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Seismic Base Isolation of the Nunoa Capital Building

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Rene Lagos is President and CEO of Rene Lagos Engineers and senior specialist in structural and earthquake engineering. During his career heading Rene Lagos Engineers, Mr. Lagos has participated in the analysis and design of more than 9.000.000 square meters in different kinds of projects worldwide, with a special vocation for tall buildings such as the Telefonica Tower (Chile's tallest building until 1999), the Costanera Center Tower (current Chile and Southamerica tallest building) and the Nunoa Capital Towers (current America tallest residential base isolated building). Mr. Lagos is currently president of the Association of Structural Civil Engineers (AICE).

Ruben Boroschek, PhD is President and CEO of Ruben Boroschek and Associates and senior specialist in structural and earthquake engineering, seismic hazard analysis, and structural control and health monitoring. During his career, Dr. Boroschek has participated in more than 200 projects related to the seismic protection of power, petrochemical, mining, industrial, government, health, and residential facilities. Dr. Boroschek is currently Professor of Advanced Structural Dynamics at the University of Chile.

Rodrigo Retamales, PhD is senior specialist in structural and earthquake engineering at Ruben Boroschek and Associates. Dr. Retamales is specialist in seismic vulnerability and risk analyses, seismic protection technologies, and structural control for residential, office, industrial, health and critical facilities. Dr. Retamales is currently lecturer of Earthquake Resistant Design at the University of Los Andes.

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Mario Lafontaine is director of new technologies and senior specialist in structural and earthquake engineering at Rene Lagos Engineers. Mr. Lafontaine is specialist in structural analysis and design of tall buildings in high seismic regions and has participated in the seismic design of several structures in Chile, Peru, Ecuador, United States, United Arab Emirates, and Romania.

Abstract

The 2010 M_w 8.8 Maule Chile earthquake caused more than 30 billion US dollars in direct losses. The indirect losses remain unknown, but it is estimated that they far exceed the direct losses. Although the standard's seismic philosophy goal for this earthquake, collapse prevention, was largely achieved (less than 0.05% of the buildings collapsed), an important percentage of the buildings suffered disruptions and required extensive and unlikely repairs (and in a few cases demolition) contrary to the principles of sustainable development. In response to this, investors triggered an increased demand for the use of seismic protection technologies such as seismic base isolation and energy dissipation systems. This paper describes the selection process for a seismic protection system for the Nunoa Capital Building, the tallest isolated residential building in the Americas. A comparison of the seismic performance of this 33-story building (42,600 m² built) when protected with viscous walls and a lead rubber bearing base isolation system is presented. The challenges for the designing engineering team and the main design criteria that resulted in the use of 24 large diameter seismic isolators are presented. Nonlinear Response History Analysis performed using synthetic records specifically developed for the project site predicts an elastic building response, reductions close to 80% in both roof accelerations and interstory drifts, and permanent compression forces on the isolators. The resulting structure is expected to suffer null structural damage, and null to minimal nonstructural and content damage. In consequence, disruption or repairs are not expected, exceeding the objective of current seismic design standards, and replacing it by a more sustainable one.

Keywords

Tall building seismic isolation, outriggers, passive dampers

INTRODUCTION

The Nunoa Capital Building (see Figure 1), with a total constructed area of 42,600 m², consists of two identical towers, both rising 29 floors (75 m) above ground level and both intended for residential use. Around the towers, there are smaller 4 story buildings destined for offices. All the buildings share a common underground level, consisting of four floors. The seismic-resistant system of the building consists of an eccentric reinforced concrete core, as well as a perimeter frame and L-shaped walls in the corners. The floor system is comprised of post-tensioned slabs. A common seismic isolation system has been implemented for the two towers, which are connected at the underground level, and rest on top of a 2 m thick slab supported by 24 natural rubber isolators, 16 of which are lead rubber bearings. The isolators are on footings connected by beams. The isolated towers and the peripheral structures are separated by a 50 cm isolation gap which is significantly larger than the requirement of the Chilean isolation code, NCh2745.Of2003 [1]. The objective of this was to minimize the probability of impact between the isolated structure and the adjacent structures (see Figure 2).

For the Nunoa Capital Building, the use of various energy dissipation devices was evaluated. These included viscous dampers, viscous wall dampers, viscoelastic walls, and tuned mass dampers in combination with viscous dampers. The use of viscous dampers was eliminated during the first stages of the project, due to their architectural effect on the facades. For the same reason, the use of tuned mass dampers was also eliminated, as they would only be used in combination with viscous dampers distributed along height. Consequently, in one of the first stages of the project, the use of viscous walls in nonstructural partitions was evaluated, as well as viscous walls coupled with the walls of the elevator shaft. These are shown schematically in Figure 3. In addition, the feasibility of using a seismic isolation system in two configurations was evaluated: below each tower on the first floor and at the base of the entire structure below the lowest underground level.

