop refined equations to accurately predict the unbounded tendon stresses and wall nominal flexural strength (Yee, & Alfred,2001)

low region of seismicity:

In low region of seismicity, precast reinforced concrete components have several advantages in building construction such as: -

- High-quality finish and lower construction tolerances
- Improved architectural finishes
- Reduced construction time
- Optimised use of materials
- Longer spans when prestressing is used
- Use of advanced technology
- Use of a small number of workers when we compare to existing reinforced concrete
- The site place is cleaner and the material in the precast is structural well calculated by factory rather than manual at the site. (Richard &Henry, 2017)

When we build the construction site as a civil engineer, we have to consider the Peak ground acceleration and ductility class values that should be considered in the analysis and design construction.

In the design nature, we have to use Eurocode 8:-Design of Structures for Earthquake Resistance, Part 1: General Rules, Seismic Actions, and Rules for Buildings (2004), and the values of peak ground acceleration (PGA) such as DCL 0.06g, it is for the lower seismic region.

DCM 0.08g - 0.14g should be considered in the analysis under response spectrum analysis of either the low or high seismic region it is recommended that future construction, either building or any civil structure project, consider the risk of seismic hazard to protect elements of the structure from being damaged.

Peak ground acceleration and ductility class values should be considered in analysis and design by Eurocode 8. Based on the above explanation, those countries having low Magnitude of the Earth < 5.5, for example, Norway, Denmark, and Sweden they are using such low seismic region (LD) the detail table which explains about the LD, DCM, and DCL we will see the next table 2-3. (Eurocode 8: EN 1998-1: 2004)

In those countries having low Magnetic (MS) <= 5.5, the design of precast reinforced concrete is not the same as those countries having high Magnetic (MS) >= 5.5. The design of seismic depends on the magnitude of the earth, it could be lower demands. The fundamental considerations of quantification and availability of precast concrete systems are based on an engineering decision relating to seismic design.

According to the meeting on the evaluation of fundamental consideration of precast reinforced concrete with the USA and Japan engineering analysis, they prefer the japan precast structural design code even if it was not well translated, the one has most 24 stories but according to the examination of a test during an earthquake, why the Japans precast design model was affected by the earthquake? when buildings with low stress (two to three stories) and Buildings with high stress (four to seven stories).

Quality control, construction economics, and the consumption of times during the building construction make the effective use of precast concrete as a seismic bracing element as a desirable goal.

In both the Medium and High seismic regions, the design of precast reinforced concrete which is MS >= 5.5. According to Eurocode 8: the design needs a high stiffness structure.

In general, according to the assessment of the high seismic region the design of structural materials, costs high because the stiffness should be in the middle of the exerted load(mass), the quality of the elements will cost high. That is why the most developing and poor country may not use the seismic resistance design because of cost benefits. Even if they face dangerous seismic results in the country, they did not use the seismic resistance design codes (Arslan et.al, 2006)

The concepts of Earthquake resistant steel buildings shall be designed by one of the following concepts (see Table 6.1 from Eurocode8)

- Concept of Low-dissipative structural behaviour.
- Concept of Dissipative structural behaviour.

Table 2.1 Design Concepts, Structural Ductility Classes

And Upper Limit Reference Values of The Behaviour Factors (Source: Eurocode 8 Table 6.1)

Design concept	Structural ductility class	Range of the reference values of the behaviour factor q
Concept a) Low dissipative structural behaviour	DCL (Low)	≤ 1,5 - 2
Concept b) Dissipative structural behaviour	DCM (Medium)	≤ 4 also limited by the values of Table 6.2
	DCH (High)	only limited by the values of Table 6.2

NOTE 1 The value ascribed to the upper limit of q for low dissipative behaviour, within the range of **Table 6.1**, for use in a country may be found in its National Annex. The recommended value of the upper limit of q for low-dissipative behaviour is 1,5.

NOTE 2 The National Annex of a country may give limitations on the choice of the design concept and of the ductility class which are permissible within that country (Source: -Eurocode 8 table 6.1)

2.3 Observation from the past earthquakes

Example 1, In Turkey, the cause of most buildings built by precast reinforced concrete exposed to damage by an earthquake, because of those building engineers have not used the design of the country code resistance to seismic and Eurocode 8: EN1998: Design of Structures for Earthquake Resistance.

In most evaluations, it exposes that, the careless design of precast reinforced concrete structures and lack of economic, using the one designed in another country without the knowledge of the country Magnitude of the earth capacity, all of these were a tremendous disaster to expose the buildings for an earthquake.

Instead of using the advantages of prefabricated technology, it supplies a tremendous disadvantage, failures, and cause damages, after observed in the structures erected.

Using these techniques in destructive earthquakes that hit Turkey, especially in the last 10 years. It gives a lesson to watch those need for the re-examination of the criteria in the Turkish Earthquake Code (TEC) and revision of the code deficiencies relative to the criteria in UBC and Eurocode-8 which are the codes in the United States and the European Union, respectively (Arslan.et.al,2006)

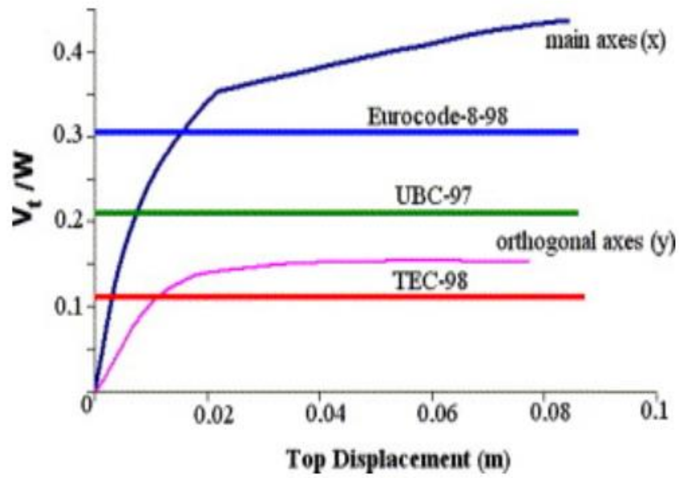


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figure 2-9 the assessment in this graph shows us the lateral force in main axes(x) is longer than all codes which is given to earthquake resistance code so it refers that the failure of the design while using without the earthquake code(arslan.et.al, 2006).

The above assessment was, after earthquake experimental value. it examines, what is the advantage and disadvantage of the precast reinforced concrete in 10 years evaluations, which was found the most considerable damage in an earthquake in Turkey.

It was by the lack of static testing on prefabricated reinforced concrete before using on the construction site, which was critical for design engineers and construction skilled peoples, because of most of the building built by precast reinforced concrete was damaged. However, the size of the earth (MS) either it is big or small no one gets into consideration, that cost others life and economic disaster.

In general, the evaluation has the lack of static tests and laboratory analysis which is conducted on characteristic configurations of a load-bearing structure and its joints manifested the required parameters of the designed solution, loadbearing capacity and serviceability were weak enough comparing with those designed by the knowledge of the Eurocode 8: resistance seismic design. (Arslan.et.al, 2006)

Figure 2-10 it shows by the lack procedural structural design the failure of column (Arslan, 2006)

In this picture, the assessment indicates, most constructions were exposed for crake, splitting its joints from each other's and easily exposed to damage but to cover the unseen it was painted instead of keeping.

Those others details pictures you can see from the next figure, in precast reinforced concrete the column of the walls was hallowed and never filled with concrete it causes the stiffness far away from the exerted loads (mass), the result may cause to be easily damaged for both hazardous and low magnitude of the earthquake which means they did not have the capacity of to hold the loads.

In Turkey, those buildings were built by prefabricated reinforced concrete and concrete construction, walls laid with filling material, whether they are bearing walls or not, support loads Particularly when damaged multi-span structures are investigated, it is seen that columns located in the peripheral axes were held by the walls laid in between, the framework cells on the interior axes, the inside of which was left unfilled for the sake of easier in-factory production, deformed easily and displaced more(Arslan.et.al,2006).

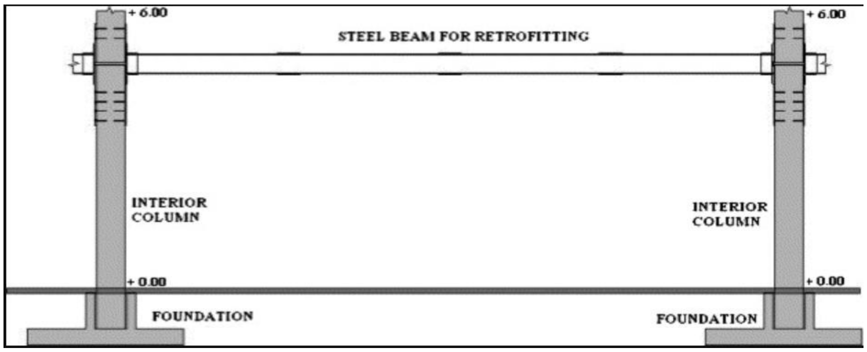


Figure 2-11 it shows that the inside column unfilled because of to easily get transportation (Arslan.et.al,2006)

Figure2-12 it shows the damage of joints of precast during earthquake (Arslan.et.al,2006)

Figure 2-13 it shows the damage of precast reinforced concrete during earthquake in most building in Turkey (Arslan.et.al,2006).

2.3.2 Summary and assessments.

The summary and assessments of precast reinforced concrete structures, which was damaged during the earthquake. The assessment exposes as they had a lack of economical, then they did not own precast industrial in their country, which they might change and design according to their country code which is related to resistance earthquake code. Even, as they were not use the design of Eurocode 8: EN1998: design of structures for earthquake resistance.

Furthermore, they were not assessing very well the geotechnical, soil mechanics strength capacity to build on the construction.

The only way they were thinking was, how to finish their site work just in a limited time, to get cover their cost estimation, that was the result of big disasters for people's life and economical.

In Turkey to design the existing reinforced concrete and the precast reinforced concrete, the Magnitude of the earth should be considered and designed with the resistance earthquake code, so even if they were studying as a civil engineer, they were not using both Eurocode 8. And the

Turkey, resistance earthquake code, while it was assessed the damaged materials were not used in both codes, all faults what those designers were doing at the end exposes for an earthquake disaster (Arslan et.al,2006).

“According to Engineering Failure Analysis of Turkey earthquake, the formula was proposed in TEC-98 for the design of connection locations for non-structural members such as ledges, corbels, and architectural members is inadequate compared with the other Codes, particularly the Eurocode-8 When the lateral loading–displacement correlation of the model structure is analysed, it is observed that whereas the capacities, especially of the framework cells orthogonal to the main axis, satisfy the required values computed according to TEC-98, they failed to satisfy the limits designated according to the Codes UBC-97 and Eurocode-8-98” (Arslan et.al,2006, p.(537–557)).

Based on journal assessment once the beam rotations are developed, the structural members do not stay in their actual positions and failure occurs. However, if beam rotation can be minimized, structural failure of precast beams would not happen to be damaged, but it implies that a slight difference from the beginning after certain years. In beam to column failures, high joint stresses are produced that cause structural failure. Plastic hinge formation near the fixed end of the beam results in concrete crushing and fracture of longitudinal bars, and again, it causes failure of the structure.

The technological test manifested that, the possibility of repetitive collision-free assembly and demounting without any damage to anchoring and connecting elements and the load bearing of precast reinforced concrete. The seismic resistance test failed the precast reinforced concrete. If we test before using on the site of precast reinforced concrete, design with the knowledge of Eurocode 8.-seismic resistance, its parts the anchoring steel and connecting elements showed no signs of failure that might not be the cause of a subsequent collapse of the joint and the structures after the earthquake test of structures.

Other examples, Italy, the Precast reinforced concrete failure during the hazardous seismic systems in developing industrialized countries such as Italy “Emilia Earthquake 2012”.

The structural design of the precast reinforced concrete seismic design code system was extremely noted well designed.

The joints and columns of the precast reinforced concrete were exposed to damage, during an earthquake in Italy, which had a magnitude of the earth size 5.8 and 5.9, the designer of the precast reinforced concrete was not using the country code and Eurocode 8: resistance of seismic design code. That causes an expectation disaster, during Earthquake in Italy, mostly it was affected at the connection systems, loss of support of structural horizontal elements, due to the failure of friction beam-to-column and roof-to-beam connections, or the collapse of the cladding panels, due to the failure of the panel-to-structure connections(Magliulo.et.al,2014.)

