Specialization certificate in geological and climate related risk

CERG-C 2014

Seismic Physical Vulnerability of Two Buildings in Asunción - Paraguay

by

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Acknowledgments

This is dedicated to Jesus Christ, my Savior, and my Master, Whom I owe everything.

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Summary

Qualitative measures have been taken for two buildings in Asunción and entered the values at the Swiss Vulnerability and Loss Model Matrix. The Swiss Model was successfully applied and adapted to the Paraguayan scenario, and, according to the yielded values, reveals that Hotel Guaraní is more vulnerable against seismic hazards than Justice Palace. Other parameters were also found and collated between the buildings, such as Damage Potential, Hazard, Collapse Probability and Risk.

A – Introduction

A.1 Location

Paraguay is located in the Southern Hemisphere, in South America, between the parallels 19° S - 28°S, and the meridians 54°W - 63°W (App.1), in the center of the South American Plate; regionally divided into two main regions, which are: Chaco, or Western Region, and Eastern Region separated by Paraguay river.

A.2 Geology

The country occupies portions of the very western margin of Paraná Basin, and the eastern margin of the Chaco Basin. The geological and geographical features are somehow coherent, divided by Paraguay river.

The city of Asunción lies upon the western portion side of the Paraná Basin, facing the Chaco Basin, limited by Paraguay river. It is located between the parallels 25.2247°S – 25.3970°S and the meridians 57.5283°W – 57.6917°W (App.2).

The final geological setting of the region, where the city is, occurred when the Middle – Upper Cretaceous, a system of tensional fracturing occurred, (Velázquez 1992) (Reference 1), (Fulfaro 1996) (R.2) (App.3), so being generated the Asunción Rift; then extended to the Lower to Medium Tertiary when a tectonic sedimentation fulfilled the rift as a first event, with coarse blocks at the base, and later on, a sequential decay of energy known by the grain size of sediments, so yielded the normal gradational stratigraphy.

These mentioned events were followed by magmatic activities, when igneous bodies made to the upper crust through the fault lines of the rift, including volcanic activity (Ricommini 1996) (R.3) Table hills of young sediments nearby the city give a clear hint that large erosion cycle occurred at the latest geological local time. Asunción lies right upon this young rift-fulfill sediments, so we know the rock material underneath the city is mainly sandstone, with lateral variations of soft rock, igneous bodies, like volcanic necks and dykes, and loosen Quaternary soils.

This Asuncion Rift is still active, generating low sized seismic events, known by the local seismological log, and according to (Harrington 1950) (R.4):

"At last is convenient to mention that on 24 december 1944, a remarkable earthquake was felt all along the depression of Ypacaraí, from San Bernardino to Paraguarí. The shock was intense enough to alarm people and made them leave their houses and it was heard, at the same time, strong sounds like distant lightnings from far away (…) This fact probes that the seismo was really local, otherwise it would not be heard "brontides", which at the same time indicates the main faults are still active in that zone".

A.3 Seismicity

Since Paraguay is located in the middle of South American Plate, the hazardous seismicity is low (R.5).Nevertheless, events of low size are frequent, and a value estimated for the zone is $GA_{475\ years}$ ~ 0.4 m/s^2 (App.4), which is almost equivalent to Seismic Zone 1 in Switzerland ($PGA_{475\ years}$ ~ 0.6 m/s^2) These events are mainly associated to active local faulting (App. 5), (Berrocal 1996) (R.6).

Three main types of earthquake sources have been recognized:

1) Type 1: Subduction of Nazca Plate generating deep earthquakes in Argentina in the range of the meridians 63ºW and 65ºW of sizes moderate to strong (very few). (Berrocal 1996) (R.6) (App.6)

2) Type 2: Local active faulting zones generates instrumental to medium size events. Actually, there are many intraplate instrumental seismic events according to logs monitored at the local seismological station (CPUP), which are important for scientific purposes, but not of relevance which may cause concern to society.

3) Type 3: Induced by dams (?)

The events type 1, are the ones which are going to be taken in consideration for this work as a main factor of hazard (App.6). It has occurred seismic events (Tab.1) in the mentioned meridian range, and observed that they should be above Mw 6 so they could be slightly felt like a swinging movement on some buildings of the city, top stories of them, not always and not all edifications, though. This is presumed, due to variations related to depth and wave paths. Waves spreading models have not been scrutinized yet.

Day	Month	Year	Time	Lat (S)	Lon (W)	Mw	Depth	Region
28	May	2012	05:07:59	28.061	63.077	6.5	588	Santiago del Estero
6	October	2011	11:12	24.181	64.25	6.2	9	Jujuy
2	September	2011	12:47	28.422	63.14	6.7	592	Santiago del Estero
12	November	2006	01:26	26.07	63.29	6.1	550	Salta
21	March	2005	08:44:49	24.94	63.36	6.4	561.6	Salta
21	March	2005	08:25:31	24.68	63.43	6.9	557.8	Salta
7	September	2004	11:53	28.58	65.83	6.5	22.1	Catamarca

Table 1: Latest Argentinean Earthquakes Related to Subduction Felt in Asunción.

More information related to Paraguayan´s Seismicity can be found at: http://www.geologiadelparaguay.com.py/Sismologia.htm (R.7).

In order to understand the probable response of buildings against strong or very strong regional earthquakes, this project was conceived. The physical seismic vulnerability of two buildings in Asunción, which is the main theme of this work, is a topic scarcely known. There are not direct studies of it, probably the reason is because no destructive earthquakes has occurred, or at least not dangerous ones, and then, the importance given to this kind of approaches or researches are not known so far.

