STRATEGIES FOR SEISMIC PREVENTION IN SCHOLAR'S BUILDINGS

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SUMMARY

Purpose: The objectives reached are:

- Evaluation and qualification of seismic capacity, functional aptitude and behavior of non-structural elements, in elementary school buildings in San Juan city.
- Identification of buildings that need to be consolidated remodeled or refunctionalized.
- Solutions to respond to detected failure.
- Action plans for seismic emergency.

Outcome: San Juan province is situated in the central-west region of the Argentine Republic. It is located in the zone of major seismic activity of this country. This area was shacked with five mayor earthquakes in the past 100 years that caused big damage and loss of human lives.

Earthquakes: The January 15, 1944 earthquake (Ms= 7.8, IMM IX) was a real catastrophe to San Juan. Almost all the buildings were seriously damaged or collapsed, 10.000 people died.

The city was totally rebuilt with a new plan with wider streets and sidewalks. The first seismic code was implemented. In 1952 another big earthquake occurred (Ms= 7.0, IMM VIII).

The performance of reconstructed buildings was good. The most recent event was Caucete earthquake (Ms= 7.4, IMM IX). A hundred of people died and 250 were injured.

Structures that had been built according to the existing seismic code provisions, performed well with only a few exceptions in publics and scholar buildings, which had several damages including the collapse of some of them. According to this situation, the entire primary school buildings of Great San Juan area, (hold 90% of the children population of the province), were evaluated. Not only structural aspects were checked but also the system operational integrity.

Conclusion: There have been proposed structural and functional recommendations for the recovering of 20 scholar buildings.

The results have been transfer to all the areas connected to the issue depending on the Provincial Government, the education community, the Civil Defense, etc.

INTRODUCTION

The cities are the principal areas of the impulse of regional economy. In this areas we can see the different activities forming one operational and functional net of infrastructure and construction.

Within them, there are some essential elements which operates and constitute the "critical and essential net for recovery emergence" (Lagorio).

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Among these, there are hospital and schools buildings, fire brigade buildings, police stations, airports, lifelines, blood banks, water treatment plants, central electric power, etc. All these constitute the buildings in “Ao & A” category (INPRES CIRSOC 103). The 1977 earthquake showed important lack in some structural typologies of scholar buildings. Some of them are still working.

On the other hand, most of the buildings were built with codes used until INPRES CIRSOC 103 (present code) was implemented, which had less requirements than actual one.

We must also consider the lack of maintenance, the soils and foundation problems, and some structural systems used that we actually known have bad performance during strong earthquakes.

If there is a strong earthquake in our area, we wish our school buildings could stand up as emergency hospitals or shelters for people. That is why it was necessary to do a research of the actual state of all the scholar buildings in our city and therefore consider the repairing, the refection or consolidation of the buildings as soon as possible.

This paper shows the results of a research project from San Juan National University. It is about the application of a seismic evaluation method on public primary school buildings in Gran San Juan urban area. These buildings contain the 60% of the scholar population in the province.

CHARACTERISTICS OF SAN JUAN PROVINCE

San Juan is situated in the central-west region of the Argentine Republic, along the Easter flank of the Andes, between longitude 66° 50’ W and 70° 25’ W and between latitude 28° 37’ S28° 37’ S and 32° 20’ S. Belongs totally to the dry zone. San Juan Province is located in the zone of major seismic activity of the Argentina Republic country. This area was shacked with five mayor earthquakes in the past 100 years that caused damage to houses, constructions, lifelines, main roads, railways, harvest and loss of human lives.

According to the modern plate tectonic concept, San Juan city is located approximately 350 km east of the boundary between the south America plate and the Nazca plate. The axis of this zone of convergence occurs along the Peru-Chilean Trench. (Figure 1). In this trench, the eastward moving of Nazca Plate is subducted beneath the westward moving South America Plate. The rate of convergence, in the latitude range of San Juan, is approximately 11 cm/year (Ukeda and Kanamori).