Figure 4 shows a comparison of the seismic responses obtained for the four analyzed cases. This preliminary comparison was completed considering historical earthquake records that are compatible with the spectrum of the Chilean isolation code.

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The preliminary analyses completed indicated that the costs of implementing the energy dissipators in partitions and coupling walls was between 2 and 2.5 million US dollars, while the cost of the isolation systems required for isolating the towers individually or together was between 700,000 and 1.2 million US dollars. In light of the economical and technical analyses performed, it was quite evident that the most appropriate option for the structure was the use of seismic isolation systems.

Amongst the existing seismic isolation systems, the team of specialists decided to use a combination of natural rubber and lead rubber bearings, because of the stability and predictability of their properties. Other isolation systems, such as frictional isolators, were discarded due to the difficulties they present for predicting and modeling the variation of the friction in the isolator during seismic movements, given the vertical effects of earthquakes. Similarly, the use of high damping rubber isolators was dismissed for the low level of damping they provide, and for the difficulties in predicting their behavior during severe strong motions.

Due to the period of the fixed base structure, around 2 seconds, it was estimated that the period of the isolated structure would be around 5 to 6 seconds, and therefore, in accordance with the current Chilean isolation code, a site specific seismic hazard study was required.

SEISMIC HAZARD EVALUATION

Chile is one of the countries with the highest seismic activity in the world, primarily due to the subduction process of the Nazca Plate below the South American continent. This subduction process gives rise to different types of earthquakes, which are classified under the following groups: inter-plate earthquakes (occurring in the contact zone between the Nazca Plate and South American Plate), intermediate depth and large depth intra-plate earthquakes (occurring within the interior of the Nazca Plate), and shallow intra-plate earthquakes (occurring in the continental crust of the South American Plate). From the late 16th century to the present, there has been a high-magnitude earthquake every 8 to 10 years on average, throughout the Chilean territory.

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Taking into account the particular characteristics of this project, such as the structure, height, rigidity, incorporation of base isolation, and also the requirements present in the national seismic design standards, it was necessary to perform a study based on the seismic hazards for the project site. The objective of this study was to establish a site specific design spectrum, according to the site's geographical location, geotechnical and geomorphic characteristics. To characterize the different seismic sources, earthquakes with a magnitude greater than 4 ($M > 4$) and an epicenter within a radius of less than 300 km from the site were considered. This allows the estimation of distances from the site to different seismogenic sources. The possible influence of shallow sources associated with the San Ramon Fault, located approximately 8.5 km from the site, was also evaluated (see Figure 5). Even though there is uncertainty about its activity, accelerations were estimated as a benchmark for analyzing its possible influence on the overall seismic hazard of the site.

Figure 6 shows the spectral accelerations of the different seismic sources that could affect the site and a comparison of the resulting acceleration spectra for two distinct earthquakes occurring at the San Ramon Fault.

From the results of the seismic hazard study, the design elastic acceleration spectrum was determined for structures with periods up to seven seconds. Additionally, in accordance with the standards for seismic isolation design, seven pairs of artificial acceleration records, compatible with the proposed design spectrum were generated.

SEISMIC ISOLATION SYSTEM

The seismic isolators of the building are located under the ends of the walls and under the columns. The project will use 24 natural rubber isolators, manufactured by Dynamic Isolation Systems. The devices are made of rubber with a strain capacity over 600%, developed by Dynamic Isolation Systems, whose long term properties are extremely stable. The design process considered an extensive database of experimental results obtained for similar isolators, subjected to comparable vertical loads, and subjected to even larger displacement levels. Of the 24 devices, 16 of them have a lead core (LRB), while the 8 remaining do not have a lead core (RB). The largest diameter Type C (RB) isolators are 155 cm in diameter and have a load capacity of more than 40,000 kN and will be located in the most

heavily loaded locations under the ends of the walls of the elevator shafts. There are 8 Type A LRB isolators, 115 cm in diameter, with a load capacity of more than 20,000 kN, and 8 Type B isolators, 135 cm in diameter, with a load capacity of more than 30,000 kN. The stiffest isolators are the Type B isolators and they are located at the perimeter to control the torsion of the structure. The seismic isolation system achieves an effective vibration period near to 5 seconds, and about 20% effective damping. Based on the results of the seismic analyses, reductions of shears, absolute accelerations and interstory drifts by 70% to 80% are obtained compared to the fixed base elastic response.