Acquire information related to qualitative value of vulnerability of two buildings, and then apply to the Swiss Matrix (App.7) (Conference B. Duvernay - CERG-C 2014) (R.8) for building vulnerability so then a value is about to be obtained. This value will indicate the relative vulnerability of the construction and they are going to be compared each other. So as to achieve this, a "field survey" was necessary, to gather information required to enter at the Swiss Matrix.

A.4 Project

After this approach, knowledge about relative physical vulnerability of buildings is going to be met after collating the Priorization Indicators of the vulnerability-risk-check-lists obtained out after the estimations. It must be stated that there has never existed a Seismic Building Codes in Paraguay, according to The Paraguayan Construction Camara (R.15). Weaknesses of buildings identification. Detailed studies behavior of seismic properties of local ground, such as ground motion models, microzonation, site effect or fundamental frecuency factors of resonance have never been measured yet, neither a local seismic hazard has been elaborated.

The present work is about to be faced based on preliminary data, techniques of survey and values estimations learnt at the CERG-C 2014 presentations(Conference B. Duvernay - CERG-C 2014) (R.9), application of the Swiss Model of qualitative considerations of vulnerability to the Paraguayan scenario, which is yielding a result and a conclusion thereof.

B – Methodology

B.1 - Building 1: Palacio de Justicia (Justice Palace)

www.abc.com.py

Fig.1 Justice Palace´s Facade

-25.286811° ; -57.654797°

125 m/a/s/l

http://www.pj.gov.py/

Fig. 2

Twin tower set of buildings. The left tower was built in 1982 and the right in 1996.

Building 1 : Justice Palace

Identification	
Description	Offices, Towers
Seismic zone	Zone 2
Characteristics	
Built in:	Tower 1: 1982 ; Tower 2: 1996
Number of stories:	11 (Above Ground)
Dimensions in plan:	100.52 m x 82.02 m
Dimensions in elevation:	Tower 1: 48.4 m ; Tower 2: 52.8 m Above Ground
Type:	Unreinforced Concrete
Value:	23 Mio. Fr. 1 CHF = 4797, 762 Gs (14/12/14)
Usage	Offices
Soil	Soft Rocks
Foundation	Unreinforced Concrete Box, with Piles
Structural type	Moment Frames
Documents	Verbal Communication

Fig.3 Building 1 – General Information

CERG-C seismic module
Seismic vulnerability and risk indicators for building stocks

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Building Justice Palace

Use Public Ministry Offices

Damage potential (round the numbers!):

AIF o 1: indirect damage much lower than direct damage in case of collapse
o 2: indirect damage ~ direct damage
o 5: indirect damage much higher than direct damage

ADP = 0,1 · 5000 people · 8 / 24 hrs · 5 / 7 days · 44 / 52 weeks = 100

ADS = 23 **value in millions CHF** **AZPS = (ADS + ADP) · AIF =** 246

Hazard:

Seismic zone:	1	2	3
WEP	**1**	**2**	**3**

Soil conditions	**WB**
Good	1
Average	2
Bad	4

WEPB = WEP · WB = 2

Structure:

Number of stories above ground, n : 11

Decks: ● rigid decks (concrete)
o flexible decks (wood,…)

Stiffening in plan	**WG**	**Stiffening in elevation**	**WA**
Appropriate and rather symmetric	0	Continuous	0
Very asymmetric	2	Discontinuous	2
None or very insufficient	5	None or „Soft Storey“	5

Structural system	**WW**	**Shape in plan**	**WK**
Shear walls	0	Compact	0
Moment frames	1	Long, irregular	1
Braced frames	2		
Frames with infill walls	2 (infill complete), 3 (openings), 4 (short columns)		
Mixed system	3		

Construction material	**WD**	**Foundation type**	**WF**
Reinforced concrete, steel	0	Continuous	0
Reinforced, confined masonry	2	Isolated	1
Prefabricated, wood	3		
Masonry, unreinforced concrete	3 + n, if flexible decks, 3 + 11/2 for rigid decks (round!)		

Position	**WP**	**Staggered floors**	**WS**
Alone or row house middle	0	No staggered floors	0
Row house end or corner	2	Row house with staggered floors	2

WBAU = (1 + WG + WA + WW + WK + WD + WF + WP + WS) = 2

Prioritization indicators **WZ = WEPB · WBAU =** 4

RZPS = AZPS · WZ = 984

Fig. 4 Building 1 – Vulnerability and Loss Check List

Data Explanation: Building 1 – Justice Palace.

Damage Potential:

AIF: Since this is a public building with an important function, the value for this field is assigned to 2.

ADP: The building is mainly inhabited, average by 5000 people, 8 hours a day, 5 days a week, and 44 weeks in a year. Usually lot of people traffic in these buildings

ADS: The cost of the building, according to source, is 111.242.995.000 Gs [R.11]. Translating this to CHF, we consider the relation between this currencies of the day 14/12/14, which is as follows:
1 CHF = 4797.762 Gs. So this is rounded to 23 Mio. CHF.

Hazard:

WEP: The Swiss Model for seismic zones [App.8] [R.10] has been applied to assign a value here, collating the seismic map of Paraguay[App.4, 5], so the value is 1, which implies the Swiss equivalent: ($PGA_{475\ years}$ ~ 0.6 m/s²).

WB: The rocks fulfilling (Cretaceous – Tertiary) the Asunción rift are mainly soft rock (red sandstone) and a thin layers at some places of loose sand. They were intruded by isolated and scattered igneous bodies related to rifting faulting lines, so the value is assigned to 2.

Structure:

Number of stories above the ground: 11 ; below the ground: 3 levels.

Decks: Rigid decks.

WG: The stiffening in plan, according to the source of information, is appropriate and rather symmetric, since the concrete columns are well distributed all over the towers, so the value is 0.

WW: Moment frames is the design for this building, according to the source, so the value is 1.

WD: Reinforced concrete is the material the building is made of, so this value is assigned to 0.

