International Journal of Constructive Research in Civil Engineering (IJCRCE)
Volume 4, Issue 4, 2018, PP 1-8
ISSN 2454-8693 (Online)
DOI: http://dx.doi.org/10.20431/2454-8693.0404001
www.arcjournals.org

The Influence of L-Shaped Structures on their Behavior against Earthquakes

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Abstract: *In this research, the effect of architectural plan or structural diagram on building behavior against earthquake with equivalent static and dynamic method sis evaluated and the results of the equivalent static and dynamic analysis as well as certain combinations of the equivalent static analysis values have been reviewed and compared. Then various types of irregularly L-shaped structures with different irregular ratios (different projections ratios) and at different heights of the model were analyzed by equivalent static and dynamic method. The rate of torsion in irregular buildings was the benchmark. The classification of the results of both of the equivalent static and dynamic analysis and their comparison showed that in regular buildings with the number of different stories. The values of the equivalent static torsion (at the critical extension) and the maximum dynamic torsion is almost the same but it is not the case in irregularly L-shaped structures. In irregularly L-shaped structures, if the number of building floors is modeled to be less than 5, a slight difference between values of the equivalent static torsion (at the critical extension) and the maximum dynamic torsion is considered to be abandoned to the extent that it can be ignored. But as the number of floors increases to the above limit, this variation of torsion from the two equations of the equivalent static and dynamic analysis increases and as the number of floors increases this difference increases. According to the results obtained in this research it is suggested that in the case of irregularly L-shaped structures, it would be possible to restrict the use of the equivalent static analysis method. It also seems that under certain conditions the maximum torsion values obtained from the dynamic analysis can be obtained by constructing suitable combinations of the torsion values obtained by static analysis in two main orthogonal directions.*

Keywords: *Torsion, Irregular Structures, L-Shaped Structures*

1. Introduction

1.1. Configuration, Regularity and Irregularity in the Plans

One of the things that needs to be carefully addressed in the design of the buildings is the configuration, regularity and irregularity of the building plan and its impact on the behavior of buildings against the earthquake.

The configuration of the building determines the ways in which earthquake forces are distributed throughout the building to a large extent and it affects the relative amount of these forces. When the building resistance criteria were applied to the structure in the earthquake, architectural design and decisions that lead to it, plays an important role seismic performance of the building. The advice in all the earthquakes regulations that discuss the configuration is that symmetrical constructional shapes prefer to asymmetrical shapes.

1.2. Configuration Problems in the Irregular Plan with Hollow Corners

A plan with a hollow corner is a common characteristic in the general configuration of buildings whose plans are shaped like L, T, H or a combination of them. In connection with these buildings, two major problems may be created:

The first is that in different parts of the building different stiffnesses are created and therefore differential movements are created that causes a localized stress concentration in the hollow corner groove.

The next problem is the torsion. The reason for this problem is that the mass and center of difficulty in these forms cannot be geometrically consistent for all possible extents of the earthquakes.

As a result, rotation is caused that tends to create transformation in the building which, in terms of the nature and size is a function of the nature and extent of the motion of the earth and they create forces that are difficult to predict and analyze.

There are two basic solutions to this problem: Separate the building in structural form in simple shapes (separator seams should be used) or closing building components to each other in a strong position at the location of the stress concentration lines and placing resistant members to reduce the torsion can be used.

2. History of Studies

Examples of damage to buildings with hollow corners are abundant and this problem is one of the first cases that are identified and identifying by an observer after the earthquake. Of course, before the beginning of this century, this problem was realized and, by the 1920's, experts had come to knowledge in these cases. Naito, for example, attributed the essential damage caused by the 1923 earthquake to kanto. Similar failures have also been reported for the earthquakes in Santa Barbara in 1930, Alaska in 1964 and Mexico City in 1985.

In previous earthquakes, most of asymmetrical buildings were more vulnerable than symmetrical buildings and on this basis; special seismic design criteria were laid down for asymmetrical buildings. Hausner and Athenen in 1985 showed that the result of the static analysis in which the exit from the center of the shear design forces is equal to the distance of the center of hardness from the center of mass (the exit from the static center). Practically not on the safety margin and the effect of the massive momentum of inertia and the dynamic behavior of the torsion result in larger torsion anchor than the static torsional anchor.

In 1960 and before that, the researchers, by defining the concept of dynamic exiting of center , attempted to define, by suing the results of dynamic analysis and calibrate its results with the static analysis results, the exit from the center of the design with the escalation of the exit from the static centrality. This case led to the introduction of the common relationships of exit from the center of design. The fact that the results of the static analysis of irregular buildings are not practically on safety margin. In other way, in the section on the interpretation of the criteria, it is recommended for lateral forces and their interpretation has repeatedly reproduced that including It the commentary provided by California structural engineers (SEAOC) can be noted:

An equivalent static method is written for buildings and uniform conditions. The application of these minimum standards (equivalent static method) in buildings or unusual conditions, in many cases, leads to unrealistic estimates. So as far as the building is away from the regular model, the amount of force obtained from these criteria will be less realistic.