The seismic isolation system was subjected to an extensive test series carried out at Dynamic Isolation Systems' laboratories in McCarran, Nevada, and Eucentre laboratories in Pavia. Prototypes and all production isolators were subjected to an exhaustive test sequence of combined compression loads and shear displacements in order to validate the properties assumed for the design and to verify the stability of the isolators under extreme seismic loads.

SUSTAINABILITY AND SEISMIC ISOLATION

From the sustainability point of view, the seismic isolation system incorporated contributes to the social, economical, and environmental aspects of the project. In fact, from the social point of view, the seismic protection system reduces the vibration doses acting on the building occupants during seismic events, increasing considerably the comfort of the residents. According to the results of a series of simulations, performed considering a set of 7 pairs of records recorded during the 2010 M_w 8.8 Maule Chile earthquake, the average reduction of vibration doses is in the order of 80 to 90%.

With regards to the economical benefit of using seismic isolation in the building, the analysis performed yielded that in the case of the conventional structure (without seismic isolation), the probabilities of observing no damage, and slight, moderate, and extensive damage are roughly 4, 36, 54 and 6%, respectively, for the maximum considered earthquake level. These values are compatible with the goals and requirements of current design codes used worldwide. In the case of the isolated structure, the same analysis showed that the probabilities of observing no

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damage and slight damage are 94 and 6%, respectively, allowing achieving a performance according to owners' expectations. The probabilities of observing higher levels of damage are zero in this case. A similar analysis performed for drift sensitive nonstructural contents, such as partition walls, showed that for the conventional structure, the probabilities of observing no damage, and slight, moderate, and extensive damage are roughly 27, 43, 29 and 1%, respectively. For the case of the isolated structure, the probability of observing no damage on drift sensitive nonstructural components is 100%. In the case of nonstructural components sensitive to floor accelerations, the conventional structure would exhibit probabilities of no damage, and slight, moderate, extensive, and complete damage are 1, 12, 56, 27 and 4%, respectively. In the case of the isolated structure, the probabilities of no damage and slight damage to nonstructural components sensitive to acceleration are 96 and 4%, respectively. All these reductions in the probabilities of damage to structural and nonstructural building contents have a direct impact on the reduction of the economical losses expected during extreme seismic events.

Finally, in relation to environmental issues, it shall be mentioned that the steels used by Dynamic Isolation Systems in anchor bolts, couplers, and shims, sole and masonry plates, are provided by manufacturers that provide steels containing 97% of recycled steel content. Fifteen percent of the recycled steel corresponds to post-industrial steel, while the 82% corresponds to post-consumer steel. The steels products are manufactured in an electric arc furnace process that melts the recovered scrap steel.

ANALYSIS METHODS AND MODELS

The Chilean isolation code allows for using either linear or nonlinear models to analyze and design the structure and the seismic isolation system. It also specifies two levels of seismic demand: the design basis earthquake and the maximum considered earthquake. The design basis earthquake (DBE) is used to analyze and design the whole structure except the seismic isolation system. On the other hand, the maximum considered earthquake (MCE) is used to analyze and design the seismic isolation system.

In the Nunoa Capital Building, both types of analyses were used. First, a linear analysis, specifically a response spectrum analysis, was performed. In this analysis, the isolators were modeled with their equivalent secant stiffness at the design displacement level. A site specific design spectrum obtained from the Seismic Hazard Evaluation was used. This spectrum represents the demand for the DBE level and was reduced by a factor of 1.99 for periods larger than 3.0 seconds to consider the extra damping provided by the seismic isolation system. This initial estimated factor was later verified through nonlinear analysis. This linear analysis was used to design the superstructure, the foundations and to define the seismic isolation system.

A nonlinear time history analysis was then carried out. In this analysis the isolators were modeled with a nonlinear biaxial hysteretic model that uses coupled plasticity properties for the two shear deformations [2]. This causes the extra damping of the seismic isolation system to be directly considered and provides an estimation of the effective damping of the system. This analysis was used primarily to validate the preliminary design of the seismic isolation system. Seven pairs of ground acceleration records obtained from the Seismic Hazard Evaluation were used. These ground acceleration records represent the demand for the MCE level. As allowed by the Chilean isolation code, all the parameters of interest such as displacements or axial loads on the isolators were obtained as the average of the peak response for each individual pair of records. As explained later, the superstructure is expected to remain essentially elastic for both the DBE and the MCE, which allows for modeling the building by using the linear elastic elements available in ETABS [2].