WP: The entire set of the building consists of a unique square base, and two main towers lying on the base, ~30 meters away from each other. The set is an isolated one emerging among housing neighborhood. Hence, the value assigned is 0.

WA: The stiffening in elevation is continuous so the value is assigned to 0.

WK: Shape in plan is compact, so the value assigned is 0.

WF: Unreinforced concrete box, with piles, according to source. Then, the value is 0.

WS: No staggered floors have this structure, so the value assigned is 0.

Source of Information: Department of Civil Works of the Justice Palace.
Telephone number is: 59521 439 4000 Int. 2070 [R.11].

B.2 - Building 2: Hotel Guaraní

www. mec.gov py

Fig. 5 Hotel Guaraní´s Facade

-25.284006° ; -57.634794°

96 m/a/s/l
http://www.guaraniesplendor.com/ubicacion/

www.panoramio.com

Fig. 6 Hotel Guaraní - Sight from Plaza de la Democracia

Building 2 : Hotel Guaraní

Identification		
Description	Leisure Activities	
Seismic zone	Zone 2	
Characteristics		
Built in:	1961	
Number of stories:	13 (Above Ground)	
Dimensions in plan:	66 m x 66 m	
Dimensions in elevation:	55 m	
Type:	Unreinforced Concrete	
Value:	4 Mio. CHF	1 CHF = 4797, 762 Gs (14/12/14)
Usage	Hotel, Casino, Theatre, Restaurant	
Soil	Soft Rocks	
Foundation	Unreinforced Concrete Piles	
Structural type	Moment Frames	
Documents	Verbal Communication	

Fig. 7 Building 2 – General Information.

CERG-C seismic module
Seismic vulnerability and risk indicators for building stocks

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Building Guarani Hotel

Use Hotel, Casino, Theater

Damage potential (round the numbers!):

AIF o **1**: indirect damage much lower than direct damage in case of collapse
o 2: indirect damage ~ direct damage
o 5: indirect damage much higher than direct damage

ADP = 0,1 · 300 people · 24 / 24 hrs · 7 / 7 days · 52 / 52 weeks = 30

ADS = 4 **value in millions CHF** **AZPS = (ADS + ADP) · AIF =** 34

Hazard:				**Soil conditions**	**WB**
Seismic zone:	**1**	2	3	Good	1
WEP	1	2	3	Average	**2**
				Bad	4

WEPB = WEP · WB = 2

Structure:

Number of stories above ground, n : 13

Decks: ● rigid decks (concrete)
o flexible decks (wood,...)

Stiffening in plan	**WG**	**Stiffening in elevation**	**WA**
Appropriate and rather symmetric	**0**	Continuous	0
Very asymmetric	2	Discontinuous	**2**
None or very insufficient	5	None or „Soft Storey"	5

Structural system	**WW**	**Shape in plan**	**WK**
Shear walls	0	Compact	**0**
Moment frames	**1**	Long, irregular	1
Braced frames	2		
Frames with infill walls	2 (infill complete), 3 (openings), 4 (short columns)		
Mixed system	3		

Construction material	**WD**	**Foundation type**	**WF**
Reinforced concrete, steel	**0**	Continuous	0
Reinforced, confined masonry	2	Isolated	**1**
Prefabricated, wood	3		
Masonry, unreinforced concrete	3 + n, if flexible decks; 3 + 13/2 for rigid decks (round!)		

Position	**WP**	**Staggered floors**	**WS**
Alone or row house middle	**0**	No staggered floors	**0**
Row house end or corner	2	Row house with staggered floors	2

WBAU = (1 + WG + WA + WW + WK + WD + WF + WP + WS) = 5

Prioritization indicators **WZ = WEPB · WBAU =** 10

RZPS = AZPS · WZ = 340

Fig. 9 Building 2 – Vulnerability and Loss Check List

Data Explanation: Building 2 – Hotel Guaraní.

Damage Potential:

AIF: It is a square block surface at base. The building faces Plaza de la Democracia at north side; small size buildings and shops at east; a school at south and small size properties at west. All separated by surrounding streets at the very downtown of the city. Prone to suffer direct damage higher than indirect damage, so the value is 1.

ADP: The building is mainly inhabited, average by 300 people, 24 hours a day, 7 days a week, and 52 weeks in a year. These values are estimated considering an average along high and low seasons.

ADS: The cost of the building, according to source, is 19.440.000.000 Gs. (R.13). Translating this to CHF, we consider the relation between this currencies of the day 14/12/14, which is as follows:
1 CHF = 4797.762 Gs. So this is rounded to 4 Mio. CHF.

Hazard:

WEP: The Swiss Model for seismic zones (App.8) (R.10) has been applied to assign a value here, collating the seismic map of Paraguay (App. 4, 5), so the value is 1, which implies the Swiss equivalent: ($PGA_{475\ years}$ ~ 0.6 m/s²).

WB: The rocks fulfilling (Cretaceous – Tertiary) the Asunción rift are mainly soft rock (red sandstone) and a thin layer at some places of loose sand. They were intruded by isolated and scattered igneous bodies, so the value is assigned to 2.

Structure:

Number of stories above the ground: 13 ; Below the ground: 2 levels.

Decks: Rigid decks.

WG: The stiffening in plan, according to the source of information, is appropriate and rather symmetric, since the concrete columns are well distributed all over the towers, so the value is 0.

WW: Moment frames is the design for this building, according to the source, so the value is 1.

WD: Reinforced concrete is the construction material used for this building, so the value is 0.

WP: Isolated building, then, the value assigned is 0.

WA: Since the building has four different "deck layers" the stiffening in elevation is discontinuous so the value is assigned to 2. The second layer acts as a "neck", upon which the triangular prism of the set rests.

WK: Shape in plan is compact, so the value assigned is 0.