According to the assessment of analytical field evidence:

The assessment of analytical and field evidence of an effect the damaging of vertical earthquake ground motion

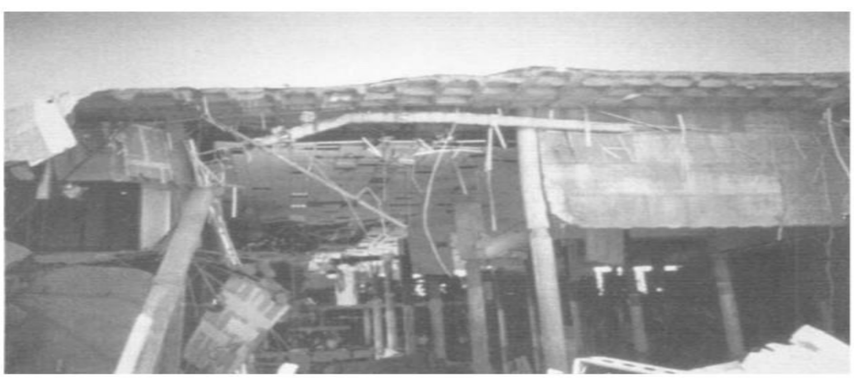


Figure 2- 14: shows punching shear failure in waffle slabs of the Bullocks store. Note intact columns and original floor levels. Photograph courtesy of Earthquake Engineering Research Institute (Papazoglou et.al 19969)

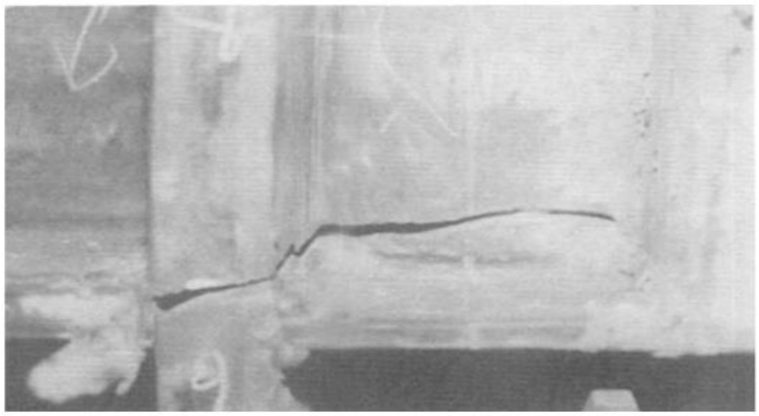


Figure 2-15-shows typical beam-column connection fracture seen following the Northridge earthquake. Photograph courtesy of EQE International (Papazoglou, & Elnashai, 1996)

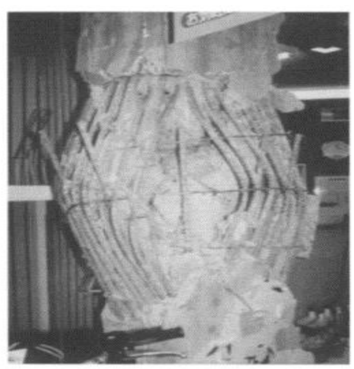


Figure 2-16 it shows the Compressive failure of internal column of the building shown in Photograph used with kind permission of Dr Minehiro Nishiyama (Papazoglou, &Elnashai, 19969)

More assessment, an overview of the geotechnical aspects of the building damage in the 1995 Hyogoken-Nambu earthquake is presented. The causes of the damage were.

Inadequate design of buildings, Ground failures including soil liquefaction that implies lack of soil mechanics evaluation during structural design. The typical features of the ground problems are settlement and foundation. Probable causes of damage include : (i) horizontal forces and overturning moments imposed on the foundation from the superstructures, (ii) kinematic forces acting on deep foundations due to shear deformation of soils,(iii) reduction in bearing capacity due to ground failures including liquefaction, and iv) lateral spreading was not proportional to the structural behaviours (Tokimatsu.et.al, 1996, p.219).

The other assessment connection with the above explanations, the lack of design soil mechanics during, the design of precast reinforced concrete, how it makes failures for the construction. In the meantime, soil mechanics is one of the basic structural concepts for construction life in any construction life. While any civil engineers design the site work for construction the characteristics of the soil mechanics should be assessed and analysed.

2.4 Recommendation

The recommendation from Eurocode 8:- seismic resistance code, US and Japan code, according to the assessment of the failure of precast reinforced concrete during an earthquake, it is similar cause at different country even if they were having different earthquake magnitudes they were not used properly the Eurocode 8: resistance of seismic spatial at joints and columns structures, the stiffness and the mass were not proportional it makes torsion. At the same time the failure of different precast reinforced concrete structures is presented in both Turkey and Italy during the earthquake were, the main reasons for the exhibited poor performances were.

- The inadequate beam-to-column connections

- The lack of transverse reinforcement in the column and beam corbels close to the beam-to-column connections,
- The inadequate confinement provided at the base of the columns, and
- The interaction with partial-height masonry infills (Magliulo.et.al, 2014.)

The stiffness and mass were not symmetry each other’s, that cause to increase torsional in the building, at that time the elasticity of the material is dispersed from each other, so it may causes for a big vibration comes like an earthquake to the building.

But, the evaluation on the precast reinforcement concrete, which damaged during an earthquake, in different places the column of the precast reinforced concrete, was splitting and cracked on the beams and columns, it was the cause of low ductility of the reinforcement in a building, which was built by the precast reinforced concrete, the damaging effect of vertical earthquake ground motion (Papazoglou, & Elnashai,1996)

According to all assessments in this chapter, it is the way how to be protected from hazardous seismic disasters, the recommendation of Eurocode 8:- Seismic resistance code, US and Japan Code is extremely applicable because different regions, were not used the country design code against seismic. Particularly if one may use the Eurocode 8: resistance seismic code, it is better than the rest codes, based on the researchers commented in their evaluation journal analysis.

3. CASE STUDY: PRECAST CONCRETE HOSPITAL BUILDING IN SANTIAGO DE CUBA

3.1 General:

Santiago de Cuba is the second largest city of Cuba and the capital city of Santiago de Cuba province located at the south-eastern shore of the island, see Figure 1. According to historical evidence, this region has experienced many earthquakes, and will certainly experience more in the future.

Critical facilities such as hospitals must imperatively survive and stay intact in case of a major earthquake, or any other disastrous event, as they are the beacon of life and hope for a community. These facilities must remain standing and functional during and after an earthquake to provide medical assistance to the injured and victims. Without functioning hospitals, it might take much longer for a community to recover from an earthquake.

Figure 3-1 location of Santiago de Cuba in Cuba

In Santiago de Cuba, there are about 13 major hospitals, constructed during the period of 1920's - 1990's; some of them designed for gravity loading only and others were designed using low seismic codes.

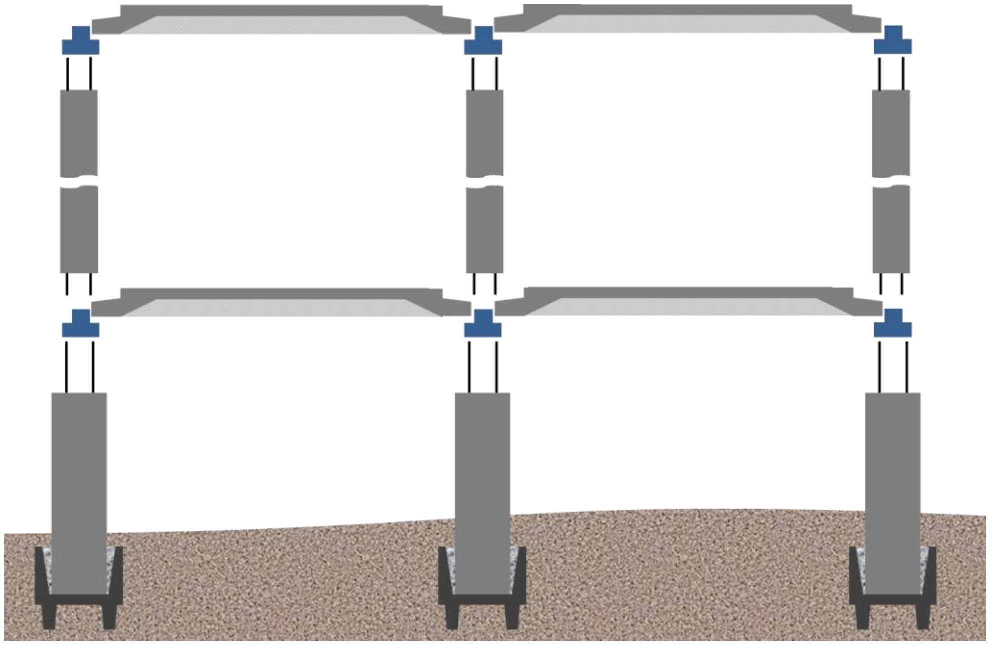
According to the structure classification (taxonomy) that has been developed at the local level (Lang et al. 2015), these major hospitals can be divided into 3 typologies:

- masonry (confined and unconfined) buildings, constructed in the earlier 1920's.
- masonry (fired clay bricks) infilled RC frames buildings, constructed during the period of 1950's 1970's.
- Girón buildings which are a special precast concrete system developed in Cuba in the earlier 1970's. The structural system consists of precast RC frames with precast RC walls assembled in-site, see Figure 2.

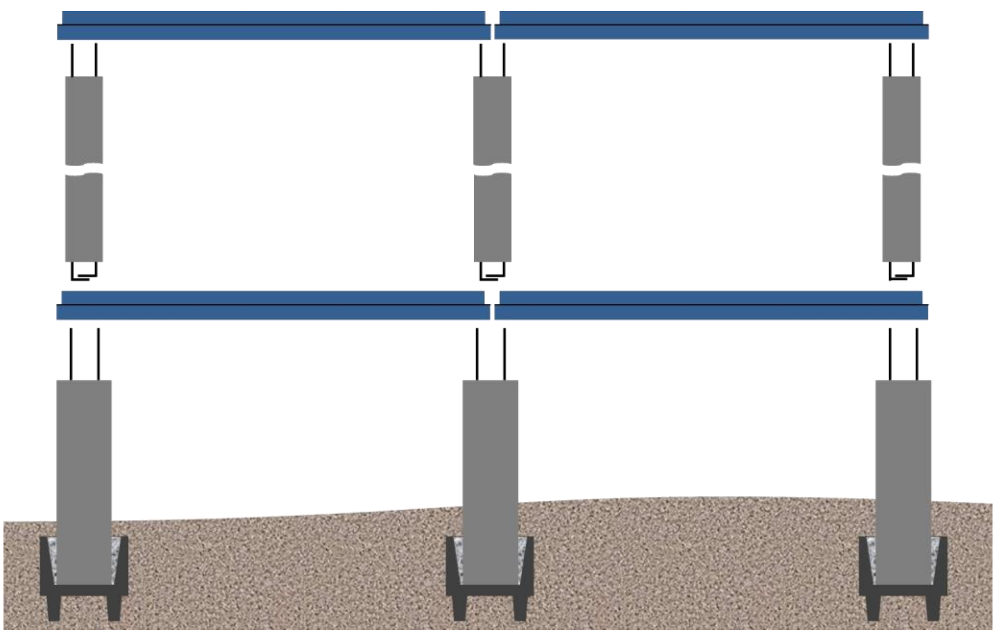
The Girón system, has been the most typically used, for hospitals as well as for other governmental and public buildings (e.g. schools, apartments etc.), in Santiago de Cuba and throughout the country. However, lessons learned from past earthquakes in different part of the world, have revealed that structures like Girón system are potentially vulnerable to earthquakes, hence should not be implemented in seismically vulnerable areas.

A detailed risk assessment is conducted for an existing hospital of highest importance for the city of Santiago de Cuba, and which is identified as Girón system. The investigated hospital building is part of a hospital complex of several structures, named "Quirurgico Geneco Obstetrico" and built in 1995 according to old Cuban design codes.

3D view of the Giron system



Longitudinal side view of the Giron system



Transverse side view of the Giron system

Figure 3-2 concrete precast structural elements girón system

3.2 Structural Characteristics of the Hospital Building

The hospital complex “Quirurgico Geneco Obstetrico” consists of several buildings, loosely connected with footbridges and with a structural joint at the centre of each building (see Figure 3-3). The structure foundation plan of the hospital complex is shown in Figure 3-4, and the investigated building is marked with hatch and stapled line.

The building is analysed as an independent dynamic structure. The influence of the connecting footbridges is considered marginal. The joint located between two structures spans 50 mm (Figure 3-4). Plan dimensions and elevations of the analysed structure are shown in Figure 3-5. The system foundations consist of spread footings with pedestals. The structural system forms rectangular columns, T-beams, and floor slabs with ribs, see Figure 3-5 (see also Figure 3- 2).