The first eight vibration periods of the structure, for the design earthquake level, are shown in Table 1. The X direction refers to the long side and the Y direction to the short side of the structure. The Chilean isolation code allows for considering the design base shear as the elastic demand divided by a response modification factor $R = 2$, but no less than a minimum percentage of the seismic weight that depends on the seismic zone, specifically 5% for this project. Usually, the minimum base shear is between the elastic and the reduced demand, which causes the effective reduction factor R^* (the adjusted R factor to achieve the minimum base shear) to be between 1 and 2. Notwithstanding this in this project, due to the long periods achieved, the elastic demand is less than the minimum. This causes the superstructure to be designed for a seismic demand greater than the elastic demand, which is

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equivalent to have an effective reduction factor R^* of less than 1. The elastic demands, effective reduction factors R^* , final design shears for each direction, and other key design parameters, are shown in Table 2.

The base overturning moments in the isolated structure (for the final base design shear) in the X direction is amplified when compared to the fixed base structure solution. This shows an important influence of the higher modes in the isolated structure (Table 3).

DESIGN CHALLENGES

As explained previously, for this particular project there were two characteristics that are not common for low rise isolated structures: a design base shear greater than the elastic demand, and an increased design base overturning moment. Those two characteristics imposed two big challenges for the structure design: to control the interstory drift and to avoid tension forces on the isolators.

The Chilean isolation code limits the story drifts to be less than 0.25% for the DBE level. This is different to other codes such as the ASCE7 [3] because it is directly measured from the reduced (by the R^* factor) DBE spectrum instead of multiplying the elastic response by C_d/I .

In order to control the story drifts, it was necessary to stiffen the building, which was a challenge because a tight architectural plan with almost no space for additional or thicker structure. This was achieved by using 2 outriggers per tower in the upper (mechanical) floor. Even though this location was not optimal, the outrigger's benefits were enough to stiffen the structure and reduce the interstory drifts to below the code limits. This can be seen for the X direction in the Figure 8.

The second challenge was to avoid tension forces on the isolator. Although the isolators can resist small tension forces, the design team decided to eliminate tension forces on the isolators for the MCE level. This was achieved by connecting the slabs of the two towers at the underground levels and by using a 2 m in thickness slab resting directly

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above the isolators. This thick slab stiffens the isolated interface so that the external isolators are coupled with the internal ones, leading to a greater lever arm that resists the overturning moment and reduces the magnitude of the seismic compression/tension forces. Final compression forces on the isolators for the MCE level are shown in Figure 9. To enhance the performance of this thick coupling slab, imbedded beams with closely spaced stirrups and ties were designed.

CONCLUSIONS

The final design demonstrates the technical feasibility of implementing seismic isolation systems in high rise buildings. The main design challenges included the use of large diameter isolators to resist large compression forces, the difficulties to achieve simultaneously a high vertical stiffness and lateral flexibility, avoiding tension forces on the isolators and controlling the interstory drifts to a level below the code limits. The feasibility of using a seismic isolation system in this 33 story structure is associated to the good geotechnical conditions at the site, the use of a relatively stiff superstructure, and the use of an outrigger system. The sizes of the structural elements were determined by the interstory drifts limits rather than the design forces. It has been proven that the use of seismic isolation systems can considerably reduce the seismic demands, even in tall buildings such as the Nunoa Capital Building, and in consequence expecting less structural damage (elastic response of superstructure), nonstructural damage (reduced interstory drifts) and content losses (lower absolute accelerations) than its fixed base counterpart for an MCE level earthquake, leading to a sustainable design.

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REFERENCES

1. Instituto Nacional de Normalización, NCh2745 Of.2003 Analisis y Diseno de Edificios con Aislacion Sismica, 2003
2. Computer and Structures Inc., CSI Analysis Reference Manual for SAP2000, ETABS and SAFE, 2005
3. American Society of Civil Engineers, ASCE7-10 Minimum Design Loads for Buildings and Other Structures, 2010

IMAGE CAPTIONS

Figure 1- Nunoa Capital Building - Isometric View (left) and Analytical Model (right)

Figure 2- Typical Floor Plan - Fixed base underground (in blue), seismically isolated sector (in red), isolation gap (in green) and typical layout isolated towers (right)

Figure 3- Energy dissipation alternatives. - Viscous walls in partitions (in red) and viscous walls coupling concrete walls (in red boxes).

Figure 4 - Comparison of the elastic seismic response of a conventional structure and the structure with base isolation and energy dissipators.