The orientation and dip of the Nazca Plate beneath South America Plate is defined by the seismicity of Benioff zone. This zone of seismicity shows that the subducted plate has an eastward dip that ranges from 5° to 30° beneath South America Plate. The depth to the subducting plate is about 100 km beneath San Juan Province. The convergence of these two plates imparts a compressional stress regime to the South America Plate. This compressional environment has been in existence, probably, for at least 20 million years.

This E-W oriented compressional stress regime is the responsible for the orientation and sense of displacement on active faults and the nature of seismicity in the Province.

The seismicity in this region is characterized by the followings: (1) High concentration of seismic activity at Peru-Chilean Trench. (2) Crustal seismicity at east of Los Andes in the upper 65 km. (3) Shallow-dipping Benioff zone seismicity at a depth of 100 km (beneath San Juan Province). (4) A gap of seismicity between 70 and 100 km. (5) Occurrence of moderate to large EQ in the crust.

There is an absence of seismicity between 65 and 100 km depth, suggesting an aseismic zone of deformation, called ductile zone. The potential seismic sources are shown in table 1.

SEISMICITY

The San Juan’s catastrophic earthquake of January 15, 1944 (Ms= 7.8, IMM IX) imposed the problem of aseismic design and construction of structures. Almost all the buildings were seriously damaged or collapsed, 10.000 people died (5 % of the population). The city was totally rebuilt with a new plan with wider streets and sidewalks. It was during this period when the first aseismic design codes were elaborated and carried out in San Juan which have so far played a considerable positive role. However, since that event, the history of earthquakes in Argentina was enriched and developed by additional events (San Juan 1952, San Juan 1977, and Mendoza 1985), while earthquake engineering science got considerable knowledge. (See Table 2).

The most recent event was Caucete earthquake (Ms= 7.4, IMM IX). A hundred of people died and 250 were injured. Structures that had been built according to the existing seismic code provisions, performed well with only a few exceptions in publics and scholar buildings, which had several damages including the collapse of some of them. This resulted in revision and improvement of the aseismic design codes, which are now entitled "INPRES CIRSOC 103”, based on the so-called spectral theory of earthquake engineering.

METHODOLOGY

A selection of the school buildings was done taking into account: number of students; number of schools working in the same building; the city area vulnerability; the maintenance present state; etc. There were selected 20 scholar's buildings to be studied.

The methodology used consisted in an evaluation process, submitting to these buildings in different precision levels, until we have the assurance that the level of seismic safety was the right one or in the other hand, the need of reparation, strengthening or/and stiffening.

Determination of the building vulnerability: It was considered 3 types of seismic vulnerability: - Functional vulnerability; - Non structural element vulnerability and - Structural vulnerability.

We defined as: **Functional vulnerability**: to the way the building behaves and it characteristics. They can be described through the architectural functional problems, which hinder the quick and safe evacuation during an earthquake.

Non-structural vulnerability: to the propension of non-structural elements to be susceptible to damage from major earthquake. Those non-structural elements include all the architectonic elements which are supported by the structure of a building (thin brick shear walls, openings, ceilings), lifelines and equipment.

Structural vulnerability: to the probability of structural elements to be damage from major earthquake. A few indicators are used to construct a comprehensive quantitative vulnerability value, in different levels of study.

The buildings can be categorized using a simplified method of seismic evaluation for ductile framed reinforced buildings of low and medium height,, that consist in the construction of a seismic safety index. The method used under San Juan conditions, is an adaptation of "Standard for Evaluation of Seismic Capacity of Reinforced Concrete Buildings", used by the Japan Building Disaster Prevention Association.

PROCEDURE

In the determination of functional, non-structural and structural vulnerabilities, we used the following techniques:

Functional and non structural vulnerabilities: After the selection of the buildings that should be studied, we checked the graphic documentation (blue prints of architecture, structure and details) and all of these items were checked on the field.

We verified also: actual use, general and structural updates and repairs.

We used tools such as tables to capture the data, in order to normalize the observer criterions, excluding in this way, errors in the data's evaluation.