WF: According to sources, this building has not a compact concrete box, but separated concrete piles, called locally "zapatas or shoes" by the experts [(R.14)]. Hence, the value should be assigned to 1.

WS: No staggered floors have this structure, so the value assigned is 0.

C - Results

Proceeding according to the methodology for Vulnerability Risk Index, interesting and brand new information has been found regarding two important buildings in Asunción:

	Damage Potential Index	Hazard Index	Vulnerability Index	Collapse Probability Index	Risk Index
Justice Palace Building 1	**246**	**2**	**2**	**4**	**984**
Hotel Guaraní Building 2	**34**	**2**	**5**	**10**	**340**

Table 2 - Results Overview

	Damage Potential Index	Description
Justice Palace Building 1	**246**	The Damage Potential Index belonging to Building 1 is relatively higher regarding Building 2 due to the people traffic at the site as a function of time and also the cost of infrastructure.
Hotel Guaraní Building 2	**34**	

Table 3 - Damage Potential Index

	Hazard Index	Description
Justice Palace Building 1	**2**	Seismic zones and soil conditions are presumed to be the same, since the distance between them is not large. Microzonation studies of the city has not been done so far.
Hotel Guaraní Building 2	**2**	

Table 4 - Hazard Index

	Vulnerability Index	Description
Justice Palace Building 1	**2**	The difference of vulnerability values is based on some structural features of both buildings, such as: 1) The stiffening in elevation is irregular ; 2) The foundation type has isolated “shoes”. These elements make the Building 2 more vulnerable.
Hotel Guaraní Building 2	**5**	

Table 5 - Vulnerability Index

	Collapse Probability Index	Description
Justice Palace Building 1	**4**	Although the damage potential is higher for the Justice Palace, we appreciate the value for Collapse Probability for Hotel Guaraní is higher, on which based on the vulnerability factors these results are coherent. This value has been obtained multiplying the factors of vulnerability and hazard.
Hotel Guaraní Building 2	**10**	

Table 6 - Collapse Probability Index

	Risk Index	Description
Justice Palace Building 1	**984**	The risk is for the Justice Palace is higher than the Hotel Guaraní. Risk has associated concept of factors such as vulnerability, hazard and costs. Having considered all these mentioned issues we have come to this result, which is coherent according to the samples gathered.
Hotel Guaraní Building 2	**340**	

Table 7 - Risk Index

D1 – Findings.

- Hotel Guaraní is physically more vulnerable against seismic hazards than Justice Palace.

- Justice Palace is more prone to suffer seismic damage than Hotel Guaraní.

- Hotel Guaraní has more probability of collapse than Justice Palace.

- Based on the concept of risk, which involves hazard, vulnerability and costs, we find that Justice Palace has a higher risk than Hotel Guaraní against seismic hazards.

- The numbers obtained at the Swiss Matrix Vulnerability and Lost are coherent with the “a priori” qualitative estimations.

- People are not concerned about seismic risk or physical vulnerability of buildings in Paraguay.

- Non of the buildings in Asunción are prepared against seismic hazard.

- Process of gathering information at different places was something really new and unique. Some of the logs are lost or hard to find. Permission notes were required at some other places.

- Having Access to the architectural or engineering blueprints of the building and being able to visit the inside of buildings should be a prerequisite for the application of this methodology as it would greatly help to assess the characteristics of the structural system which are in general imposible to ascertain with street surveys.

D2 – Contributions

- A new sight for studying buildings in Paraguay applying the Swiss model for vulnerability.

- A qualitative new way to find weakness and fastness of buildings against seismic hazard.

D3 – Recommendations

- To enforce seismic design for new buildings.

- To enforce the assessment of the seismic safety of existing buildings by important retrofits.

- To check the seismic safety of important and vital buildings.

E- Conclusions

The Swiss Model for Vulnerability and Loss for buildings is totally applicable to the Paraguayan context as it has been demonstrated though this work, which was successfully applied. According to this model, value of physical vulnerability for Hotel Guaraní is higher than the one for Justice Palace. This kind of work can be extended to other buildings of the city in the future. The presented methodology is only meaningful for the qualitative evaluation of a large set of existing buildings. The ranking of the seismic risk is helpful to be able to select a subset of the building stock with a potential high seismic risk for detailed evaluations through engineering analysis. In no case can this methodology be used to make a conclusion about the adequate seismic safety of an individual building.

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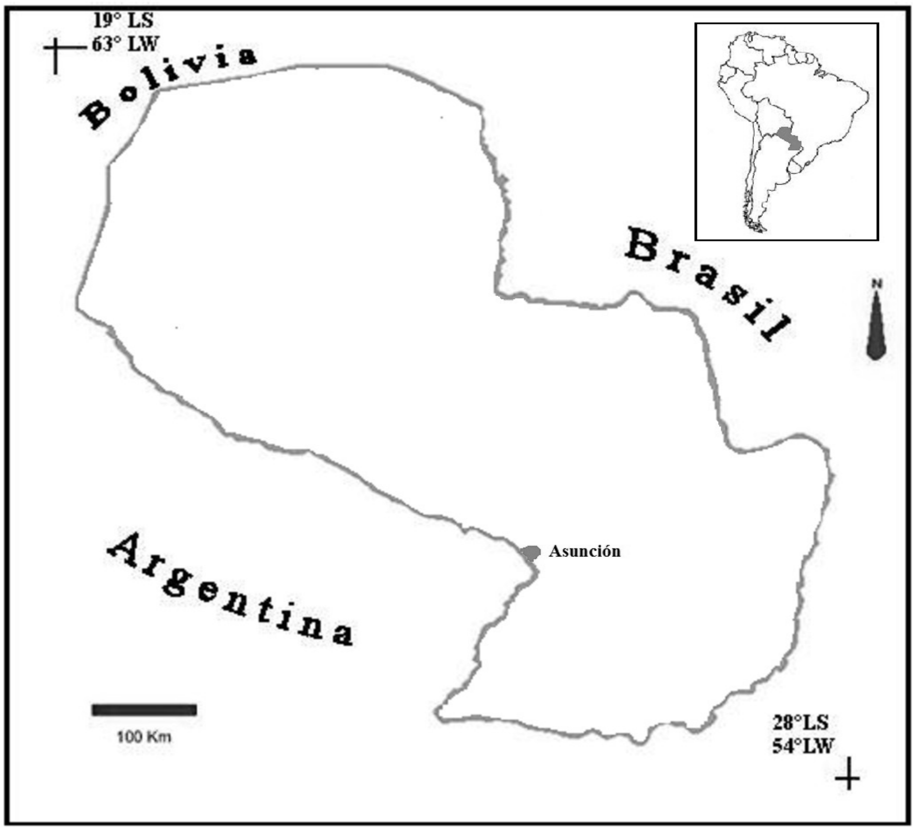
15 – Vidal Lovera E. (2014), *Personal communication*, Civil Engineer, Paraguayan Construction Camara, Paraguay.

