SEIEMIC ARCHITECTURE AS AN ESSIENTIAL COMPONENT of the Structural Integrity of Apartment Buildings in Israel

M. Sever [1] and D. Yankelevsky [2]

[1] *M.Sc in architecture, Faculty of architecture, Technion-Israel institute of Technology, , Haifa, Israel*
[2] *Professor, Faculty of Civil&Env. Engineering, Technion- Israel institute of Technology, Haifa, Israel*
Email: maritts@gmail.com, davidyri@tx.technion.ac.il

ABSTRACT :

The purpose of this work is to highlight the architect of the need to be aware of seismic issues as part of the various design considerations and constraints. The research in that field is important for architects since some of the buildings are designed for seismically prone areas. Israel for example is located in such an area. With its developed infrastructure and dense urban areas, Israel is highly vulnerable to earthquake events. Analysis of the relevant literature yields a number of aspects which should be taken into account by the architect. This study has focused on four of them: symmetry, continuity, distribution of mass and dimensions. Architectural decisions related to the construction materials are not within the scope of this work. A tool has been developed in order to enable a preliminary analysis of building drawings according to the general principles that were studied from the literature. This tool makes it possible to differentiate types of buildings according to the number of characteristics that have been found problematic from a seismic perspective. With this tool, Three representative designs of apartment buildings from the Israeli public sector have been analyzed. The architect can use this tool for having a qualitative picture about the characteristics of a building from a seismic perspective. No other data is necessary for this analysis but a ground story and typical floor plan and typical sections of the building. However, in order to conclude what the structural resilience of the building is, one cannot rely solely on this preliminary analysis. The common goal of the two professions- architecture and structural engineering- is to ensure the safety of the people inside a building. Seismic architecture will take into account seismic aspects together with other matters of concern in order to make sure the building will not only be functional but also will be able to structurally survive an event of an earthquake.

KEYWORDS: Architecture, building, earthquake, resilience

1. BACKGROUND

Israel is located between the Arabian and African plates (figure 1). With its developed infrastructure and dense urban areas, Israel is highly vulnerable to earthquake events. The first seismic code for designing buildings had been introduced some forty years ago. It has been significantly revised in 1975. In 1995 a new comprehensive code has been applied and it is currently updated.

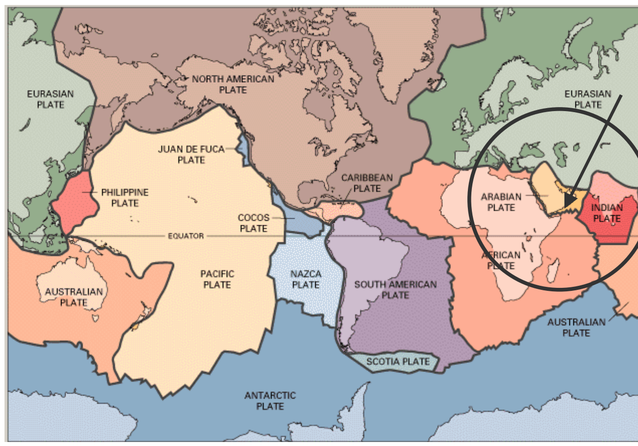


Figure1: The location of Israel between the Arabian and African plates (http://pubs.usgs.gov/gip/earthq)

1.1. The seismic conditions in Israel

There are two active faults in Israel: (1) the dead sea rift along the African-Arab fault (2) The Carmel faults.
In the last thousand years, a strong earthquake event took place in the area averagely every one hundred years. There were thousands of victims as a result of the 1837 earthquake that took place in the northern part of Israel. Almost a hundred years later, the 1927 earthquake resulted in hundreds of victims and a lot of damage to the urban areas around Jerusalem.

1.2. the Israeli preparedness

Most of the Israeli buildings were built before 1975 and therefore have not been deigned for seismic resistance. In 1995 a new comprehensive code, which consists of guidelines for designing buildings for seismic resistance, has been applied in Israel and it is being updated nowadays. In August 1999 the Israeli Government decided on a preparedness program for an earthquake event. As a result, a steering committee was established and its early assessment mentions the anticipated damage due to a strong earthquake whose focus would be in Israel. (See table 1.1).