Figure 3-3-overview hospital complex "quirurgico gineco obstrtrico" ref. google maps

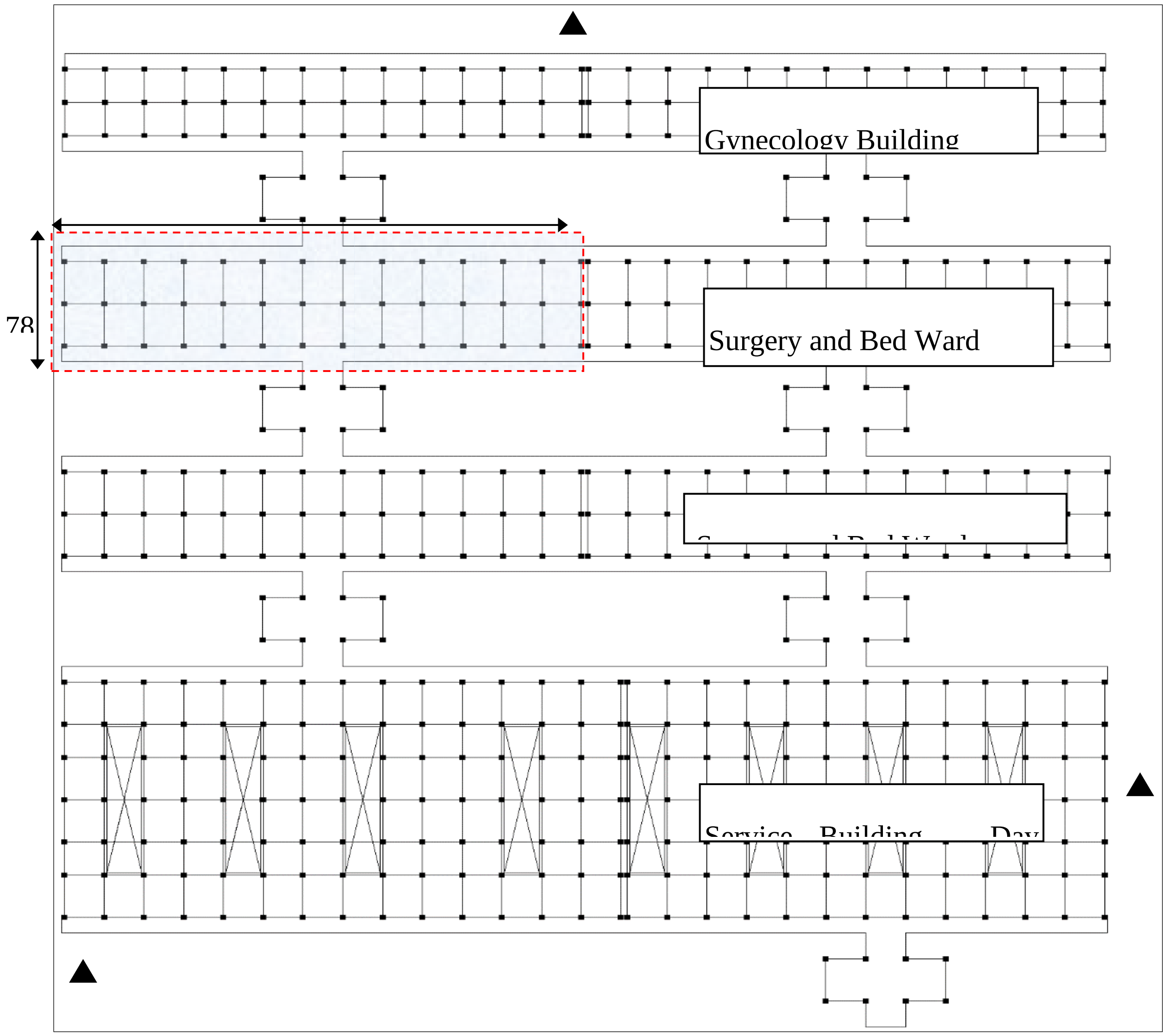
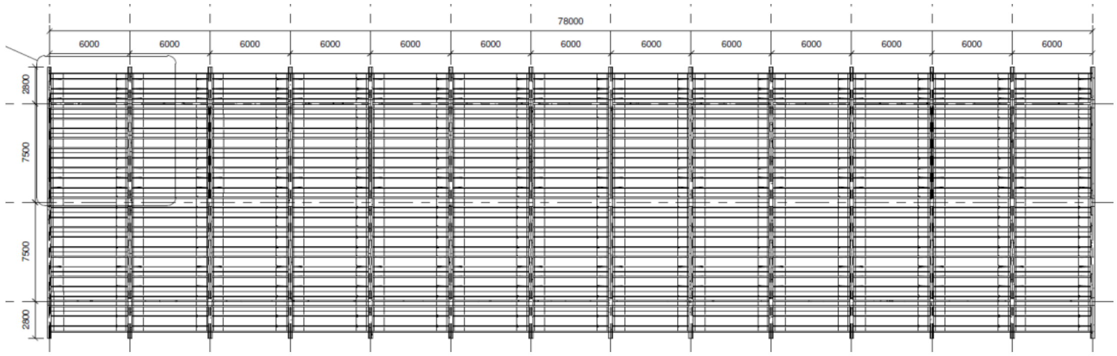
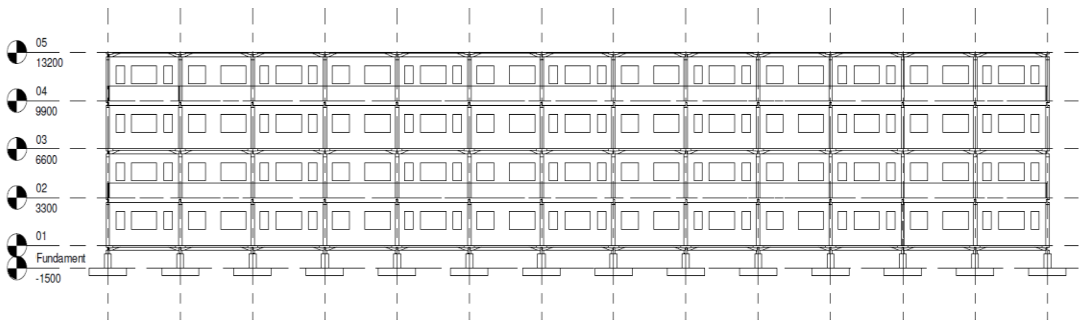


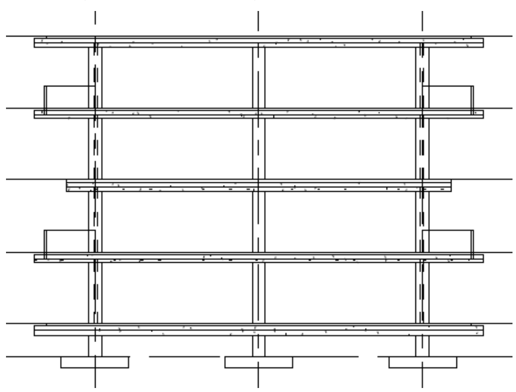
Figure 3-4 overview hospital foundation plan. analysed unit shown with hatch and stapled line. triangles indicate the locations of ambient vibration measurement on the ground surface**.**



Plan view main dimensions



Longitudinal side view (UX direction)



Transverse side view (UY direction

Figure 3-5 plan dimensions and elevations of the analysed structure

3.2 1 Structural System

The lateral force resisting system of the structure in the longitudinal direction comprises square 600x600mm column pedestals which form a stiff connection towards individual footing plates with dimensions ~2x2m. The footing plates provide lateral stiffness by passive soil pressure and friction. The first story has column dimensions 350x600mm. Story 2, 3 and 4 have columns dimensions 300x400mm. The pedestals and columns are connected to the beams through 4 steel bars only; see Figure 3-6 and Figure 3-7.

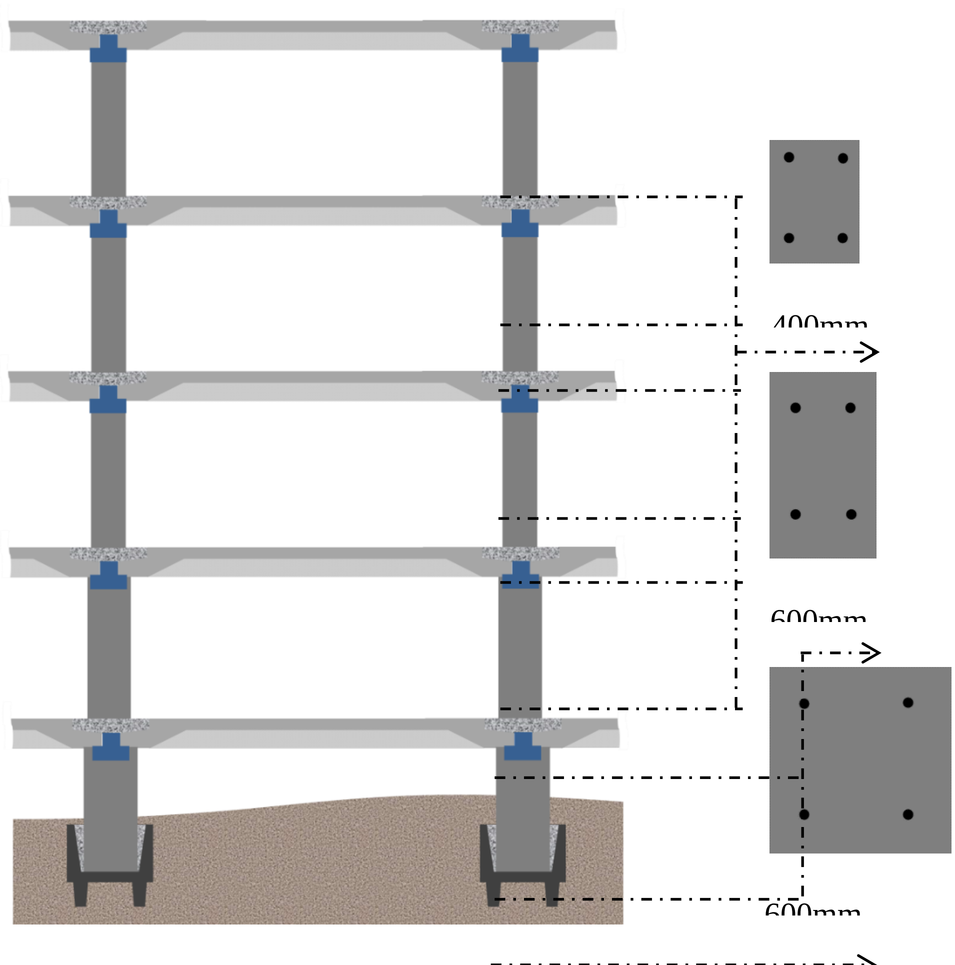


Figure 3-6 assessed building: typical dimensions of the pedestals and columns. Only 4 steel bars were used to connect the pedestals and columns to the beams

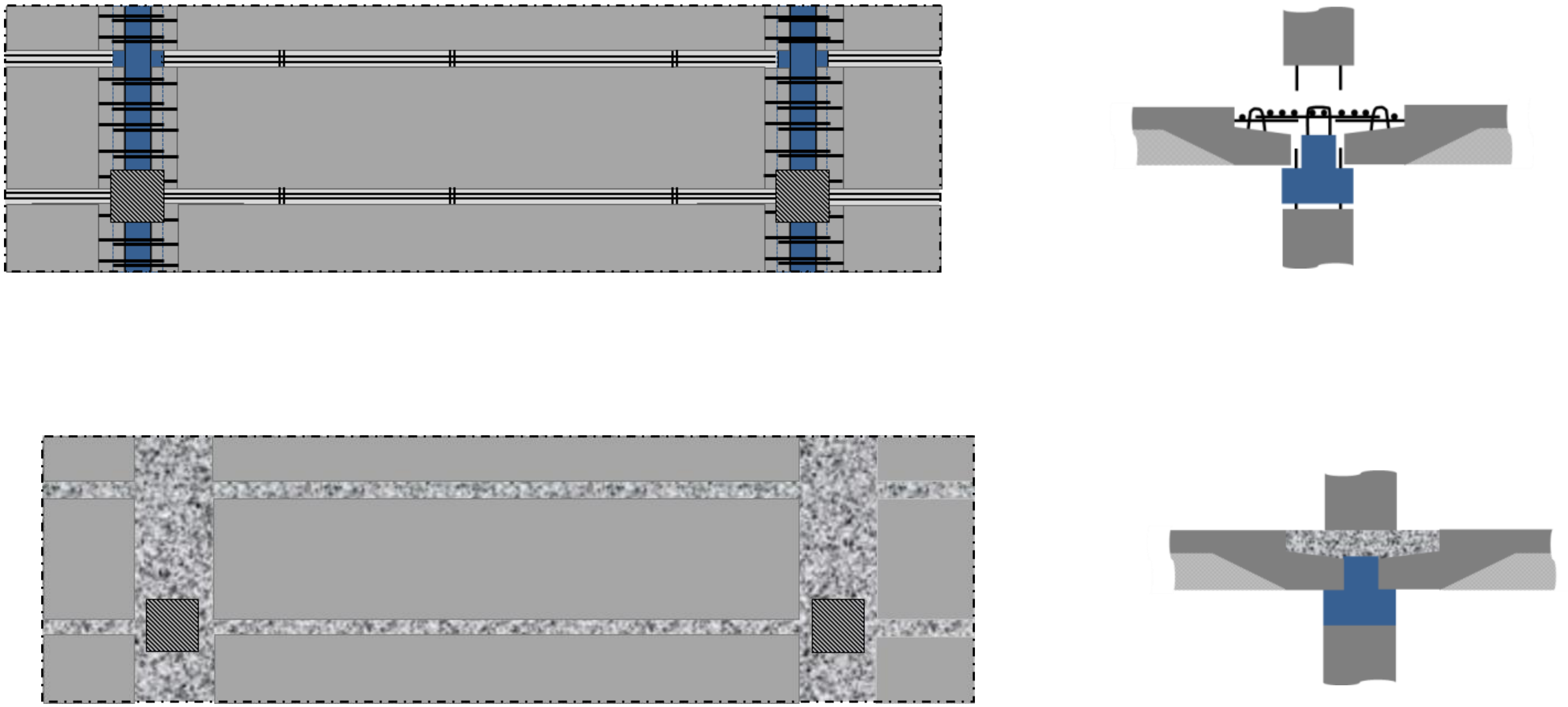


Figure 3-7 typical column-beam-floor slab assemblage in-situ

The prefabricated floor slab elements are supported by concrete beams. Slab continuity is set up by cast in place concrete with horizontal lap spliced reinforcement in the upper layer as shown in Figure 7. Horizontal reinforcement in the lower side of the slab is not continuous through the joint.