Appendix

App. 1 – Paraguay´s Location



App. 2 Asuncion's Map

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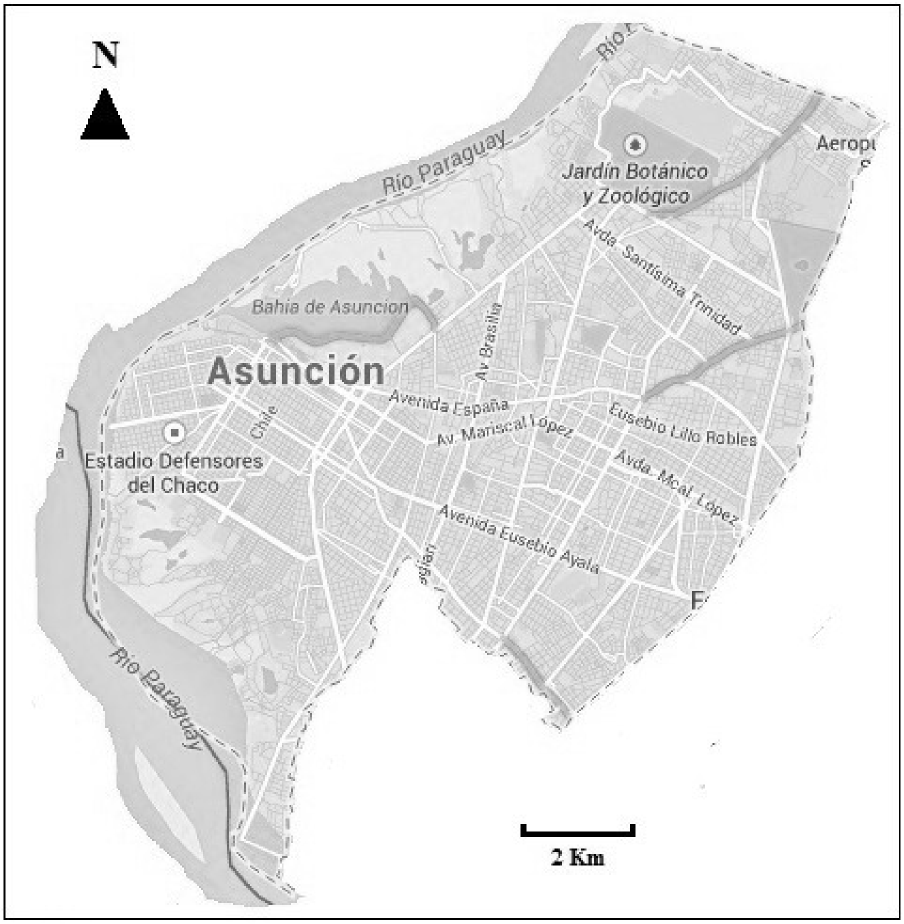
-57.5283