Table 1.1 Assessed damages due to a strong earthquake in Israel
(Steering Committee for Earthquake Preparedness in Israel ,2007)

The damage	**Quantity**
Victims	16,000
Severely injured	6,000
Not severely injured	83,000
Evacuated people	377,000
Demolished buildings	10,000
Heavily damaged buildings	20,000
Lightly damaged buildings	104,000

2. THE PURPOSE OF THE PRESENT STUDY AND ITS METHODS

The major question to address is: What are the architectural building properties which influence mostly its behavior in an earthquake event. A following mission is to identify these properties in Israeli apartment buildings, in order to assess the architectural design effect on their resistance. The study is composed of a theoretical part and a practical part. First the principles of seismic architecture have been studied from the literature. Then a tool has been developed to enable a preliminary analysis based on the building's drawings of the ground story and typical floor plans as well as typical building's sections..

3. THE PRINCIPLES OF THE SEISMIC ARCHITECTURE

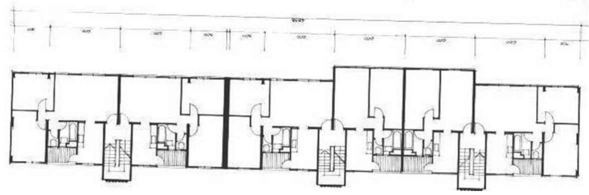
In order to understand the impact of architectural decisions dealing with the geometry of the building on its behavior in an earthquake, various aspects of geometry have been examined. Studying the building's geometry includes an investigation of: (1) Symmetry (2) Continuity of the resisting elements (3) Distribution of mass (4) Dimensions. The matter of dimensions refers not only to the location of the building in the site but also to the size of elements and to their arrangement in the building system as well as their relative position and the locations of the centers of mass and rigidity. From a seismic perspective, if located properly, piers of elevators and staircases which are usually continuous from the foundation's level to the building's top level can contribute to the capability of the building to resist lateral loads (Yankelevsky D., Swartz S.,2005).

4. ANALYSIS OF DRAWINGS OF ISRAELI BUILDINGS

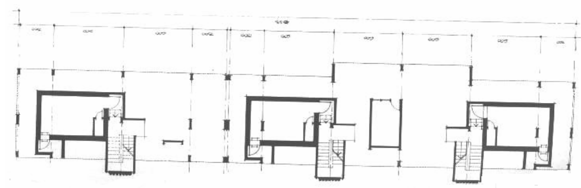
The "architect-oriented" tool that has been developed in this study enables a preliminary analysis of building drawings. With this tool, three representative designs of Israeli apartment buildings from the public sector have been analyzed. (1) a linear residential block (2) an "H" block (3) a centric block. These are typical apartment buildings built by the Israeli Government during the state's first decades, before a seismic code for design buildings has been effective. A checklist was formulated to examine various aspects of the design (see table 4.4). A positive answer to any of the questions indicates an apparent seismic weakness of the building. In that way the architect can use this tool when designing a building or when evaluating a design. He may focus on the questions whose answer has been positive in order to figure out if he can modify and improve the design to avoid that weakness. The answers get points. In its simplest version a positive answer gets 1 point. A negative answer gets no points. In its advanced version each question may get a different grade according to its importance and effect on the entire building under consideration. This tool makes it possible to sort buildings according to the number of deficiencies which are considered a problem from a seismic perspective.

4.1. a linear block

The plan of a four stories building that was built in 1972 in an industrialized method of construction is shown in figure 2. The structure is made of prefabricated concrete frames. Each floor consists of 55-70 square meters apartments. The ceilings are made of modular prefabricated units of 1.20 meters width. They are supported by the concrete frames. The interior partitions are made of gypsum boards and have no contribution to the building's lateral resistance. The exterior walls along the facades are made of prefabricated decorative concrete. The staircases shafts are made of prefabricated concrete walls. Table 4.2 analyses the building's configuration in plan and section.