Figure 5- Seismic Hazard Study - Epicentral distribution of the earthquakes around the site between the years 1973 and 2012. The location of the site is indicated with a red triangle (left) - Hypocentral distribution of the earthquakes in EW profile, with a width of 50 km, centered on the site (upper right) Trace of the San Ramon Fault and schematic of geological-structural profiles of the area (bottom right)

Figure 6 - Site spectra - Spectral acceleration considering inter-plate, intermediate and shallow intra-plate seismic sources (left) and comparison spectral accelerations for San Ramon Fault, considering magnitudes of $M=6.5$ and $M=7.4$ (right)

Figure 7 - Isolator Layout

Figure 8 - Interstory Drift for the DBE with and without the Outrigger.

Figure 9 - Compression Forces on each Isolator for the MCE.

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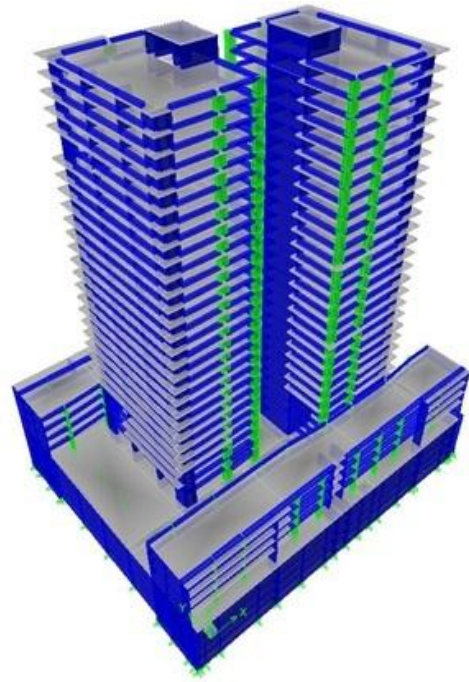
Table 1 – Periods of the Structure for the design earthquake level.

Table 2 – Elastic and Final Design Base Shear.

Table 3 – Contribution of each vibration mode to the base overturning moment in X Direction.

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Figure 1:



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Figure 2:

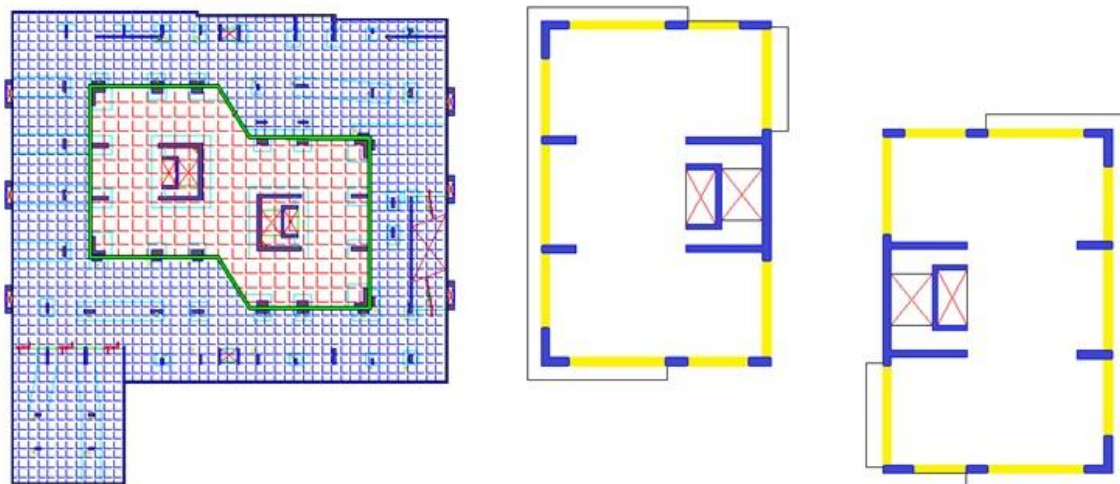
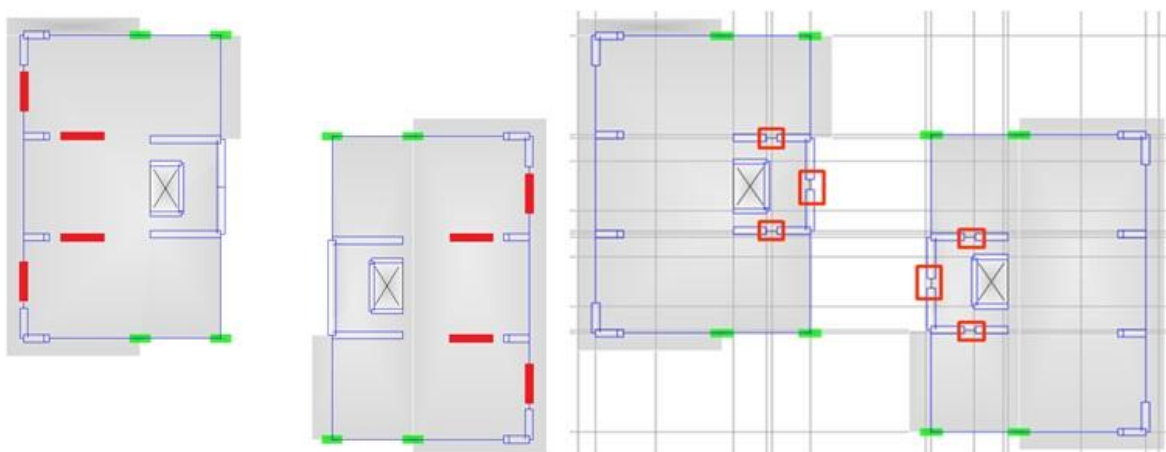