The facade is made by prefabricated concrete elements with thickness 120 mm. The façade elements are loosely connected towards slabs and columns with brackets. These walls provide stiffness for normal loads such as wind. For seismic loading these walls with major window openings are vulnerable for failure. Due to the openings these walls are not included in analysis model.

In the transverse direction of the building the lateral force resisting system is dominated by the concrete shear walls with thickness 100 mm distributed at given axes. The shear walls are loosely connected towards beams and columns with brackets. These walls provide stiffness for normal loads such as wind. For seismic loading these walls are vulnerable for failure. These walls are included in the analysis model.

The total system is a combination of walls and columns, and according to EC8 the structure is defined as dual system.

3.2.2 Material Properties

3.2.2.1 Concrete

The concrete design of the Hospital is originally performed according to Cuban design code at the given time of erection. In this project information relies on available drawings and visit on site. By inspection on site concrete surfaces looks good with absence of cracks and sign of spalling due to reinforcement corrosion. No “on site” concrete tests have been taken.

Concrete prefabricated elements have been produced in factories. It is not likely that the production quality surveillance system follows the Eurocode requirements. Precast elements are told to be built with consistent steel quality G40. Cast on site joints might be reinforced with “available” reinforcement in example G60 which have is a less ductile steel quality.

Concrete compression strength is told to be B25 which has characteristic compression strength of 25 MPa. Concrete cover is told to be 30 mm.

3.2.2.2 Steel

There are two steel factories in Cuba producing steel rebar for the construction industry. Characteristic for the structural rebar steel is a relatively high carbon content which gives a reduced maximum strain and also makes the steel not suitable for welding. Typical steel qualities are given in Table 1.

Table 3.1 Material Properties of Steel

Steel	Fsy [MPa]	Elongation at fracture [%]	Equivalent carbon content
G40	300	12	0.384
G60	420	9	

Although the Giron system was designed based on G40 steel, most of the buildings had been constructed using the G60 steel. Therefore, it was assumed that G60 steel was used in all the computations.

Local experts at CENAIS and Universidad de Oriente informed us that, although the Giron system was designed based on G40 steel, most of the buildings had been constructed using the G60 steel. Therefore, it was assumed that G60 steel was used in all the computations.

3.2.3 Knowledge level

The knowledge level was decided as knowledge level 2 (KL2) based on the guidelines in section 3.3 and Table 3.1 of EN1998:3.

Accordingly, a confidence factor of CFKL2=1.2 was adopted in the assessment. Consequently, the material properties that are used in the analysis were computed as

- Concrete compressive strength:

$$f_c' = {}^{f_c'}\!/_{CF_{KL2}} = {}^{25}\!/_{1.2} = 20MPa$$

- Steel yield strength:

$$f_y = {}^{f_y}\!/_{CF_{KL2}} = {}^{420}\!/_{1.2} = 350\ MPa$$

4 BASIC FOR SEISMIC ASSESSMENT

The structural analysis of the selected hospital building is based on Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings

The response analysis is conducted by implementing Response Spectrum Method (Linear Dynamic-based method) which is a linear mode combination method. The analysis is done with a q-factor 1.5 thus nonlinear structural response is incorporated on the load side of the capacity equation

4.1 Static Loading and Member Utility Levels

During a seismic event, the utility levels of the structure due to dead load in the accidental limit state must be superposed with seismic loading to achieve total loading situation to be finally checked against code strength requirements. Governing loads are shown in table.

Table 4.1 1oad Table Static Loads on Floors

Load	Number	Unit
Live load floors[1)]	3.0	kN/m2
Density concrete	25	kN/m3

1) Assumed LOSA 300A L-1.1, GIRON

Simplified capacity checks are made of initial load situation to be superposed with seismic loading. The results are given in Table 4 together with comment on possible failure mechanisms.

Table 4.2 Results utility ratios for static loading in ACC limit state

Structural element	Max Utility ratio	Possible failure mechanism in seismic event
Foundation plate	Low	Failure not likely
Pedestal	0%	Shear failure
Column	Low	Bending/Shear failure
T-beam	Medium	Shear failure (under interior walls)
Floor slabs1)	48% bending,26% transverse shear	Failure out of plane not likely. Failure in plane
Walls	0%	Buckling out of plane likely

4.2 Numerical Modelling and Selected Models

The software SAP2000 is used for both modelling and analysis.

SAP2000 software is used for the dynamic analysis of structures with seismic isolation and energy dissipation systems. It can analysis both nonlinear static (push over-analysis) and nonlinear dynamic analysis (Time history analysis) under different ground motions.

By using SAP2000 software we can analysis Linear and Nonlinear Dynamic analysis, Equivalent static analysis and structural modelling and analysis. (Wilson,2005).

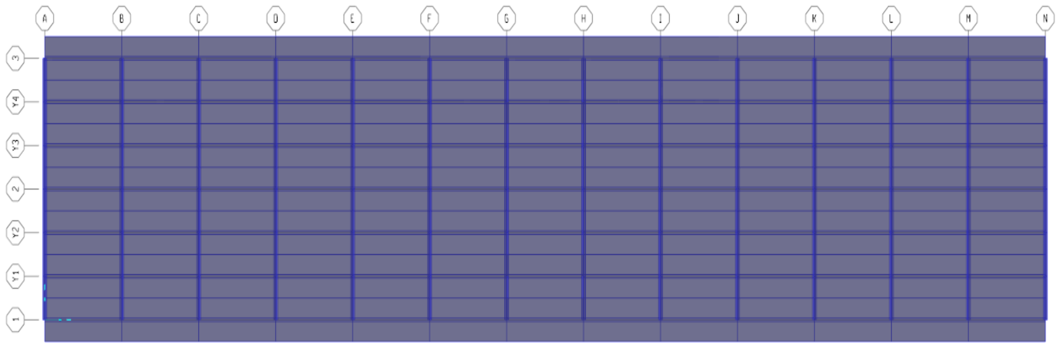
In general, the sap2000 software program adds unlimited capacity, bridge live load analysis capabilities, a complete range of finite elements frequency domain analysis (both steady-state and power spectral density). Ground motion effects with multiple base excitations can be involved.

In advance, you can get detail analysis by SAP2000 about a nonlinear (gaps, hooks, isolations, dampers, and multi-linear plasticity), a multilinear plastic hinge for use in farm elements, fibres hinge, a catenary cable element, a nonlinear shell element, and geometric nonlinearity analysis for material and geometric effects by modal superposition or direct integration and buckling analysis(Wilson,2005).

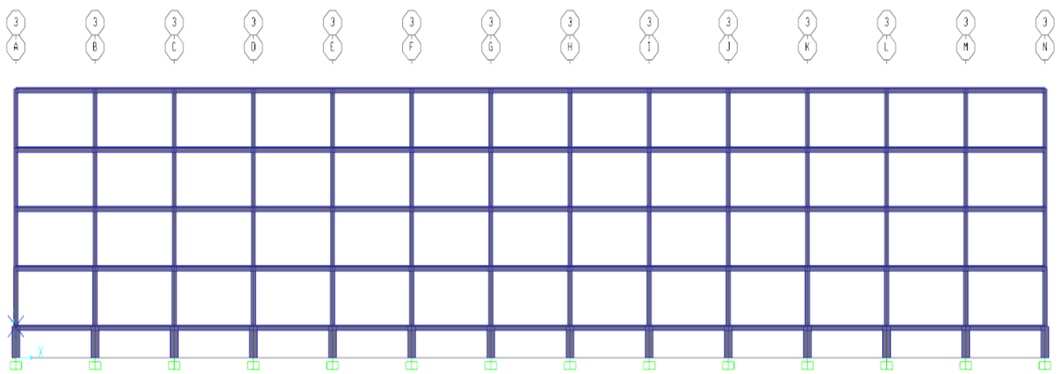
SSAP2000 modal analysis is about the calculation of dynamic modes of the structure using eigenvector or Ritz-vector method. Loads are not applied, although they can be used to generate Ritz vectors. And Response-Spectrum Analysis is the statistical calculation of the response caused by acceleration loads. It also requires response-spectrum functions.

When an analysis is run, SAP2000 automatically converts the object-based model into an element-based model that is used for analysis. This element-based model is called the analysis model, and it consists of traditional finite elements and joints (nodes). Results of the SAP200 analysis are displayed in the analysis model. SAP2000 provides options to control how the meshing is performed, such as the degree of refinement, and how to handle the connections between intersecting objects (Wilson,2005).

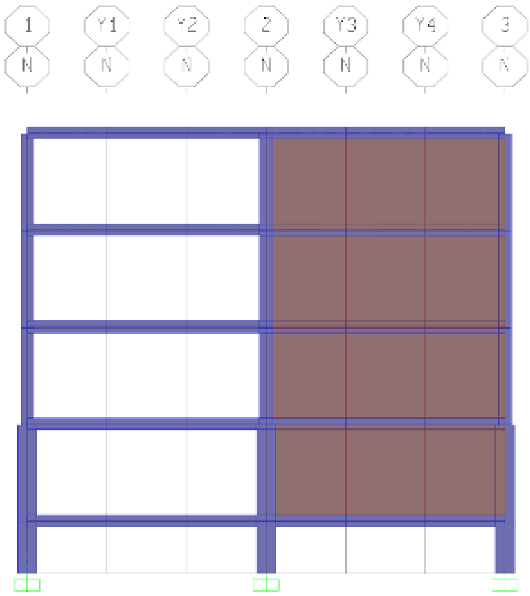
For the hospital building, the analysis model is made by shell elements for slabs and walls. Pedestals, columns, and beams are modelled by frame elements. The pedestals are modelled as fixed at a level -1.75m below base slab. The analysis model with modelled sections is shown in Figure 11



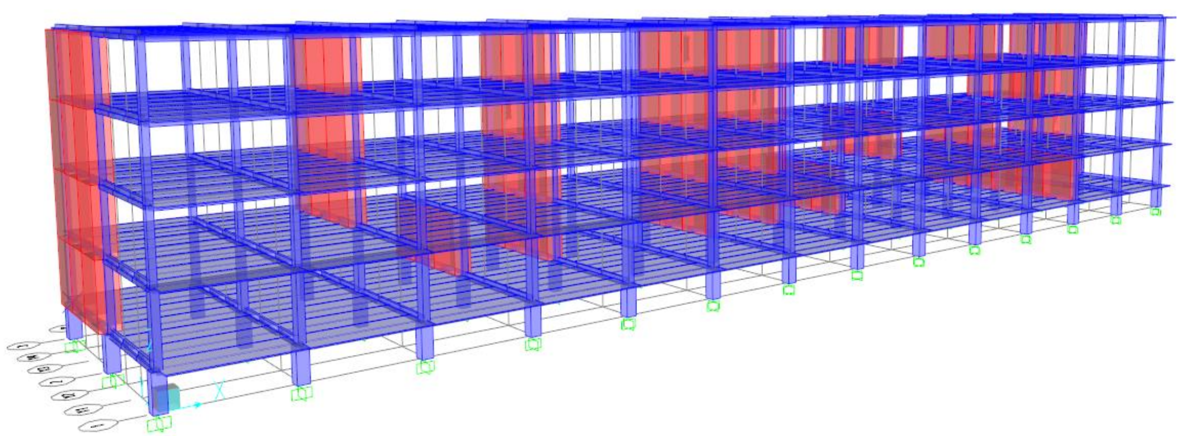
a) X-Y view of the building



b) X-Z view of the building



c)Y-Z view of the building



d) 3D view of the building

Figure 4-1- Numerical model of the hospital building in SAP2000

The level of rigidity and flexibility at the joint where beams are connected to columns and walls can significantly affect the overall behaviour of the structure.