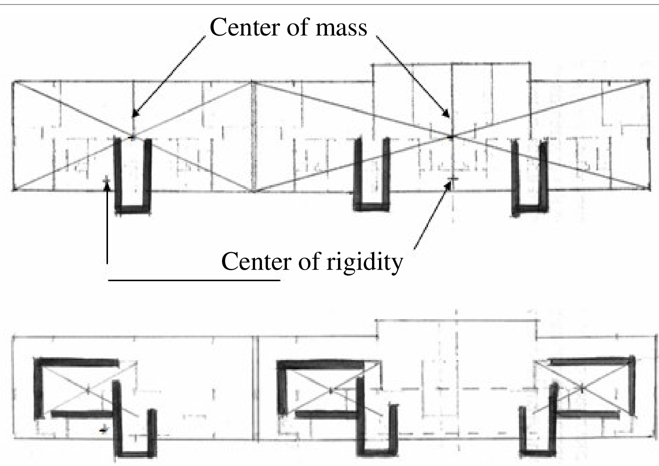
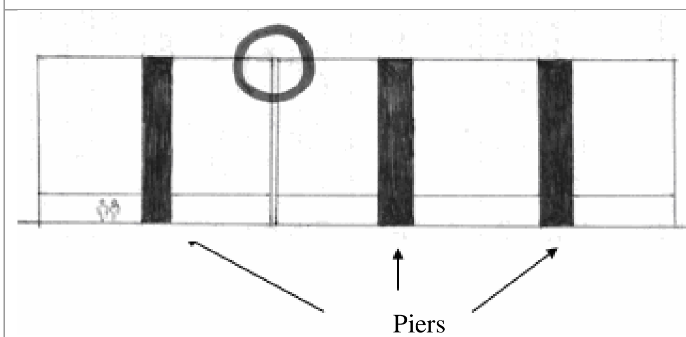
(a)



(b)

Figure2: A linear residential building (Golani, 1973)
(a) a typical floor (b) a ground floor

Table 4.1 Identification of problems in a linear residential building-in plan and section

The plan configuration	**Checklist**
	Is the plan configuration complex? ***No{0}***
	Is there asymmetry with respect to the X axis? ***Yes {1}***
	Is there asymmetry with respect to the Y axis? ***Yes {1}***
	The center of mass and the center of rigidity do not coincide? ***Yes {1}***
	Are there large openings in the ceiling that affect the diaphragm action? ***No{0}***
The section configuration	**Checklist**
	Is the section configuration complex? ***No{0}***
	Are there discontinuous columns? ***No{0}***
	Is there asymmetry with respect to the vertical axis? ***Yes {1}***
	Are there narrow joints that might cause pounding of adjacent parts of the building? ***Yes {1}***
	Is there a soft storey? ***No{0}***
	Are there short columns? ***No{0}***

4.2. A type "H" building

The plan of a seven stories building that was constructed in 1972 is shown in figure 3. The structural system is made of concrete bearing walls along the X direction of the building. The staircase shafts were constructed of reinforced concrete and may be considered as stiffening elements. The area of each apartment is 70-90 square meters. Table 4.2 shows the evaluation of the building's configuration.

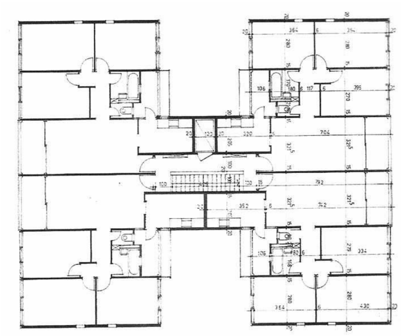
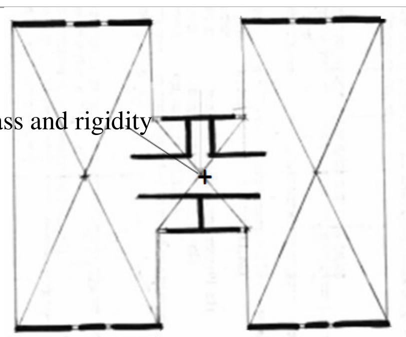
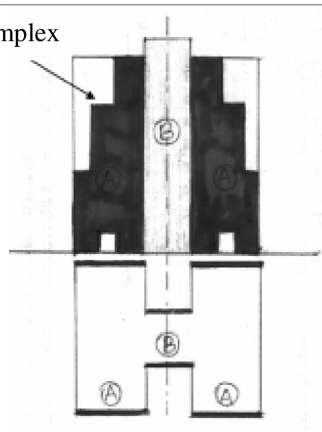
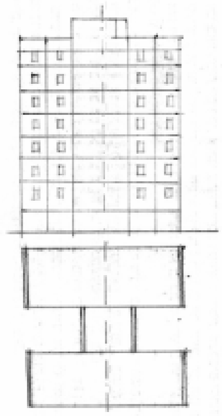


Figure 3: A type "H" building (Golani, 1973)