We elaborated records in order to syntetize the information, in which there was expressed the results of seismic evaluation in each one of the different aspects: functional and non-structural. The vulnerability factors were evaluated based in a scale.

Structural vulnerability: At the first stage we checked the existing graphic documentation: structural blue prints, codes used, soil characteristics, document about inspection done, quality of used materials, etc.

Because in most of cases the documentation found was not completed, it was necessary to evaluate the characteristics of the buildings and their structures.

We verified in the field the existence of short columns, soft level, bricks wall, reinforced concrete wall and columns missing in the original blue prints. The damages and performance observed in previous earthquakes were evaluated.

The **Security Seismic Index** was done in the following way: it was determinate **"K"** which is the resistant coefficient of the studied buildings and it was compared with **"Ks".** This **"Ks",** was obtained using our codes and it depends on: site location, soil conditions, structural type, building uses, characteristics of the material used and natural period in both directions.

Index uses the following parameters: basal shear force and their height distribution, damage correction factor, structural weight, seismic zoning, building main uses, the existence of short columns, soft level, bricks wall, reinforced concrete walls and columns, ductility factor used, life and death weight, damages caused by previous earthquakes and torsional eccentricity.

The allowed values for **Ks** factors are: Soil type III: Ks= 0.20; Soil type I and II: Ks= 0.15. (Ref: INPRES CORSOC). This is known as level 1.

Using the **K** factor obtained for each building, they were classified based on the following values:
If K>Ks → OK; and if K<Ks → to level 2.

The evaluation done in level 1 allowed us to distinguish the cases that need to be studied in detail (level 2). Level 2 determinates the seismic capacity of the building using the methodology indicated in our code (INPRES-CIRSOC 103). The software used was SAP90, Super ETABS and DRAIN 2D.

We considered very important to identify the conceptual problems of the structures, because the conventional mathematical models do not easily find some of them.

The usual problems found were: (1) Excessive eccentricity caused by a non-adequate stiffness distribution in plant. (2) Big changes of stiffness and strength in height. (3) Little or non seismic joints. (4) Short columns caused by brick walls with opening in upper part. (5) Bad quality of used materials and bad workmanship. (6) Non adequate maintenance. (7) Little amount of stirrups in joints and columns with high compression.

RESULTS

Twenty school buildings were evaluated. In each one it was determinate their vulnerability functional, non structural and structural. We wrote records of this evaluation (small tables).

The blue print was digitised (AutoCAD 14) in order to build a data bank which will be actualised and completed.

Recommendations were suggested in each building, in order to decrease the functional and non-structural vulnerability to an acceptable level.

In the cases in which the results showed structural problems it was suggested different consolidation and strengthening alternatives. An emergency evacuation plan was proposed for each building.

Synthetic technical evaluation records were done. In these records were included the evaluation of functional, non structural and structural aspects (Figures 4, 5 and 6).

CONCLUSION:

It was necessary for the seismic evaluation of all these buildings to use a methodology, which have the following conditions: (1) to cover different aspects that had a high influence in the seismic security and in their relation, increasing the general concept of the structural security. (2) the quick diagnoses of the buildings and an accurate evaluation to determine the seismic capacity of them.

In relation to the first topic the results showed that there were functional deficiencies in almost all the buildings studied such as: maximum distances to exits, circulation minimum dimensions, door with, etc. These problems were due to the changes in the original project because of the number of students has increased notably. Another aspect that had not been taken into account was the way of the door opening. They all open to the inside.

The main danger during a big tremor would be the crack of non-structural elements, specially thin walls made with hollow bricks, braking of glasses, falling of ceilings or furniture.

In the second topic, the application of the Qualification Method of R. C. Buildings allowed us to work in different levels to determinate the seismic vulnerability of a big number of buildings. Most of them were evaluated in level1 and only a few in level 2.

All things considered, verify the validity of the use of this method in other context in which you need a quick answer to prevent earthquake risk effects.