For precast structures, like the case of the present building understudy, the connection cannot be assumed rigid, and the option that we have is to consider flexible and partial fixity connection of beams to columns and walls

In general practice, the connection of both beams to columns and walls at the joint for cast in-site concrete structures are modelled as rigid with fixed connection.

In the following, a partial fixity model, model 1, was created to be the case of the present structure, precast structure.

To get a clear picture regarding the weakness of this type of structure, a second model, model-2, was also created with fixed connection, representing the case of cast in-site structure, to compare the differences in terms of seismic performance.

4.2.1 Model-1: Pinned and Partial Fixity Connection between structural members

A pinned connection permits rotation in the joint between members (allows all connected members to rotate freely, i.e. moment equals zero.) The beam-column joint is modelled using centrelines to centreline, which is the simplest modelling approach, where the beam section is continued to the column center.

A pinned connection permits rotation in the joint between members (allows all connected members to rotate freely, i.e. moment equals zero.) The beam-column joint is modelled using centreline to centreline, which is the simplest modelling approach, where the beam section is continued to the column centre.

When the connection is fixed partial and pinned it will cause the irregularity of force distribution under lateral loading, these irregularities can lead to stress concentrations and localized lateral drift that may be difficult to quantify and accommodate in design, and in some cases may result in an undesirable seismic response. (Eurocode 8)

The body of partial connections are not symmetry and the stiffness, and the mass is not proportional, and the stiffness is not in the centre of the mass. these indicate that the beam-column joints exposed for irregularity and torsional may happen so that makes to be crack and damage easily because of torsional the stiffness splitting from each other’s and the strength going to weakened (Eurocode 3 & Eurocode 3

Besides lateral resistance and stiffness, building structures should own adequate torsional resistance and stiffness to limit the development of torsional motions which tend to stress the different structural elements in a non-uniform way. In this respect, arrangements in which the main elements resisting the seismic action are distributed close to the periphery of the building present clear advantages (Eurocode 3).

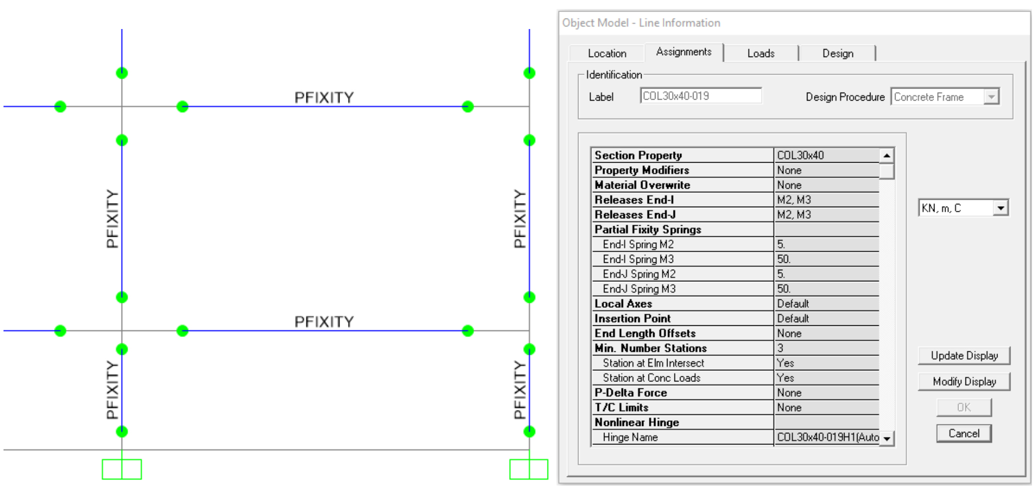


Figure:4.2-Partial fixity connection by releasing moment M2, M3

4.2.2 Model 2: Fixed Connection between structural members

A fixed connection prevents rotation of connected member(s). The beam-column joint is modelled using rigid link. The rigid link connects the end of the beam at the column face to the column.

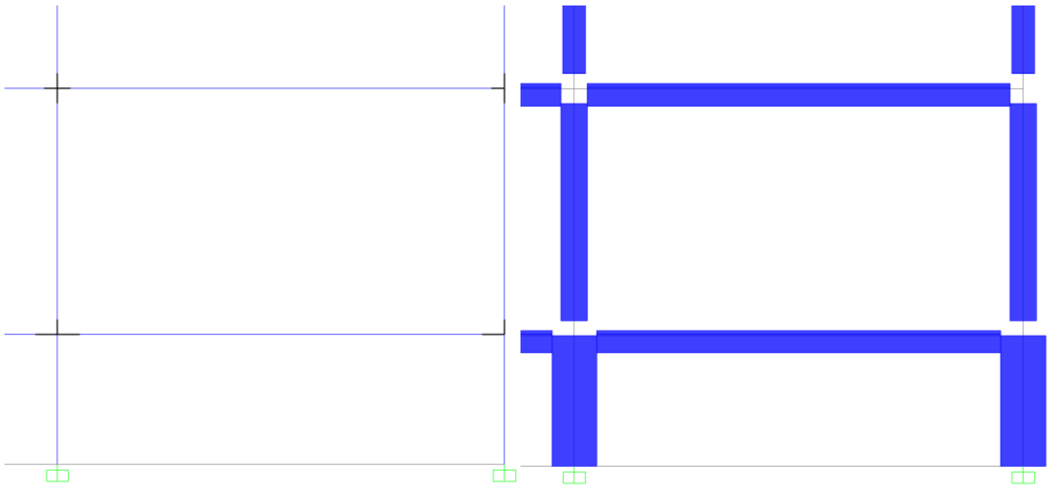
A fixed connection prevents rotation of connected member(s). The beam-column joint is modelled using a rigid link. The rigid link connects the end of the beam at the column face to the column.

At the joint connecting the shear force and the momentum are well distributed without any irregular partial distribution. While the fixed connection lateral force distributed in equal with the centre of the mass the stiffness has more near each other's so the strength gets more and more stiffness, and the mass is proportional to each other's when stiffness is symmetry and at the centre of the mass, the connection may not make torsion so the fixed one has more strength and stiffness when the fixed connection the diaphragm connectivity In a building braced by structural walls, inertial forces generated by building vibration is transmitted through diaphragms to the walls, which in turn transmit the forces to the foundation. (Eurocode3 &Eurocode8)

Good diaphragm transferability is helped by solid diaphragms surrounding walls, rather than significantly perforated diaphragms. So when the fixed connection the force distribution may not displace the internal tensile and forces so it depends on the ductility of the materials and the strain and strain capacity of the materials which we use during the construction. In general, When we design beam-to-column joints to the column minor axis and major axis should be considered because of the thickness of the column is limited according to Euro-code 3 are considered, the adopted design process generally assumes these joints as pinned (Eurocode3 &Eurocode8).

Throughout the analysis of a beam-column using the ordinary idealized structural unit method, an element is regarded to be elastic until the fully plastic condition and/or the buckling criterion is satisfied. When the axial force is in tension, a relatively accurate ultimate strength may be evaluated with the former conditions along with the post-yielding calculation.

However, when the axial force is in compression, the ultimate strength evaluated by the latter criterion is not so exact, as the latter criterion is based on a semiempirical formula ((Eurocode3)



Modelling beam-column connection using rigid link (the most common for cast in-site concrete structures)

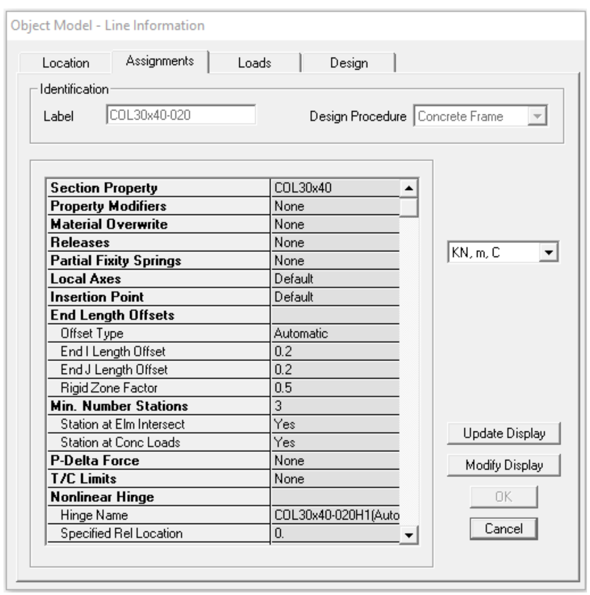


Figure 4.3- Assignment of level of rigidity for cast in-site concrete members

4.3 Selected Methodology for Seismic Analysis

4.3.1 Defining Seismic Action

One of the pillars of the seismic assessment procedures is the definition of the seismic action that will be used in the assessment. As per Eurode-8 requirement, the ground motion to be implemented for seismic assessment to Significant Damage limit state is defined by using design spectrum standing for a 475-year event.

In the assessment of the hospital building, both Eurocode-8 design spectrum (CEN 2004) and Cuban design spectrum (NC 46, 1999) were implemented to define the seismic action, and the demand is taken as the maximum response obtained from all the different combinations (as per EC8 and Cuban Code) for the two records.

Eurocode-8 design spectrum are anchored at the peak ground acceleration (PGA) value and require only the PGA value as a ground motion parameter to be created.

Peak ground acceleration for a 475-year event for Santiago de Cuba has been estimated as 2.75 m/s2 by Garcia et al. (2008). This value has been adopted in the seismic assessment of the building. Another important point in defining the response spectrum is the soil type. Unfortunately, not much information could be achieved on-site regarding the soil.

Table 4.3. Parameters used in the computation of seismic action.

Input	Value	Code and reference
Q	1,5	As per point 4.2(3) of EN 1998:3
Seismic class IV	1.4	4.2.5, Table 4.3
A_g	2.75 m/s^2	Garcia et al. (2008)
Soil type C[1)]		3.2.2.2 of EN 1998:1
Spectrum Type 1		3.2.2.2 of EN 1998:1

Following the recommendation from CENAIS, the soil type was assumed to be class C (shear wave velocity, vs30, between 180m/s and 360 m/s). Finally implementing an importance factor of I=1.4 (importance class IV) and q-factor of 1.5, the following response spectrum is created and used in the seismic assessment of the existing building. The parameters that have been used to define the seismic action are summarized in Table 2. The resulting EC-8 response spectrum is depicted in Figure 8.

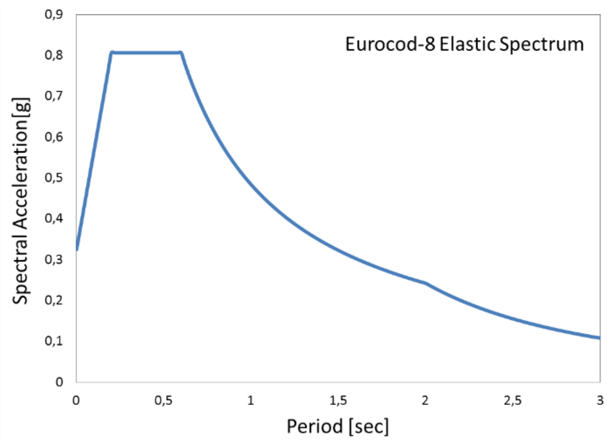


Figure 4.4- Eurocode-8 Response Spectrum Used In Seismic Assessment Of The Existing Building In Santiago De Cuba

4.3.2 Modal Analysis

In seismic assessment, a modal analysis precedes all other analyses, and is carried out in order to understand the dynamic properties of the building.

4.3.3 Linear Dynamic Analysis

Using q-factor method, modal response spectrum analysis is carried out to compute the effect of seismic loading (in addition to the gravity loads) on the building and the components of the building. In accordance with EC-8 and Cuban seismic code (NC 46-1999), the seismic action has been combined with the gravity loads (permanent and live loads). As a result, a total of ten load combinations (eight for EC-8 and two for NC 46) have been created and applied.

The safety evaluation of each structural element in the building (i.e. column, beam and walls) is conducted for each of the ten load combinations at two ends of each element. This leads to 20 sets of demands that consist of axial load (N), shear force (V) and moment (M) for each element. The values of these different demands are calculated at maximum response displacement of the building for each of these given combinations.

The most critical force demand in each structural element obtained from these ten load combinations has then been compared with the respective capacity of the element in order to verify if that particular element satisfies the Significant Damage limit state, which is the target performance level assessed in this study.