Table 4.2 Identification of problems in a type "H" building-in plan and section

The plan configuration	**Checklist**
Center of mass and rigidity 	Is the plan configuration complex? ***Yes {1}***
	Is there asymmetry with respect to the X axis? ***No{0}***
	Is there asymmetry with respect to the Y axis? ***No{0}***
	The center of mass and the center of rigidity do not coincide? ***No{0}***
	Are there large openings in the ceiling that affect the diaphragm action? ***No{0}***
The section configuration	**Checklist**
Complex  	Is the section configuration complex? ***Yes {1}***
	Are there discontinuous columns? ***No{0}***
	Is there asymmetry with respect to the vertical axis? ***No{0}***
	Are there narrow joints that might cause pounding of adjacent parts of the building? ***No{0}***
	Is there a soft storey? ***No{0}***
	Are there short columns? ***No{0}***

4.3. A centric residential building

The plan drawing of a (three) four stories building that was built in 1960 is shown in figure 4. There were a few design alternatives for the ground floor: columns, two apartments and columns, four apartments and an entrance to the building. Table 4.3 evaluates the building's configuration.

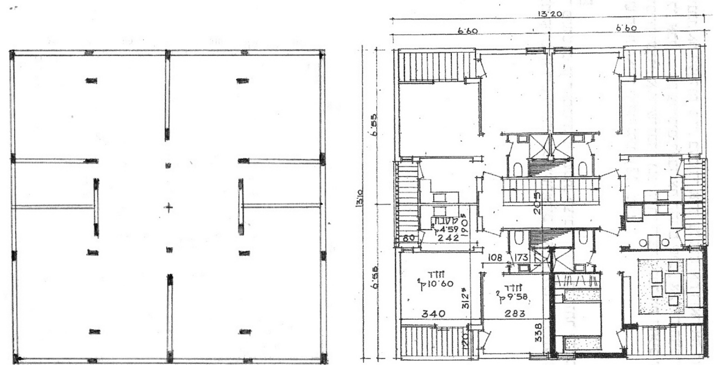
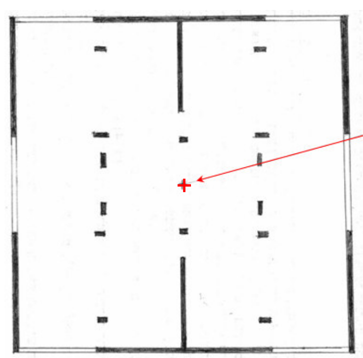
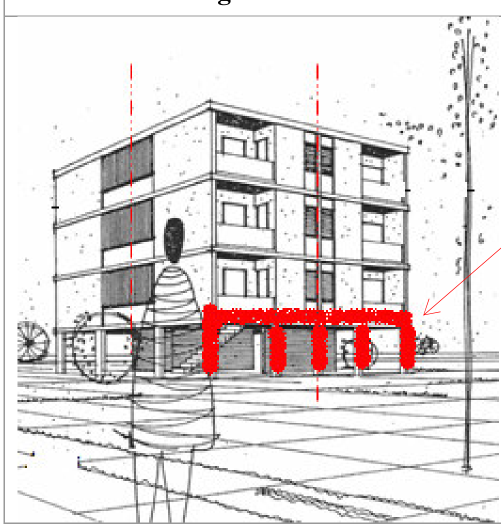


Figure 4: A centric residential building (Perlstein,1960)

Table 4.3 Identification of problems in a centric residential building -in plan and section

The plan configuration	**Checklist**
	Is the plan configuration complex? ***No {0}***
	Is there asymmetry with respect to the X axis? ***No{0}***
	Is there asymmetry with respect to the Y axis? ***No{0}***
	The center of mass and the center of rigidity do not coincide? ***No{0}***
	Are there large openings in the ceiling that affect the diaphragm action? ***No{0}***
The section configuration	**Checklist**
	Is the section configuration complex? ***No{0}***
	Are there discontinuous columns? ***No{0}***
	Is there asymmetry with respect to the vertical axis? ***No{0}***
	Are there narrow joints that might cause pounding of adjacent parts of the building? ***No{0}***
	Is there a soft storey? ***Yes {1}***
	Are there short columns? ***No{0}***

4.4. Results

This preliminary evaluation tool has made it possible to differentiate between the types of building as illustrated in table 4.4. [Note: Architectural decisions related to the construction materials are not within the scope of this work and they deserve a separate discussion.]