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Table 1 - POTENTIAL SEISMIC SOURCES (Figure 2) (Source: INPRES)

Source	Source Name	Length Km	Strike	Historical EARTHQUAKE	*Maximun credible Eq* Magnitud (Ms)	Recurrence (years)
Active Faults	El Tigre	420 (1)	N-S	- - -	8	1250
	Precordillera Oriental	120	N-S	Jan 15 1944 Ms= 7.4	7 3/4	400
	Punilla-La Bolsa	300	N-S	Oct 27 1894 Ms= 7.5	7.6	900
	Pismanta	50	N-S	- - -	7.2	4000
	Niquizanga	90	(2)	Jul 7 1941 Ms= 6.3 Nov 23 1977 Ms= 7.4	7.7	4000
	Maradona-Deheza	130	N-S	Jun 11 1952 Ms= 6.2	7.2	8000
	Las Chacras-V.Fértil	180	N 70°W	- - -	7.0	3000
	La Cantera	20	N-S	Mar 3 1924 Ms= 6.2	6.9	5000
Zones	Subduction	- - -	- - -	Apr14 1927 Ms=7.1 (3)	7.5	500
	S-E San Juan	- - -	- - -	- - -	6.0	200
	N-W Mendoza	- - -	- - -	Dec 17 1990 Ms= 6.0	6.0	200
	Central Chile	- - -	- - -	Nov 11 1922 Ms= 8.4	8.5	100

(1) Other authors consider 1000 km of length. (2) Variable strike. (3) Epicentre in Mendoza Province.

TABLE 2 - MAJOR EQ IN THE PAST 100 YEARS IN SAN JUAN AREA. (FIG 2) (SOURCE: INPRES)

Date & Time	Active Fault	Mag	Epicentre	Population Death Injured	IMM Epicentre	Area inside IMM III Km²
Oct. 27, 1894 (16:30)	El Tigre	7.5 ÷ 8	N-W San Juan Province	N/D N/D	IX	3.000.000
July 3, 1941 (3:12)	Nikizanga	6.3	S-E San Juan Province	2 N/D	VII	40.000
Jan. 15, 1944 (20:50)	Prec.Oriental – La Laja	7.4	North San Juan Province	10.000 20.000	IX	1.600.000
June 10, 1952 (21:30)	Prec.Oriental– Maradona	7.0	S-W San Juan Province	1 5	VIII	1.000.000
Nov. 23, 1977 (6:28)	Nikizanga	7.4	S-E San Juan Province	100 250	IX	2.600.000

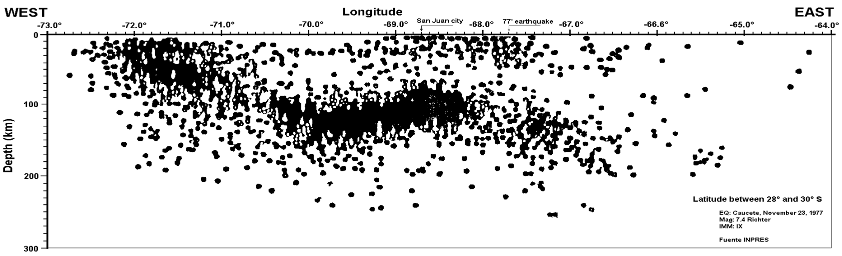
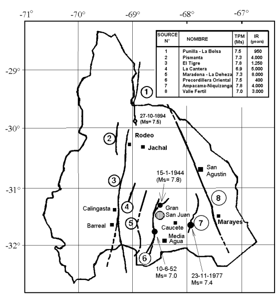


Figure 1: Hypocenter Cross section distribution beneath San Juan city (Latitude 28° to 30°)



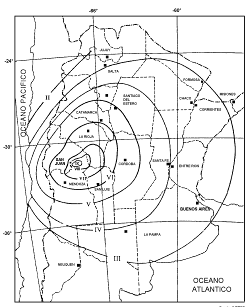


Figure 2: Main faults and earthquake **Figure 3: Caucete Nov 23, 1977 Isoseismal map**

CAPITAL

GEGENERAL

INFORMATION

Strategies for Seismic Prevention In Scholar Buildings
Bernardino Rivadavia School