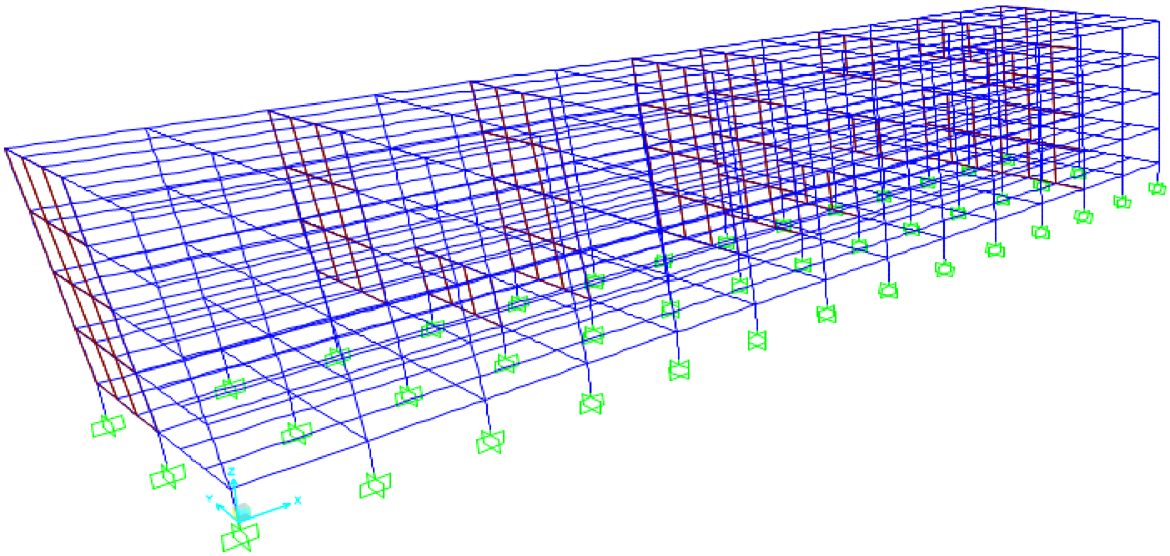
In accordance with EN1998:1 point 3.2.4, the seismic action is combined with the gravity loads. As a result, a total of eight load combinations are created and applied:

$$1.0Q + 1.0G \mp 1.0E_x \mp 0.3E_y$$

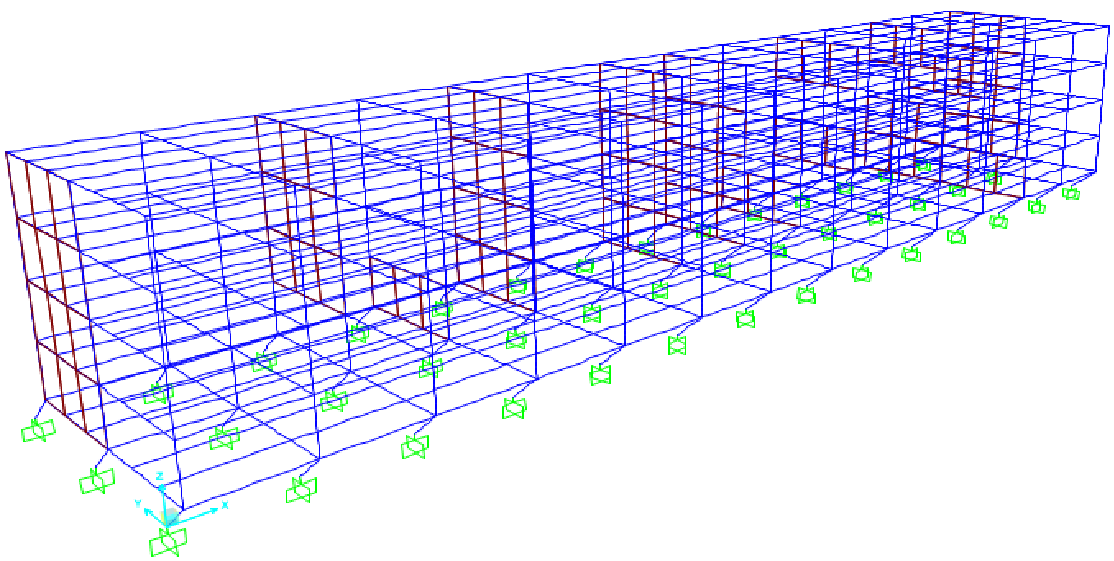
$$1.0Q + 1.0G \mp 0.3E_x \mp 1.0E_y$$

5 SEISMIC BEHAVIOUR OF THE HOSPITAL BUILDING RESULTS AND DISCUSSION

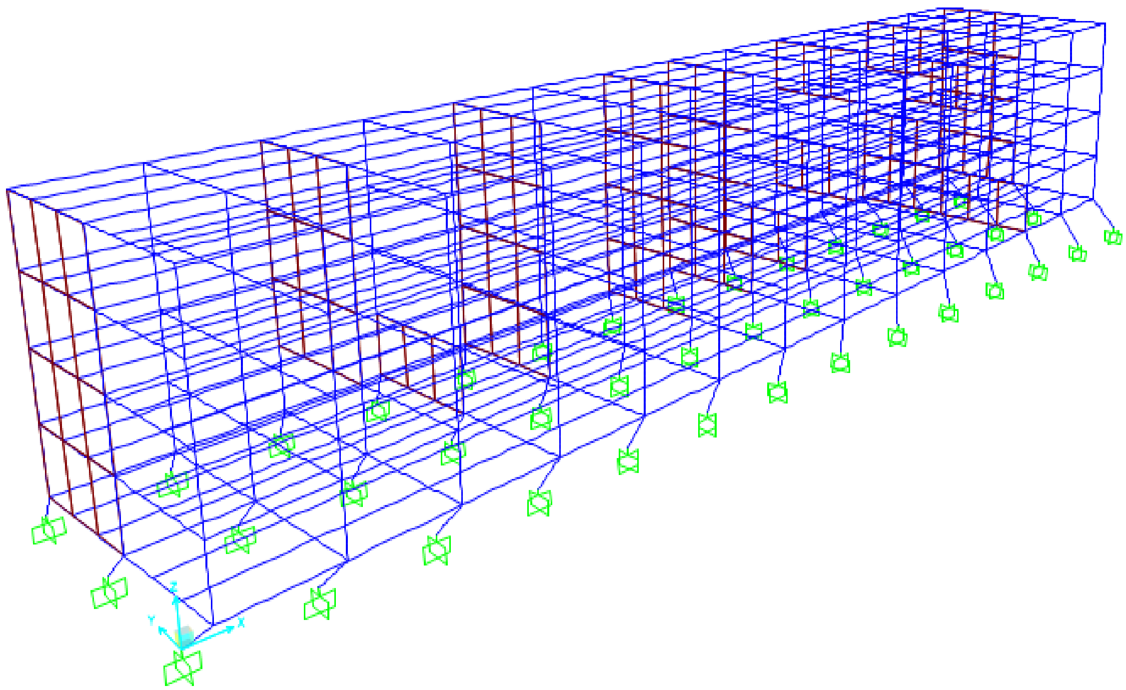
5.1 Result of Modal Analysis



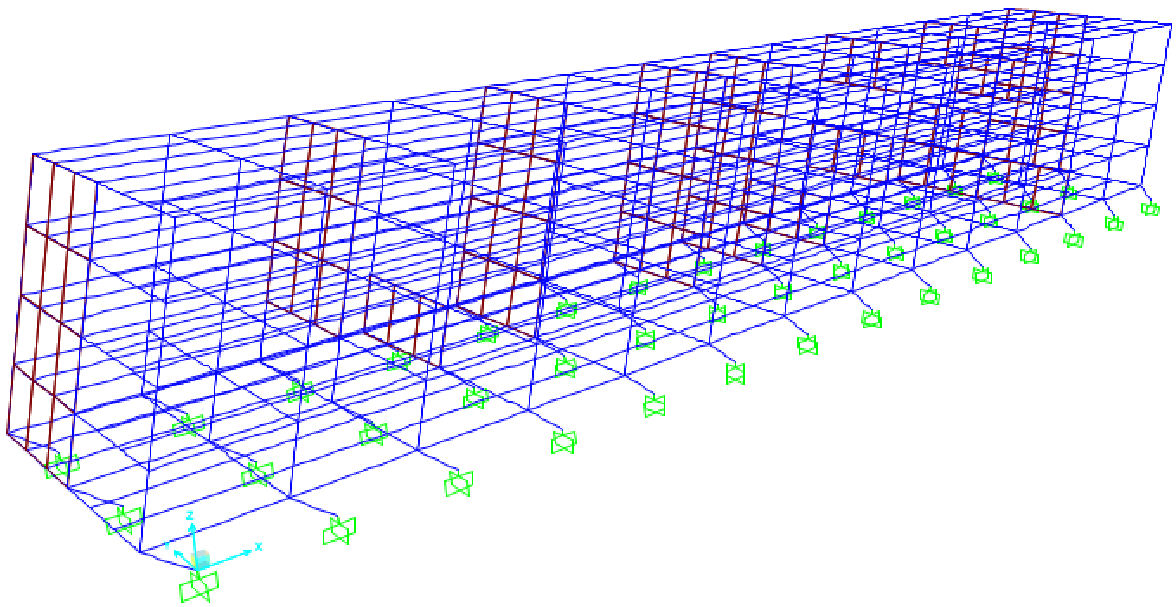
Mode 1



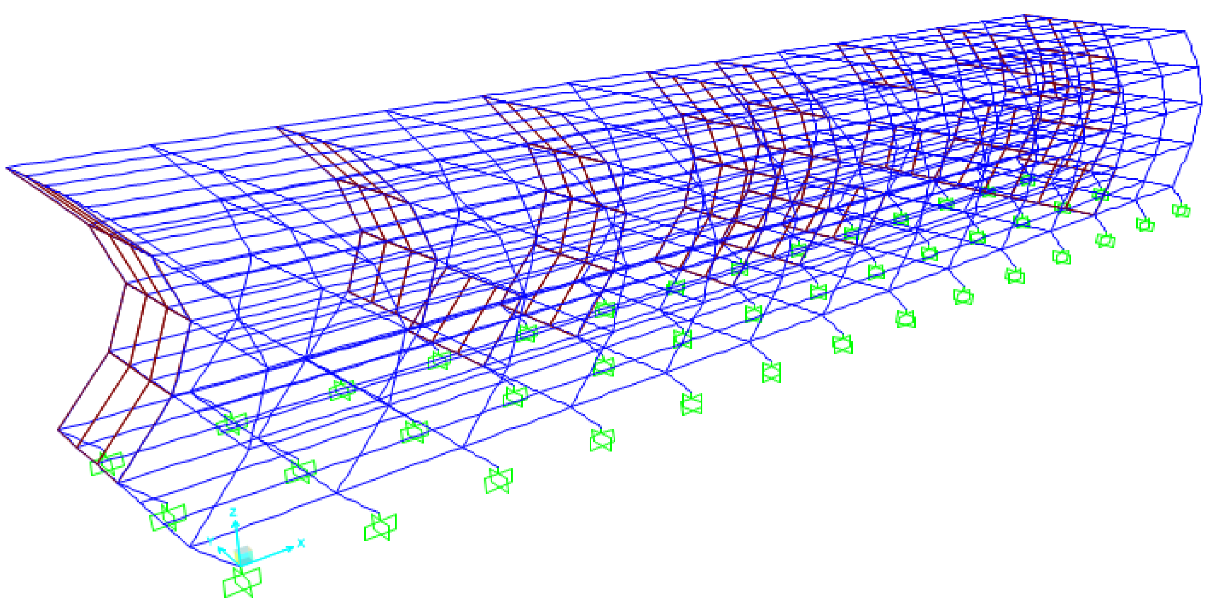
Mode 2



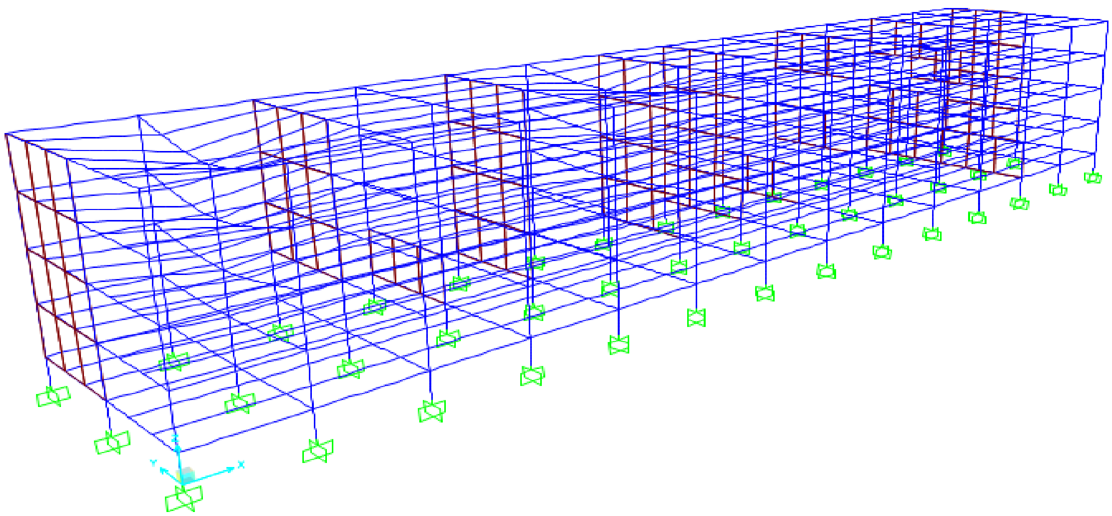
Mode 3



Mode 4



Mode 5



Mode 6

Figure 5.1-Result of Modal Analysis

Mode	Model-1 (Partial Fixity Connection)				Model-2 (Fixed Connection)			
	Period (sec)	Modal Participating Mass Ratios			Period (sec)	Modal Participating Mass Ratios		
		UX	UY	UZ		UX	UY	UZ
1	10.326058	0.71298	2.483E-12	1.394E-14	0.607999	0.69451	2.628E-08	7.343E-10
2	3.799251	3.084E-12	1	1.577E-10	0.121567	0.000006718	0.691	0.00031
3	2.340726	0.000007693	1.238E-08	3.675E-11	0.110909	0.00009572	0.20994	0.00005814
4	1.16331	0.28701	4.797E-14	1.986E-13	0.095586	0.1681	0.00004992	3.147E-08