Table4.4 Identification of problematic issues through a preliminary analysis- results

The area of analysis-questions	**The elements which have influence on the resistance of the building**	**Answers**		
		Linear	**"H"**	**Centric**
1. Plan configuration	Is the plan configuration complex?	0	1	0
	Is there asymmetry with respect to the X axis?	1	0	0
	Is there asymmetry with respect to the Y axis?	1	0	0
	The center of mass and the center of rigidity do not coincide?	1	0	0
	Are there large openings in the ceiling that affects the diaphragm action?	0	0	0
2. Section configuration	Is the section configuration complex?	0	1	0
	Are there discontinuous columns?	0	0	0
	Is there asymmetry with respect to the vertical axis?	1	0	0
	Are there narrow joints that might cause pounding of adjacent parts of the building?	1	0	0
	Is there a soft storey?	0	0	1
	Are there short columns?	0	0	0
3. Resisting elements	Are there any missing resisting elements in the X direction?	1	0	0
	Are there any missing resisting elements in the Y direction?	0	1	0
	Are the building shafts located asymmetrically in the floor plan?	1	0	0
Summary		**7**	**3**	**1**

The preliminary evaluation of the linear type building indicated 7 problematic characteristics**.** The evaluation of the "H" type building indicated 3 problematic characteristics and from the evaluation of the centric type building only one problematic characteristic was observed.

Since all three building types were built when no seismic code existed in Israel, we can surely assume that they were not designed to resist any earthquakes.

Nevertheless, some of their characteristics contribute to their natural earthquake resistance to a certain extent. No disturbance of the continuity of the columns has been indicated in any of the building types. No large openings or short columns have been found either.

The linear type building, for which the largest number of problematic characteristics has been identified, has a simple plan but it lacks symmetry in plan. The building consists of two parts which differ from each other in shape and size. The resisting elements are distributed asymmetrically. As a result of it, the center of mass and the

center of rigidity do not coincide. In the event of an earthquake torsional moments will develop as a result. Another issue to deal with is the risk of pounding between the two parts of the building.
The linear building is stiffened only in its width direction. There is lack of resisting elements along the longitudinal direction of the building. A lack of resisting elements along one of the axes of the building characterizes **the "H" building** as well. The "H" building has a complex plan shape but it is symmetrical. Because of the symmetric plan, torsion is avoided. **The centric building** also has a symmetric plan shape. The building comprises of resisting elements in both directions. Assuming that the walls can function as resisting elements, the configuration of the centric building is the best one from a seismic perspective. Designing the building on columns though, might make the ground floor a soft one and considerably weaken the entire building.

5. CONCLUSIONS AND IDEAS FOR A FUTURE RESEARCH

5.1. Conclusions

The "architect-oriented" preliminary evaluation tool that has been introduced in this paper is most basic, yet it allows examining architectural design flaws of a building system. It also allows successfully comparing different building design schemes and evaluating their relative natural resistance. If the architect does not deal with the deficiencies in order to improve the building's resistance, they will be dealt by the engineer, under the architectural constraints. Consequently the design process may be more complex and more costly. This work may highlight the need of the architect to be aware of seismic issues in order to make sure the building will not only be functional but will survive an earthquake event.

5.2. Future research

The preliminary evaluation tool which has been introduced here should be extended. Additional aspects such as construction materials, construction details and the site aspects should be introduced and analyzed. Analyzing buildings drawings from the history of architecture may expand the view of proper architectural considerations which enable the building to better withstand lateral loads effects even though it has not been designed to resist any specific earthquake. Another future step of this study will be directed towards the development of guidelines for strengthening of existing buildings. Finally it is highly recommended to include this body of knowledge in architecture schools as part of the architect's basic training.

REFERENCES

Arnold, Ch.(2001). Architectural Considerations, in Naeim, F: The Seismic Design Handbook, Boston Mass, Kluwer Academic Publisher. Pp 257-326.

Golani ,Y. (Editor), (1973). Design and Construction Activity 1971-1972, The Israeli Ministry of Housing, Meir Tadmor print (in Hebrew)

FEMA, (2006). Designing for Earthquakes- A Manual for Architects.

http://www.fema.gov/library/viewRecord.do?id=2418

Perlstein Y. (1960). Residential Buildings Types (in Hebrew).

The Standard Institution of Israel (1995). The Israeli Seismic Code.

Steering Committee for Earthquake Readiness in Israel (2007).

http://www.eqred.gov.il

Yankelevsky D., Swartz S. (2005). Improving the structural integrity of high buildings in earthquakes by the use of protected spaces in the building, NBRI Report (in Hebrew).

http://www.eartquake.usgs.gov