-25.397051
-57.691784

App.3 Asuncion's Rift

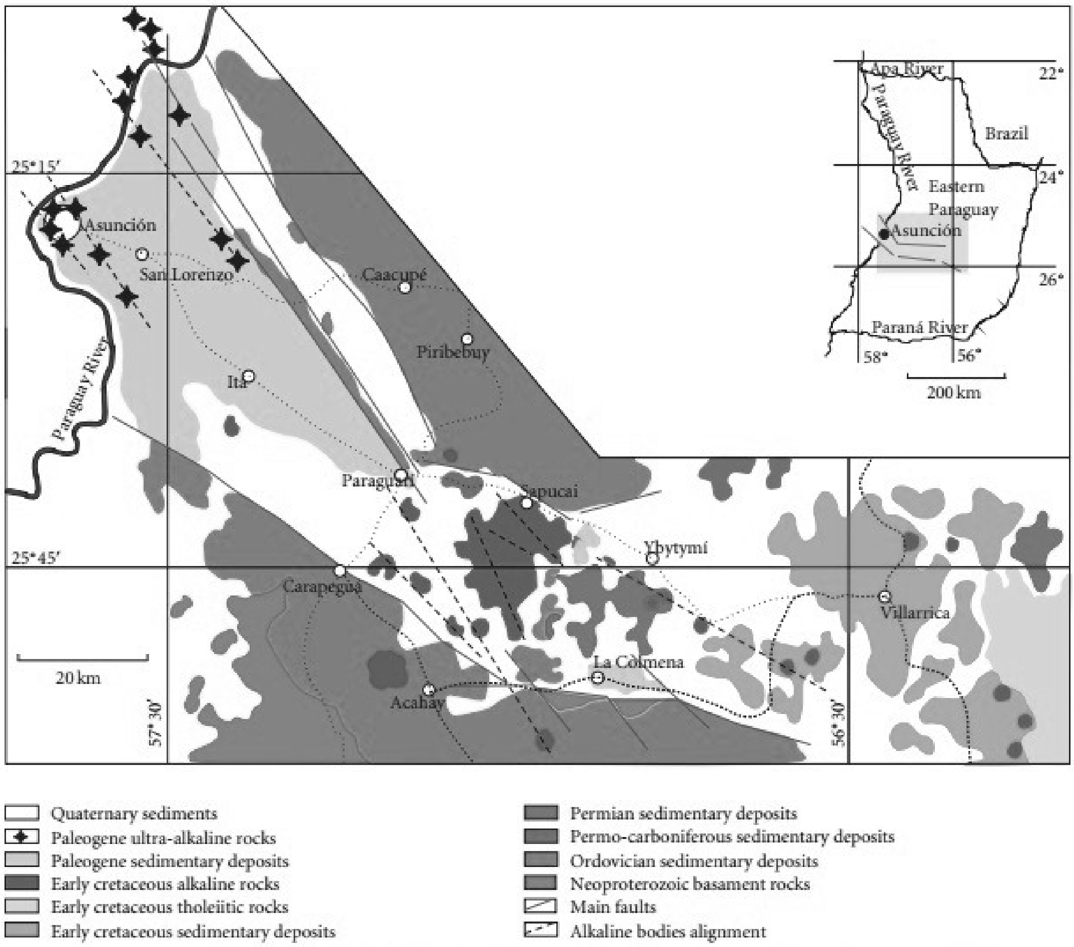
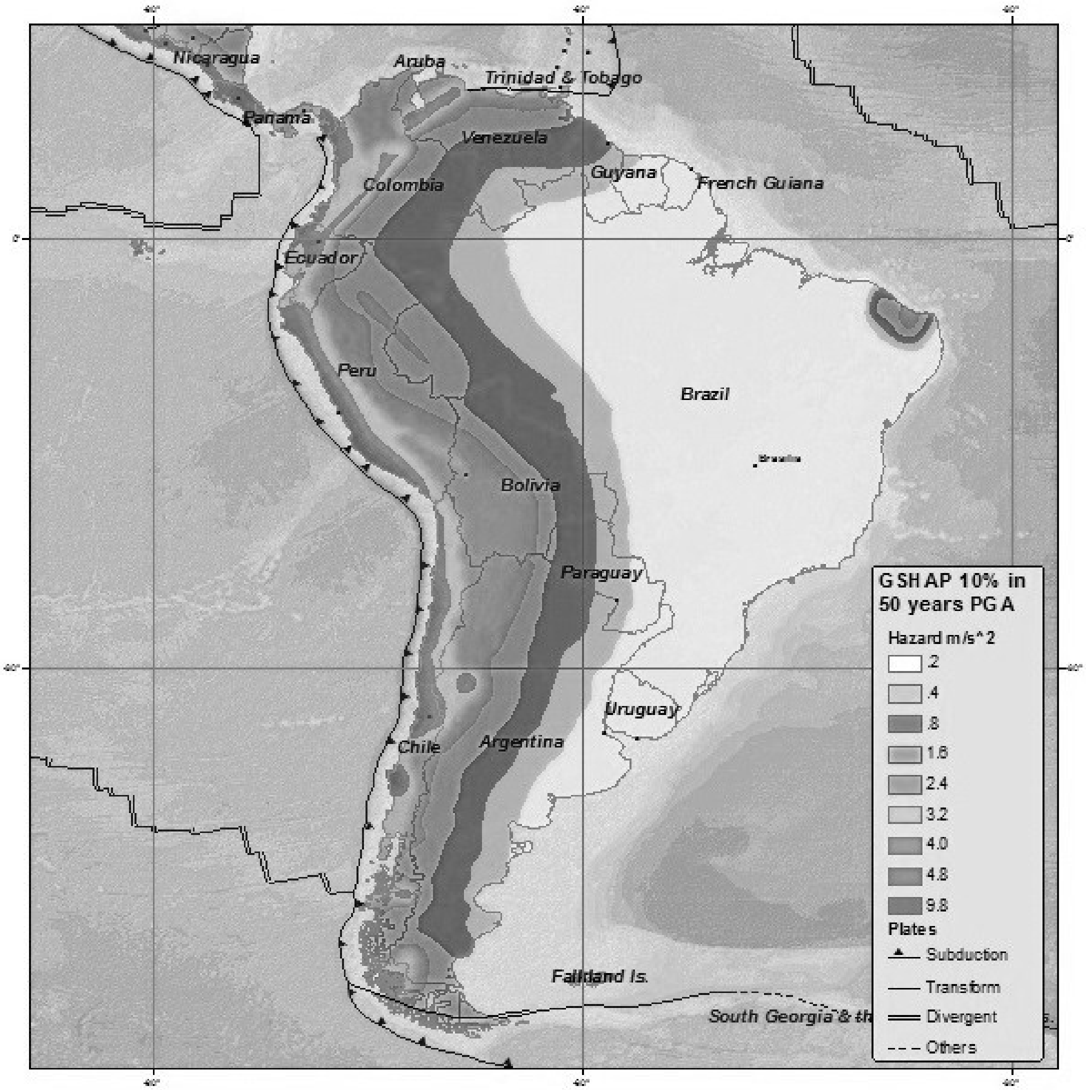