5	0.07784	0.000003943	2.048E-13	5.714E-08	0.0614	1.287E-09	0.00001621	0.02485
6	0.062945	4.907E-14	4.14E-12	0.05037	0.06138	9.241E-09	0.00001082	0.02534
7	0.062944	3.572E-13	8.898E-14	0.0153	0.061361	4.984E-10	0.00001096	0.01943
8	0.062944	6.349E-16	8.535E-15	0.00002331	0.054211	4.852E-07	0.00463	0.05867
9	0.060077	2.97E-11	4.778E-08	0.01448	0.053994	0.000000326	0.0001	0.00482
10	0.055697	5.909E-11	2.521E-09	0.02582	0.053297	8.58E-11	0.00087	0.03948
11	0.054795	7.386E-12	8.386E-10	0.00219	0.051587	8.177E-11	0.00001422	0.11923
12	0.054423	3.357E-12	3.774E-09	0.03946	0.051532	1.076E-09	6.169E-07	1.523E-07

13	0.052437	4.761E-11	4.173E-09	0.00467	0.051438	1.296E-08	0.00000214	0.01258
14	0.051712	2.742E-15	1.918E-12	0.04729	0.051296	5.424E-09	9.683E-07	0.000008338
15	0.051708	2.008E-16	4.035E-14	0.00458	0.051104	2.848E-08	0.00001296	0.00285
16	0.051707	8.866E-15	6.257E-13	0.00691	0.050927	0.000000051	0.00002813	0.01532
17	0.051698	1.793E-15	8.387E-14	0.01689	0.050855	7.914E-10	0.00001647	0.00178
18	0.051694	1.492E-16	6.947E-14	0.04868	0.050685	4.584E-09	0.00001297	0.02039

Table 5.1 The description of Analysis Model_1 and Model_2

In the Result of Modal analysis, we have used SAP2000 software by comparing both partial fixed and Fixed model, so when we look at from table Models results, the Partial Fixed Model from 1 to 6 shows the mass Ratio of X, Y, Z in the Model and the period of the Model in this result we learnt the partial fixed Model took more period in Second.

But on the other hand, when we look at the Result of Fixed Part of the Model has it has a low period, in second.

According to the modal results we have compared in Table 5.1, about the mass ratio in both Partial Fixed and Fixed and Period, But coming to the point the result of Modal Analysis it depends on the period, that means the one has more period gives law Frequency contrary to that point the one has a low result of the period has high Frequency. So, The Modal Analysis gives us the result of how our modal has a resistance during an earthquake, that means the one has high frequency has a high possibility of resistance of Earthquake, and the one has low frequency cannot resist earthquake this what we have analysed by using modal analysis.

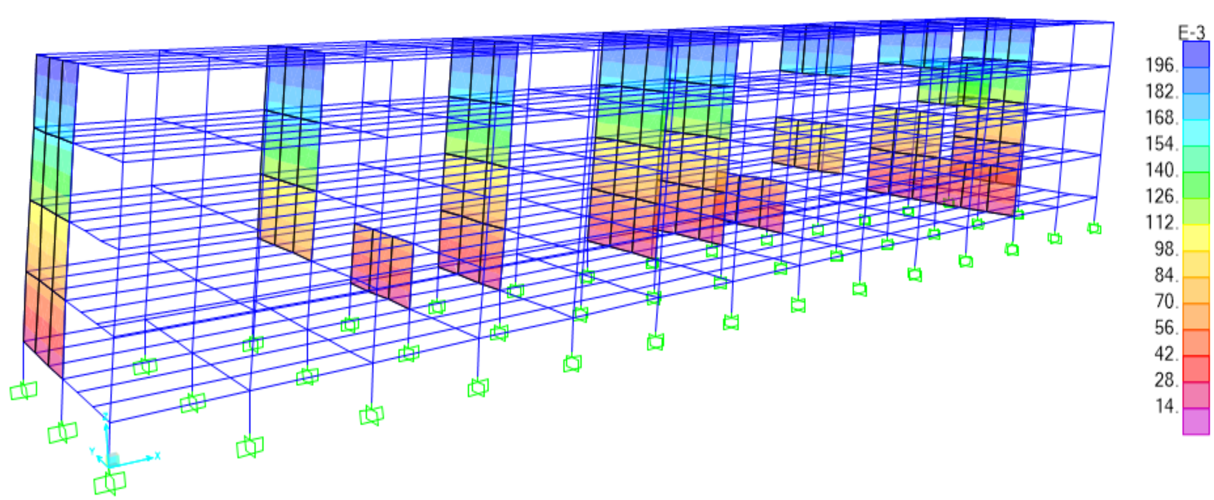
The resistance of Earthquake is directly proportional to Frequency and Inversely Proportional to Period

Conclusion, the Partial Fixed model has a low capacity of resistance and those Fixed Model has High capacity of resistance due to Earthquake analysis. I have Put some of the Frequency results of each modal analysis. (Chopra,2013)

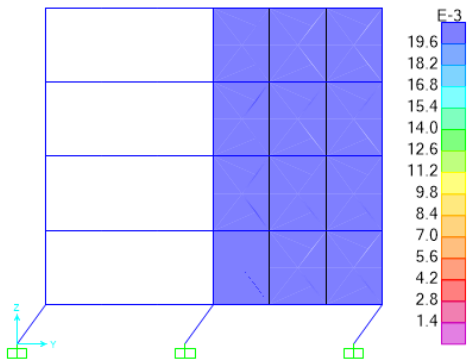
Table 5.2. The Result of Modal Analysis based on Period and Frequency

Number of Models from	Partial Fixed Model Period	Partial Fixed Model Frequency	Fixed Model Period	Fixed Model Frequency
1	10.326058	0.0968	0.607999	1.4398
2	3.799251	0.2632097748	0.121567	8.225916573
33	2.340726	0.4272178803	0.110909	9.016400833
4	1.16331	0.8596160955	0.095586	10.46178311
5	0.07784	12.84686536	0.0614	16.28664495
6	0.062945	15.88688538	0.06138	16.29195178

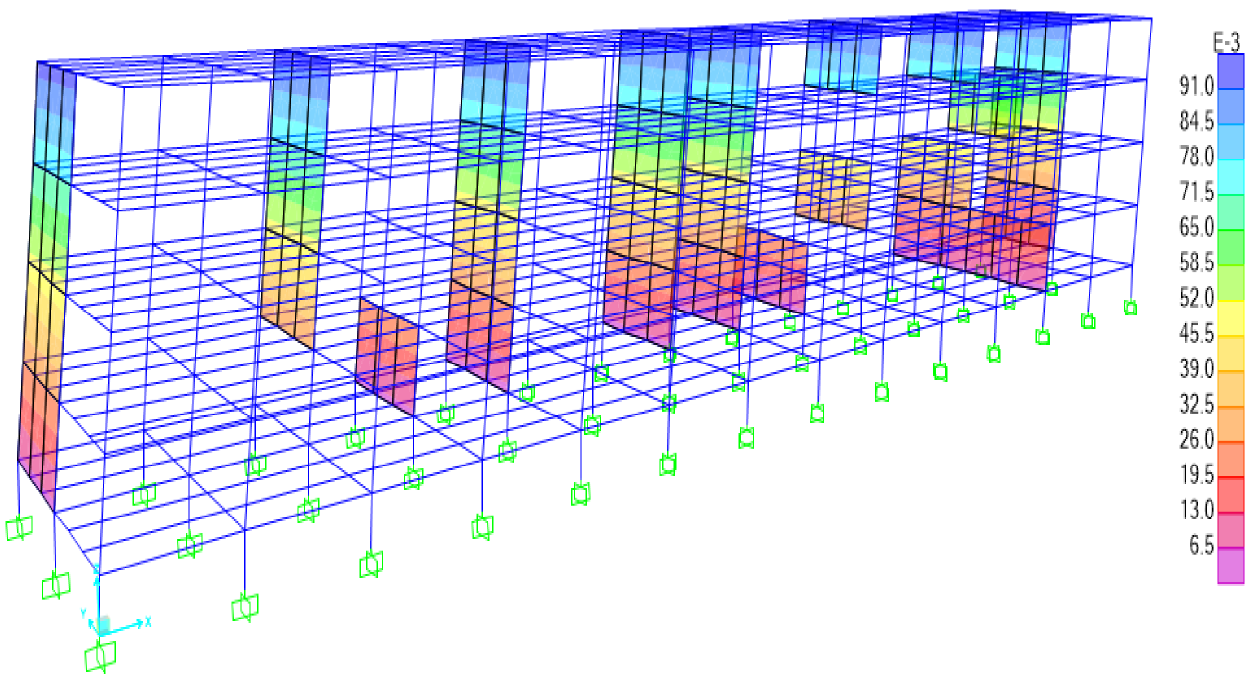
5.2 Result of Linear Dynamic Analysis



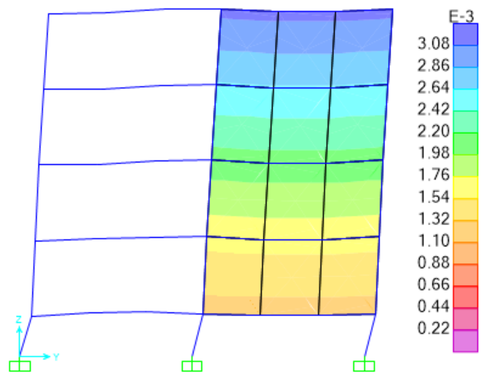
a) Model-1: Response spectrum analysis and computation of seismic demand in **UX** direction



b) Model-1: Response spectrum analysis and computation of seismic demand in UY direction

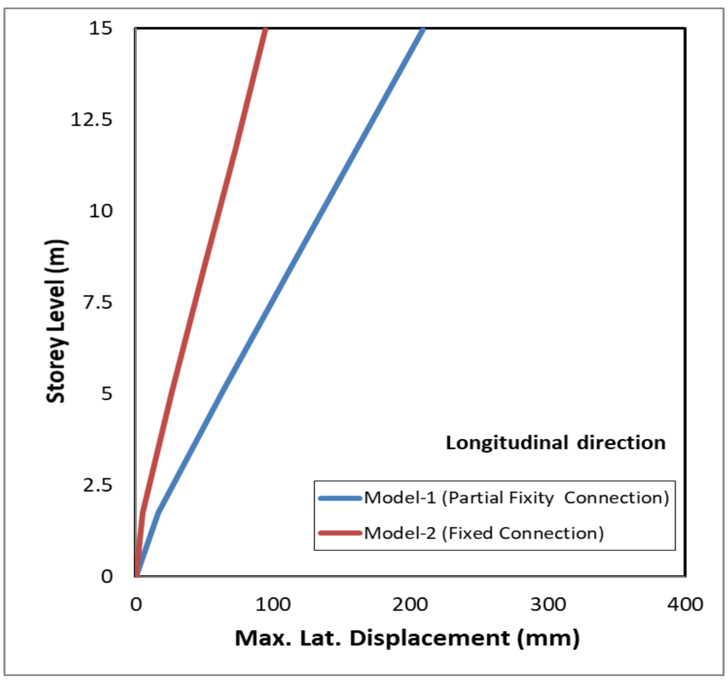


c) Model-2: Response spectrum analysis and computation of seismic demand in UX direction