Figure 3:



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Figure 4:

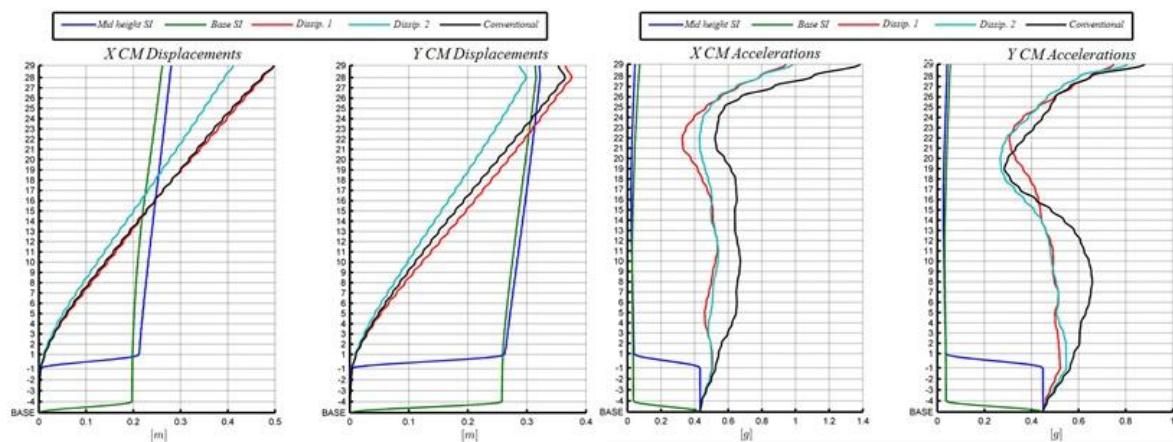


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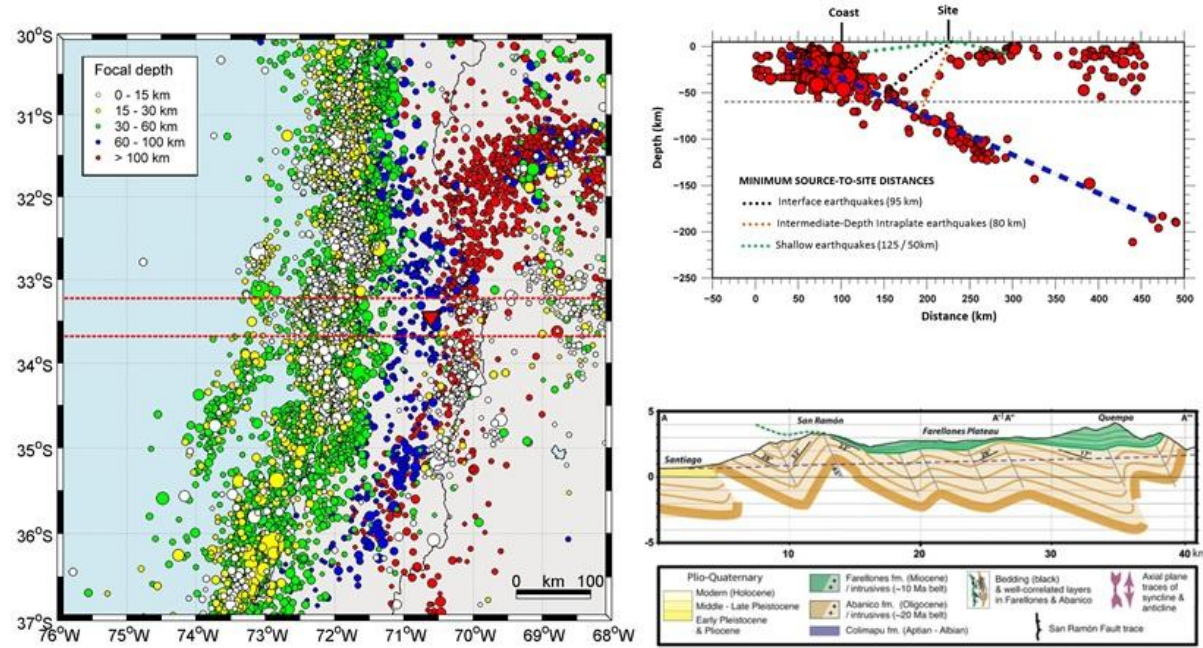