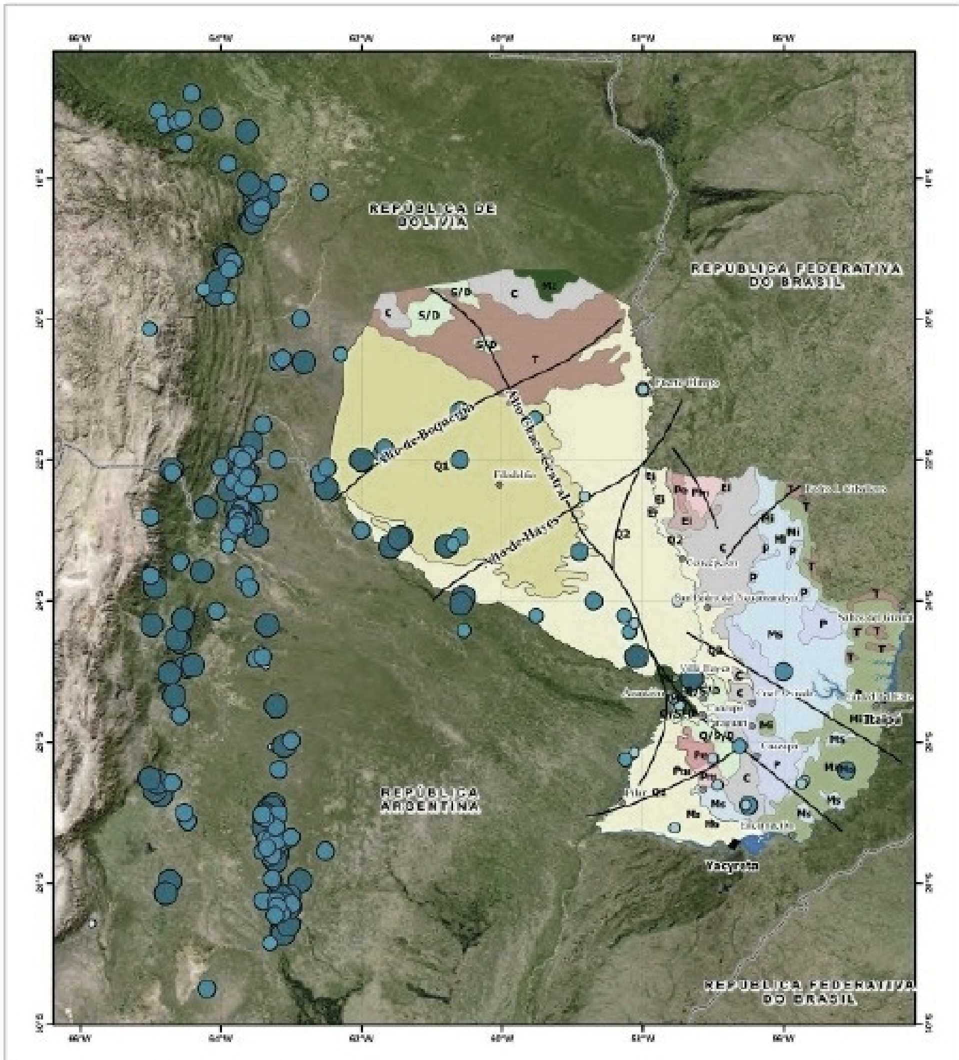
FIGURE 2: Geological map of the Asunción Rift and associated alkaline occurrences (after Velázquez et al. [17]).

App. 4 South America´s Seismic Hazard Map



http://earthquake.usgs.gov/

App. 5 Seismicity of Paraguay



App.6 Deep Earthquakes Related to Subduction of Nazca Plate.

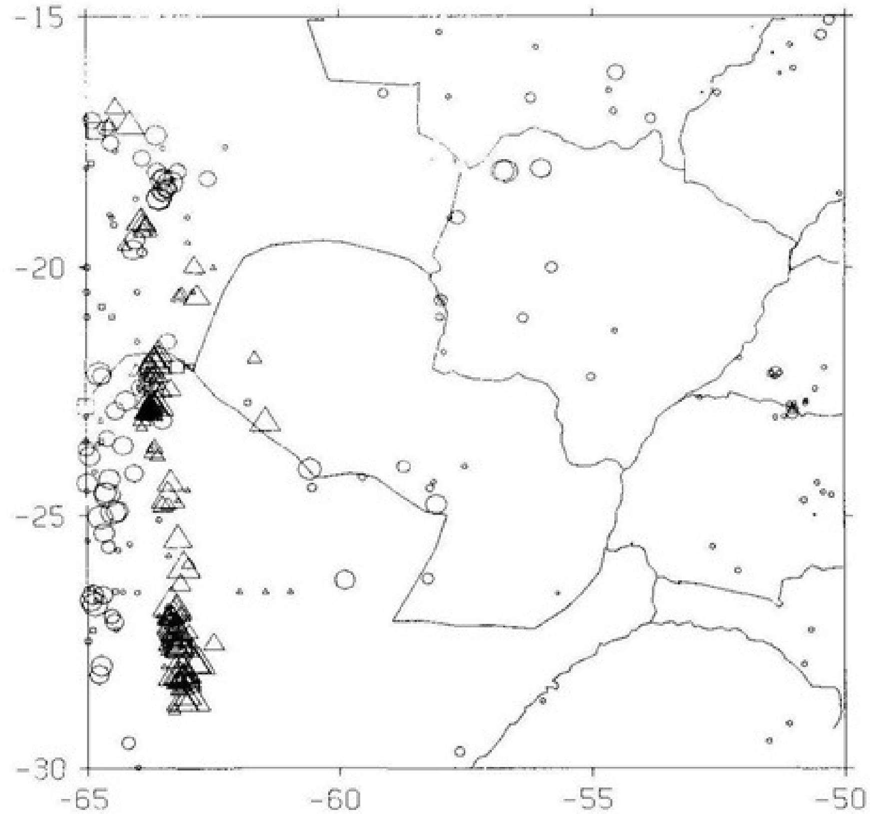


Figura 3 - Sismicidad del Paraguay y regiones vecinas utilizando datos seleccionados de los archivos NEIC e ISC y todos los datos confiables del Catálogo Sismico Brasileño, mostrando terremotos ocurridos en el intervalo Julio 1942 - Junio 1993. Las formas de los simbolos se explican en la Fig. 1 y sus tamaños representan eventos con magnitud mb entre 1.0 y 6.6.