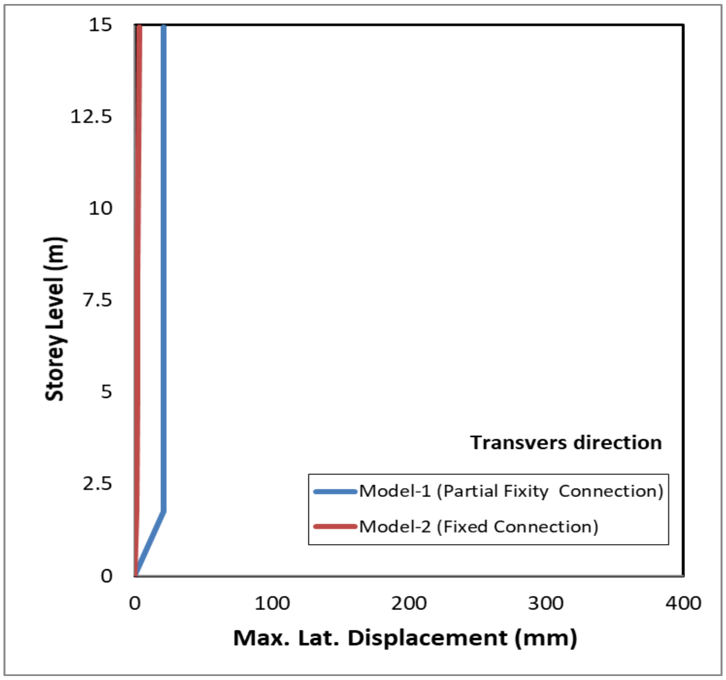


d) Model-2: Response spectrum analysis and computation of seismic demand in UY direction

Figure 5.2-Response spectrum analysis and computation of seismic demand

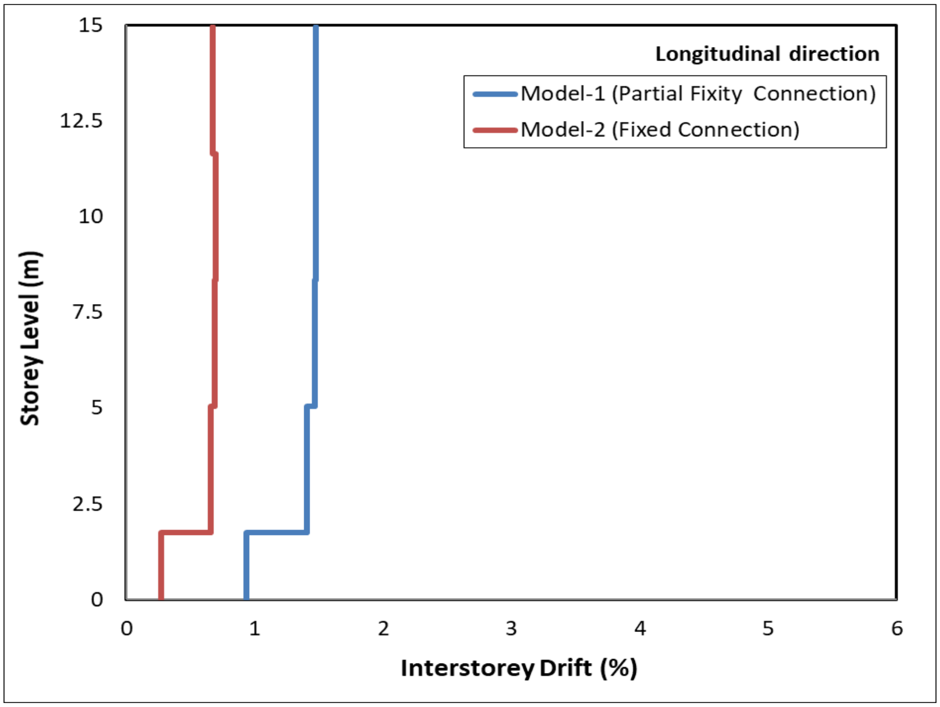


a) Maximum Lateral Displacement in UX Direction

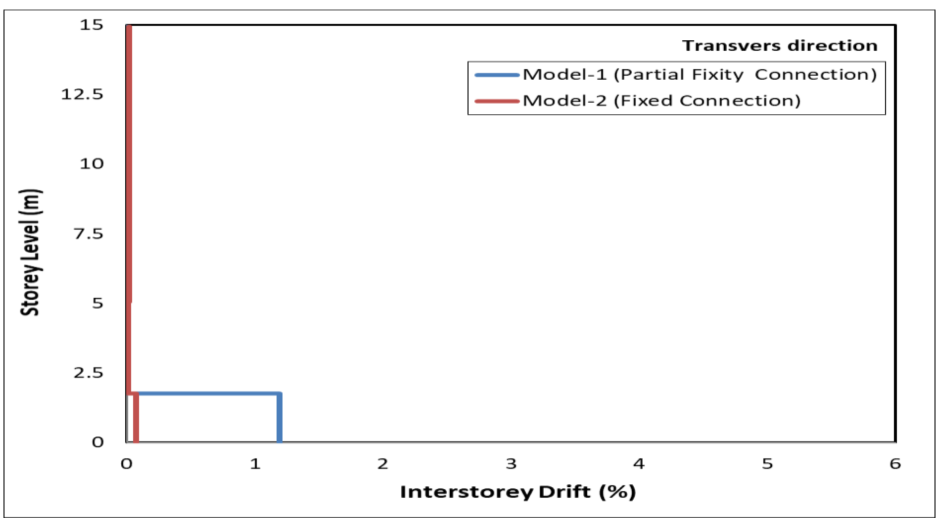
b)


b) Maximum Lateral Displacement in UY Direction

Figure 5.3- Maximum Lateral Displacement



a) Maximum Interstorey Drift in UX Direction



b) Maximum Interstorey Drift in UY Direction

Figure 5.4-Maximum Interstorey Drift

Table 5.3 Lateral seismic demand displacement from response spectrum analysis

Response spectrum analysis in UX direction		Response spectrum analysis in UY direction	
Model 1 (Partial Fixity Connection)	Model 2 (Fixed Connection)	Model 1 (Partial Fixity Connection)	Model 2 (Fixed Connection)
20,89cm	9,42 cm	2,09 cm	0,19 cm

Table: 5.4 Base Reaction (Shear) From Response Spectrum Analysis

Response spectrum analysis in UX direction		Response spectrum analysis in UY direction	
Model 1 (Partial Fixity Connection)	Model 2 (Fixed Connection)	Model 1 (Partial Fixity Connection)	Model 2 (Fixed Connection)
227.82 KN	13105.65 KN	145.59 KN	10169.03 KN

In the Result of Linear Dynamic Analysis, We have summarized above in table 5.3(Lateral seismic demand displacement from response spectrum analysis) and 5.4 (Base Reaction (Shear) From Response Spectrum Analysis), with, comparing both the Model_1(Partial Fixity Connection) and Model_2(Fixed Connection). So, coming to the result, While the earth shakes, what we observed from Table 5.3 in both X and Y direction the Partial Fixed Model_1 has more displacement value in cm, and the Fixed Model has low displacement in cm in both X and Y direction.

According to linear dynamic analysis, the one has more displacement in both X and Y direction has a low capacity of resistance against earthquake, likewise, the one has low displacement has the capacity of the resistance from the earthquake disaster.

At the same level in Table 5.4, we have seen the result of Base Reaction Shear Force from response spectrum analysis, with, comparing both Partial Fixed Connection (Model_1) and Fixed Connection(Model_2), the partially fixed connection has a very small amount of Shear Force in KN, likewise, the Fixed Connection has more Shear force in KN, so, from this observation the one has more shear force has more capacity to resist the reaction of Earthquake, while the one has low shear force is exposed for earthquake disaster.

Conclusion, According to the assessment what we have got a lesson from above, both table results as the Partial Fixed Connection is exposed for earthquake disaster and it has also, a low capacity to resist the reaction of Earthquake. Whereas, the Fixed Connection has the capacity to resist the reaction of Earthquake.

From this result of linear dynamic analysis, the Fixed connection Model has a high capacity to resist the earthquake, based on this result analysis, the region which is exposed for high seismic should be built by Fixed connection Model_2 to get protected from the unexpected disaster of an earthquake in the meantime, most today modern analysis, they use the major axis by linear dynamics analysis instead of analysing the minor axis by nonlinear analysis the one which uses FEM. (Chopra,2013)

5.3 Discussion

In this thesis, most discussion based on the analysis and the observations and designed in each modal analysis and the journal of the references, which is used as assessment and analysis witness, based on the result of Modal Analysis and modal linear dynamic analysis?

When we examined, the precast reinforced concrete why it has failed during an earthquake? according to the researcher's test assessment, before and after the earthquake, the result exposes about the weak design of precast reinforced concrete and also because of the economic problem they were using the one designed in another country which has no the design knowledge of the country seismic resistance code.

So, because of these, the country was exposed to seismic disasters for several years. Furthermore, the researcher's testing assessment apparatus about the damaged of precast reinforced concrete exposes, an important result as it has a lack of design materials and those were designing the precast reinforced structures, as they were not considering the ductility of the material strain and stress ability of design materials in the reinforced construction.

Elsewhere, the reason of the lack of design code, in most of the figures as shown in this thesis, the cracks of pear and the column to beam connection was easily fragile and exposed to damage during an earthquake.

Moreover, the discussion from researchers referred, mostly the design weakness of the structure was not only in precast reinforced concrete but also there was a weak analysis of the soil mechanics, which was not considered the strong ability of the soil mechanics, and the durability of soil mechanics, it is basic and particularly important in any construction design analysis.

The assessment result of the Hospitals in Cuba which built by precast reinforced concrete, it has not only weak because of built by precast reinforced concrete but also the building has irregularity shape, which means the mass and the stiffness was not proportional to each other.

Furthermore, the column to beam connection and walls joints were not connected very well and its connection dispersed from each other and it may expose unexpectedly for the earthquake disasters.

Besides the fact that, in the result of Modal analysis and linear dynamic analysis, the analysis deeply investigating and gave lesson us in each modal beam to column and wall joints connection in the x-y direction, there the result confirms that the Fixed Connection (Model_2) as it can resist the seismic disasters.

As the result of Comparing in both model of the cast-in-situ concrete structure and the precast structure. Highly recommended cast-in-situ concrete structure, as it has more stiffness and resistance capacity against seismic disasters. So, mostly recommend using the existing cast-in-situ-concrete structure for those regions exposed to high Seismic disasters.

6. CONCLUSIONS

The conclusion will be short and understandable, based on the study result in this thesis, and discussion.

Further assessment, the performance of precast reinforced concrete and the cast-in-situ concrete structures, with detail analysis by using each modal design column to beam and walls joints connections.

In one attempt of being the connections true behaviour, which analysed in partial fixed and Fixed connection, many models were changed, for the major axis, Based on the fact that, partial fixed (Model_1) has low capacity against the resistance of the earthquake disasters, while, the Fixed connection(Model_2), has a strong capacity to resist the resistance of earthquake disasters.

In both model's assessment results, the modal response spectrum lateral shear force, which holds the internal beam to column and joints connections and the linear dynamic analysis, which examine, the internal mass ratio and period.

According to modern Technology, Eurocode 3 and Eurocode 8 resistance against seismic is depended on the beam to column and walls joints connection, one of the most crucial factors affecting the strength and stiffness.

In a Fixed design Model, the design of the model can be applied to any kind of joint (major or minor axis) as a set of components (springs) assembled in series or/and in parallel.

The comparison between curves obtained from the proposed model (Eurocode.8-resistance seismic).

Finally, the model is analysed with modal analysis and linear dynamic analysis -based on each design model. These direct applications of this model will be used throughout the paper in all analytical calculations for the moment–rotation response of the joints.

In addition to numerical simulations have been after performed to improve the damaging mechanism of the precast beam-column connection. In detail, the arrangement of the reinforcing steel has been updated to avoid the yielding of the steel inside the column and to move the plastic zone inside the beam.

The so-obtained damage pattern has been thus concentrated in the beam, allowing for easier restoration works that should be conducted after a severe earthquake.

When comparing to both the precast and cast-in the strength of both are quite different from each other.

According to, Modal analysis, the precast has exceptionally low strength to resist Earthquake. Whereas the cast-in-situ concrete structures have more double strength than the precast concrete structures.

As it explained, the earlier Hospital which supposed to in Cuba was built by precast reinforced concrete structures, and it has two systems of weakness.

1, The Hospital, which was built in Cuba built by precast reinforced concrete structures, it was having weak connections web to column and walls joint. Moreover, the structural elements were not symmetry to each other’s, the mass and the stiffness were not proportional to each other’s and many of its structural body exposed as irregularity, the one which exposes the structures for torsional.

2, The Hospital Precast Reinforced Structures is not good to recommend around a high seismic region because of the Precast Reinforced Structure itself has a low capacity to resist Earthquake disasters.

Assessments result, In the region which exposed to high seismic disasters, like Cuba, the Hospital will be built by Fixed design model, a cast-in-situ concrete structure model. because it has more ability to resist seismic disasters.

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B .LIST OF FIGURES

C. LIST OF TABLES