Figure 6:

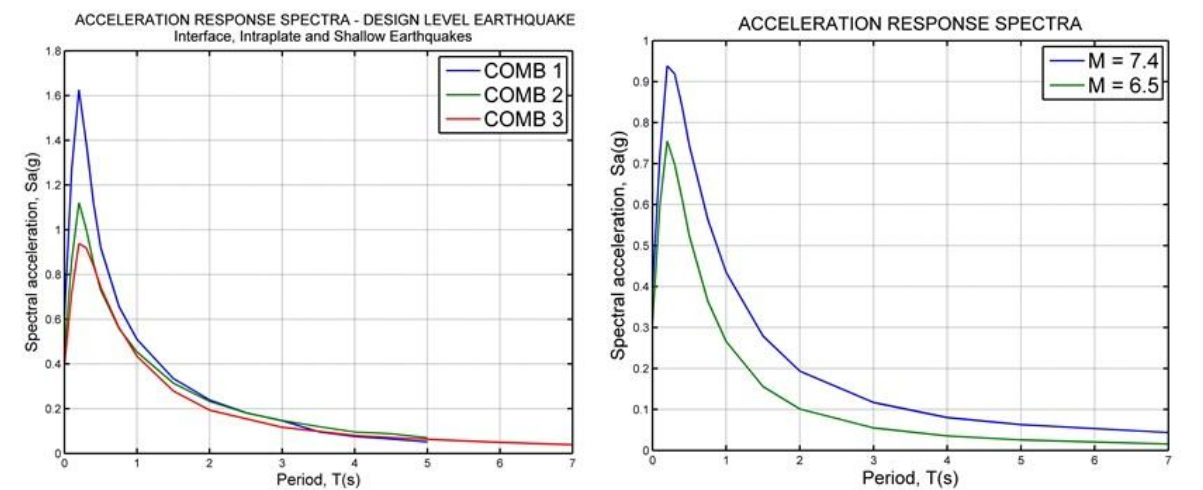


Figure 7:

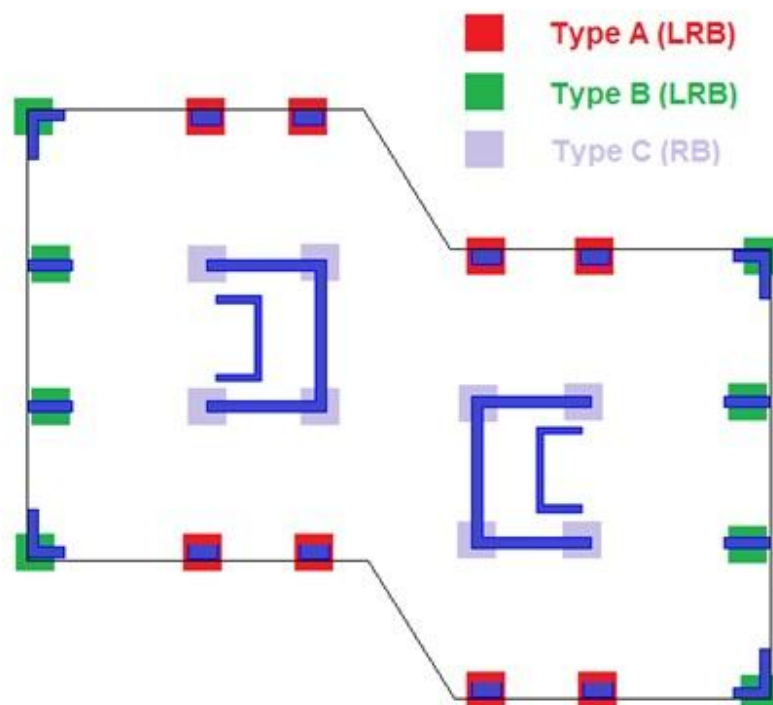


Figure 8:

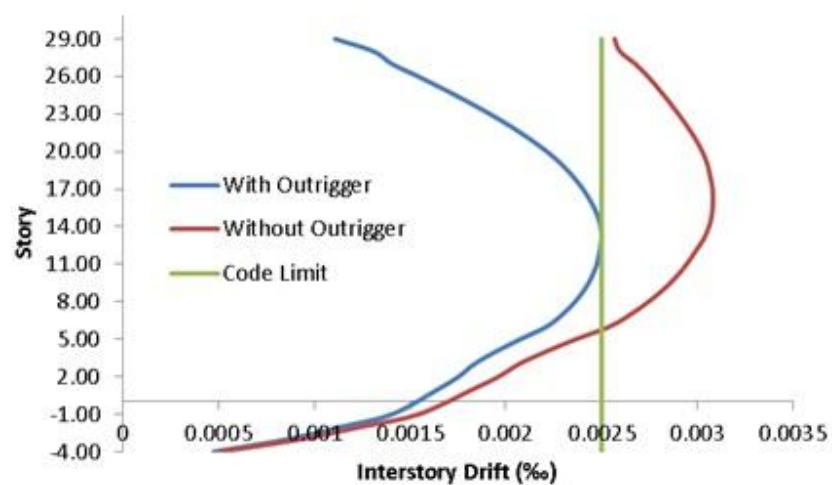


Figure 9:

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<https://upload.ctbuh.org> 上传您完成的文件。Password (密码): ctbuhupload)

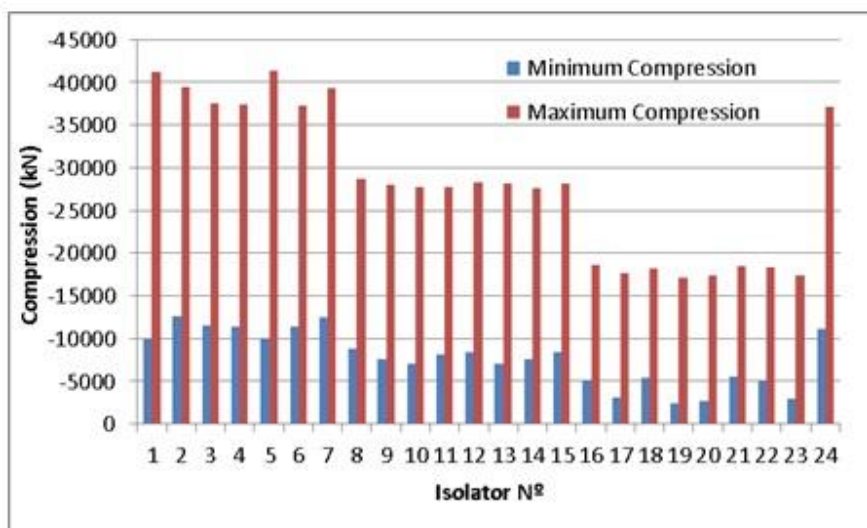


Table 1:

Mode	Period	Dir X Mass Ratio	Dir Y Mass Ratio	Rot. Mass Ratio
	(s)	(%)	(%)	(%)
1	5.34	98.25	0.56	0.04
2	5.26	0.56	98.61	0
3	4.83	0.04	0	98.65
4	2.13	0	0	0.05
5	1.55	0.03	0.53	0
6	1.41	1.1	0.01	0.01
7	1.4	0.01	0	0.68
8	1.13	0	0.28	0

Table 2:

	X Direction	Y Direction
Elastic Base Shear (kN)	13,368	13,734
Design Base Shear R=2 (kN)	6,684	6,867
Minimum Design Base Shear (kN)	20,346	20,346
Effective Reduction Factor R*	0.657	0.675
Final Design Base Shear (kN)	20,346	20,346

Table 3:

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	Mode	Base Shear kN	Base Overturning Moment kN-m	Base Overturning Moment % of combined (CQC)
Isolated Structure	ALL MODES (CQC)	20,346	1,043,967	100
	MODE 1	19,955	837,546	80
	MODE 2	117	4,861	0
	MODE 3	11	376	0
	MODE 4	0	0	0
	MODE 5	61	10,334	1
	MODE 6	2,906	607,879	58
	MODE 7	30	6,257	1
	MODE 8	1	291	0
Fixed Base Structure	ALL MODES (CQC)	20,346	868,339	100
	MODE 1	13,950	835,313	96
	MODE 2	395	23,367	3
	MODE 3	43	2,529	0
	MODE 4	4	236	0
	MODE 5	13	587	0
	MODE 6	1	42	0
	MODE 7	8	74	0
	MODE 8	43	206	0