U.N.S.J. **F.A.U.D.**

Code	School name	Level	M	T	I	V	N	Pupils
P/1/064	Bernardino Rivadavia	P	x					1037
B/1/004	Francisco N. Laprida	P		x				517
C/1/005	Domingo C. Valve	L					x	22
S/1/002	Mons. Dr. S. Martinez	T				x		365

General Information

Address: San Luis 526 - East -

Construct. year	1954	Sup. Terreno	5445.17
Nomen. Catastral	01-40-500100	Sup. Cubierta	4858 m^2
F y R Censal	F1-R3	Sup. Impronta	3386m^2
F.O.T.	0.89	F.O.S	62%

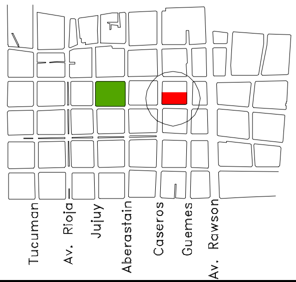
Urban Vulnerability Index

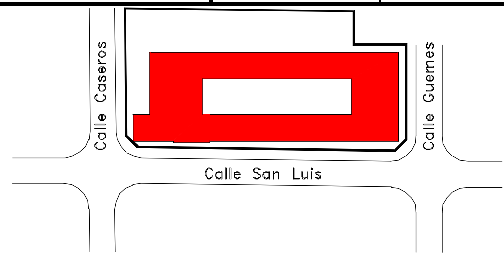
Functional	Direct
MA - 70	B - 6.60
Total	M - 76.60

Use Coefficient

N° of Rooms	34
Exclusive	30.5
Primary	45.70
Complem.	57.09

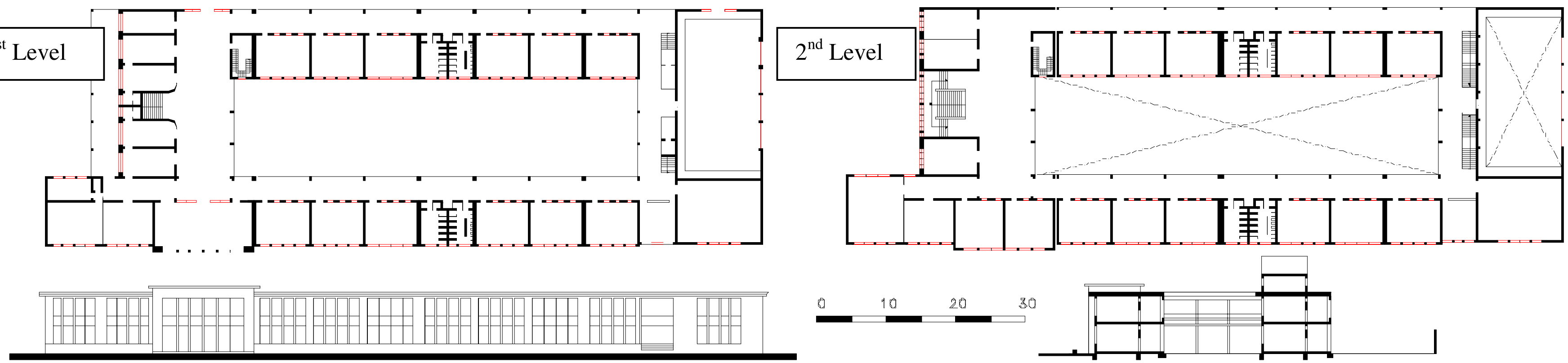
Location:





1st Level

2nd Level

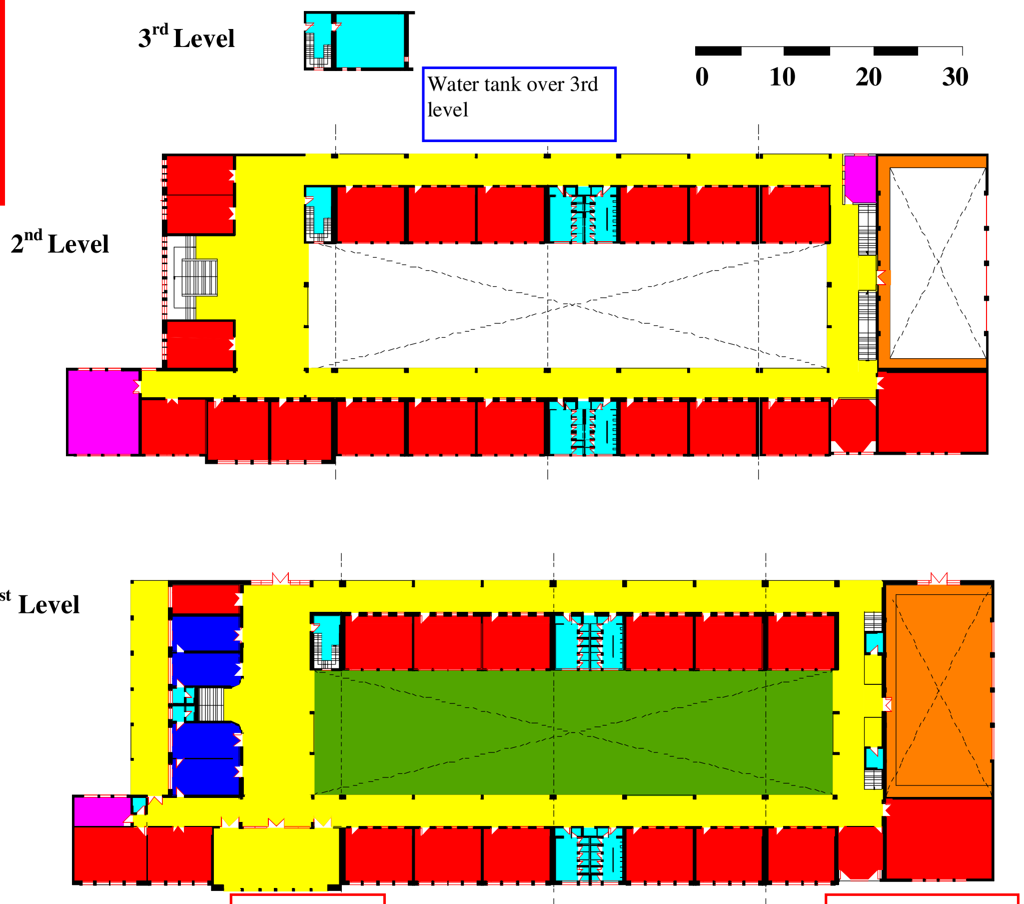


CAPITAL

Facade

Strategies for Seismic Prevention In Scholar Buildings **U.N.S.J.** **F.A.U.D.**

Bernardino Rivadavia School



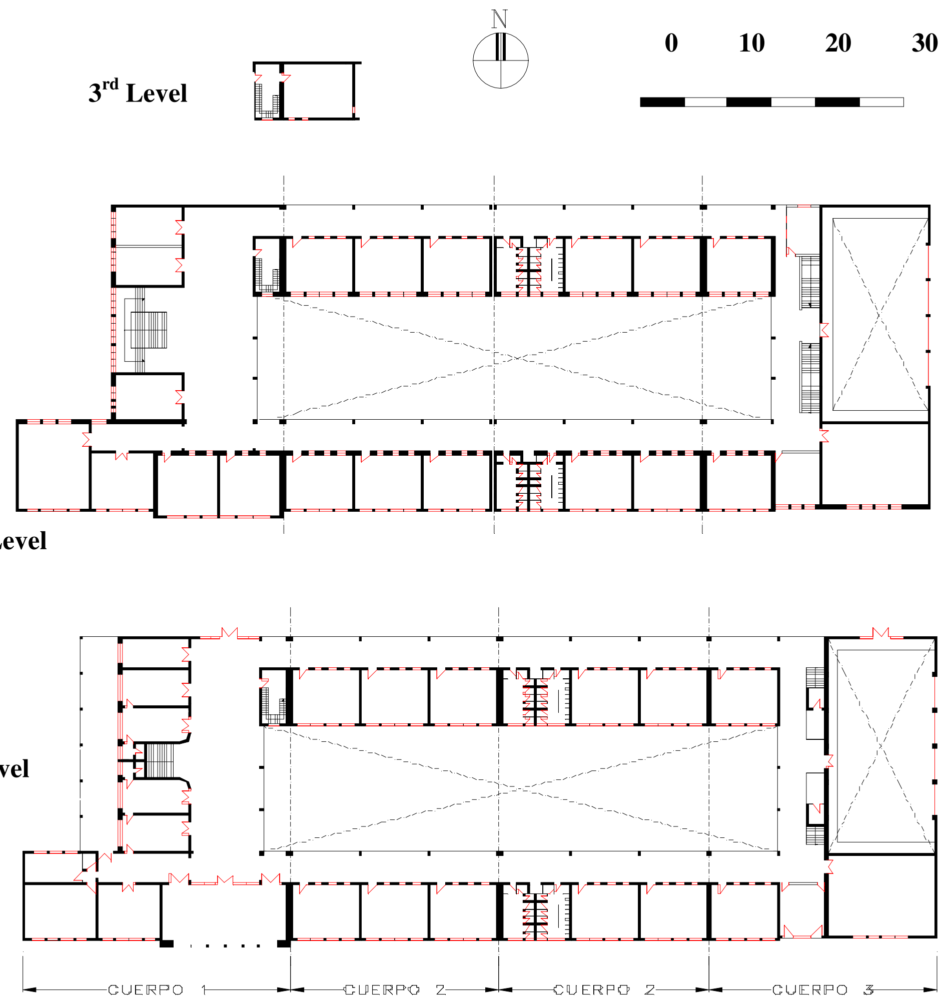
Especial Educational space		Service Area		Typology	Rectang. with central curt
Complementary Area		Circulation space		Contextual relation	Aisle in the block

FUNCTIONAL ASPECTS		
		VALUATION
Horizontal Circulation	Hall: 3.50m	1
Vertical Circulation	3.8m - 2x2.00m	1
Maximum distances to exits	Classroom: 45m. SUM: 85m	1
Maximum distances to stars	40.00m	1
Classroom width doors	1.00m	1
Opening	Inside	0
Number of doors	1	-
Main Access	3 de 2.00 m c/u	1
Opening	Inside	0
Number of doors	2	-
OBSERVATIONS	A secondary hall was occupied as classroom in the first and second level.	

NON- STRUCTURAL ELEMENTS		
		VALUATION
Electric installation	Good Condition. There isn't security interrupter	0.5