App. 7 Building Vulnerability and Loss Model.

CERG-C seismic module
Seismic vulnerability and risk indicators for building stocks

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Building ....

Use ....

Damage potential (round the numbers!):

AIF o 1: indirect damage much lower than direct damage in case of collapse
o 2: indirect damage ~ direct damage
o 5: indirect damage much higher than direct damage

ADP = 0,1 · .... people · ...... / 24 hrs · ..... / 7 days · ..... / 52 weeks = ☐

ADS = ☐ **value in millions CHF** **AZPS = (ADS + ADP) · AIF =** ☐

Hazard:

Seismic zone: 1 2 3
WEP 1 2 3

Soil conditions	**WB**
Good	1
Average	2
Bad	4

WEPB = WEP · WB = ☐

Structure:

Number of stories above ground, n : ....

Decks: o rigid decks (concrete)
o flexible decks (wood,…)

Stiffening in plan	**WG**
Appropriate and rather symmetric	0
Very asymmetric	2
None or very insufficient	5

Stiffening in elevation	**WA**
Continuous	0
Discontinuous	2
None or „Soft Storey“	5

Structural system	**WW**
Shear walls	0
Moment frames	1
Braced frames	2
Frames with infill walls	2 (infill complete), 3 (openings), 4 (short columns)
Mixed system	3

Shape in plan	**WK**
Compact	0
Long, irregular	1

Construction material	**WD**
Reinforced concrete, steel	0
Reinforced, confined masonry	2
Prefabricated, wood	3
Masonry, unreinforced concrete	3 + n, if flexible decks; 3 + n/2 for rigid decks (round!)

Foundation type	**WF**
Continuous	0
Isolated	1

Position	**WP**
Alone or row house middle	0
Row house end or corner	2

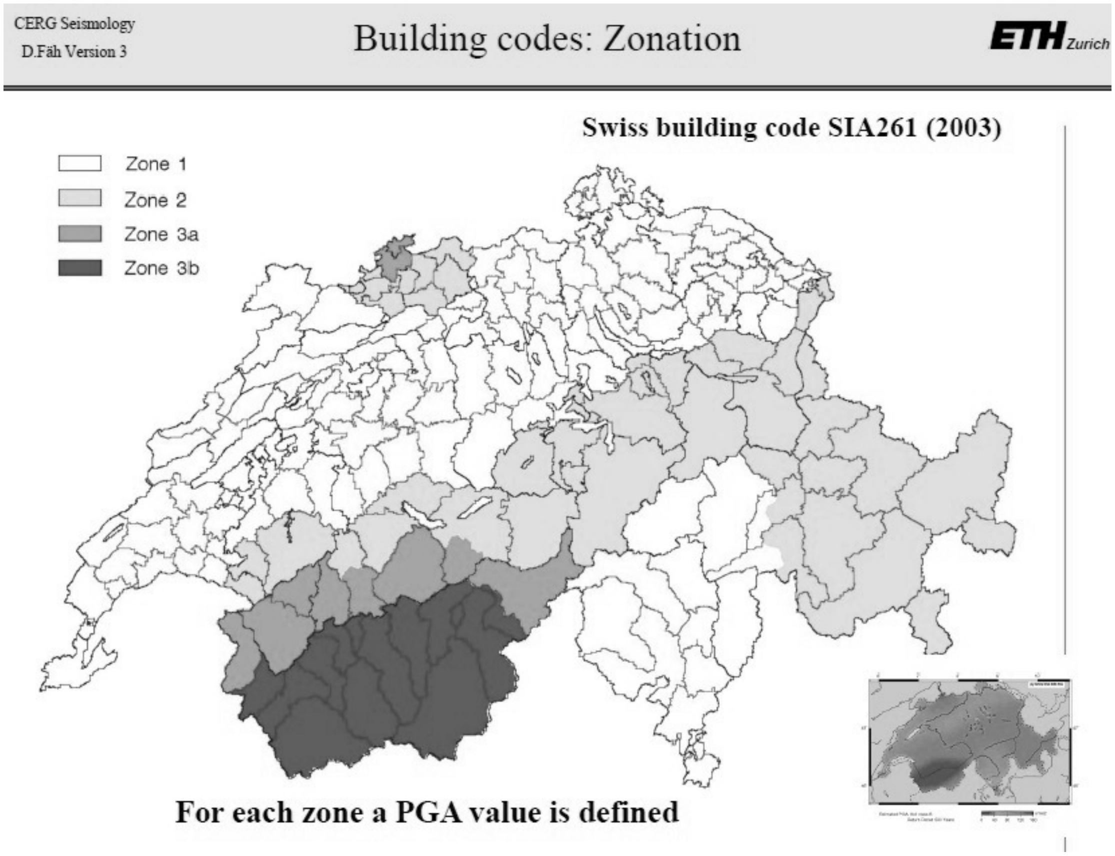
Staggered floors	**WS**
No staggered floors	0
Row house with staggered floors	2

WBAU = (1 + WG + WA + WW + WK + WD + WF + WP + WS) = ☐

Prioritization indicators **WZ = WEPB · WBAU =** ☐

RZPS = AZPS · WZ = ☐☐☐☐☐

App. 8


CERG Seismology
D.Fäh Version 3
Building codes: Zonation
ETH Zurich
Swiss building code SIA261 (2003)
Zone 1
Zone 2
Zone 3a
Zone 3b
For each zone a PGA value is defined