Water and sewer installation	Good Condition	1
Gas installation	Outside installation without security valve.	0
Glasses dimensions	(2.8x1.5) m	0
Library and Video room equipment.	There isn't	1
Ceiling	Gypsum -	1
Classroom equipment	Fixed	1

CAPITAL

…istration Area		Expansion		Modifications	Split classroom in 1st level	Hanging elements	There isn't	



STRUCTURAL ASPECTS

Building	Direc.	Level	File IN	File OUT	Coefic. K	Qualification
1	X	FIRST	RIV-C1X.DAT	RIV-C1X.RES	0.156	OK
		SECOND			0.299	OK
1	Y	FIRST	RIV-C1Y.DAT	RIV-C1Y.RES	0.159	OK
		SECOND			0.284	OK
2	X	FIRST	RIV-C2X.DAT	RIV-C2X.RES	0.200	OK
		SECOND			0.314	OK
2	Y	FIRST	RIV-C2Y.DAT	RIV-C2Y.RES	0.271	OK
		SECOND			0.426	OK
3	X	FIRST	RIV-C3X.DAT	RIV-C3X.RES	0.216	OK
		SECOND			0.311	OK
3	Y	FIRST	RIV-C3X.DAT	RIV-C3Y.RES		OK
		SECOND				OK

EVALUATION: Method Of Standard Evaluation Of Seismic Capacity Of Reinforced Concrete Buildings (Low And Medium Height)

SATISFACTORY