3. Specifications of the Examined Models

As discussed in previous discussions, one of the problems in irregular buildings with hollow corners is the problem of torsion. The reason for this problem is that the center of mass and the center of hardness in these irregular shapes cannot be consistent for all possible earthquake stretches.

Therefore, in order to study the effect of geometric shape and architecture of irregular L-shaped structure was provided be ETABS (V: 9.17) software.

Building type: Concrete

Structural system type: Modular reinforced concrete bending frame with moderate ductility and behavior factor R=7

Building location: Isfahan (A=0.30)

Area soil: Type 3

Importance of building factor: I=1

Stories dead load: DL= 650 Kg/m^2

Stories live load: LL= 200 C

Stairs live load: LL= 350 Kg/m^2

Peripheral wall load: 650 Kg/m^2

Stories height: h= 3m

It should be explained that irregularities are defined by selecting the different ratios of outsourcing of the plans and of course, this protrusion varied only in an extension (x-axis) and protrusion along the other (y-axis) remains fixed. Each irregularity in the plan has been modeled from two to eight floors and each of them was analyzed in to equivalent static and dynamic methods and according to clause 2.4.2 of the building designs against earthquake regulations, Iran standard 2800, the baseline cutting values were adjusted and according to clause 2.5 of the same regulation, the relative displacement of the same floors was limited and protrusion ratios a/L= 1.05, 0.70, 0.35, 0.00 were defined for irregular expression in the plan.

4. Introduce the Protrusion Ratio

For easy naming and identification of models, a criterion was defined based on the ratio of protrusion and the number of floors that is as follows:

In this introduction, a/L is the protrusion ratio and n is the number of stories of irregular L-shaped model.

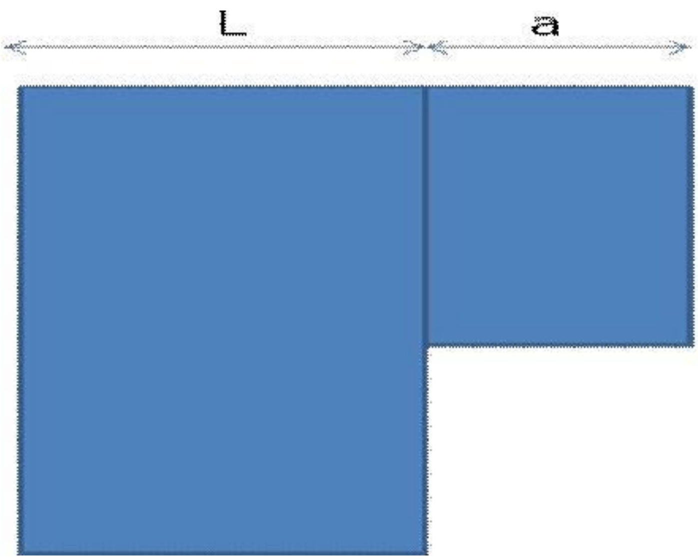


Fig1. *Introduce the protrusion ratio (a/L)*

5. Modeled L-Shaped Plans

Geometrical specifications of irregular L-shaped plans with different protrusion ratios (a/L) that were modeled in this research are as follows:

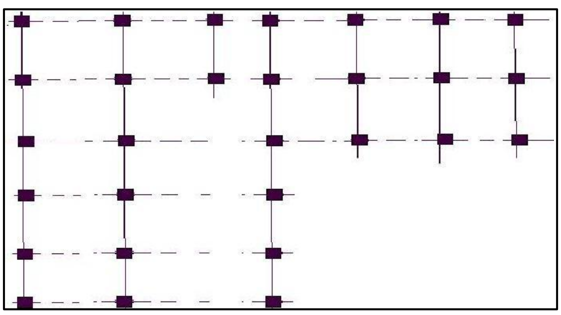


Fig2. *L-shaped plan with ratio a/L= 1.05*

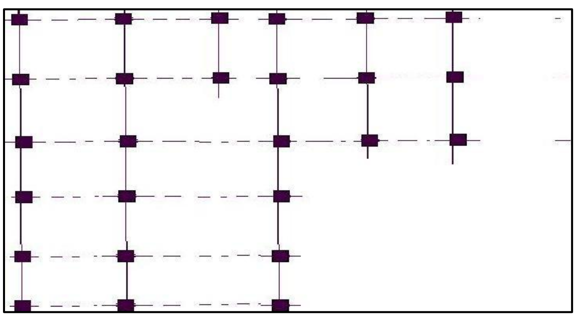
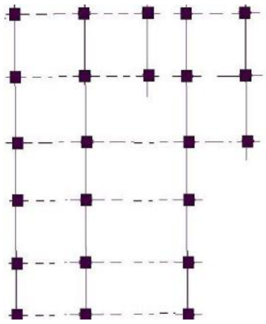


Fig3. *L-shaped plan with ratio a/L= 0.70*



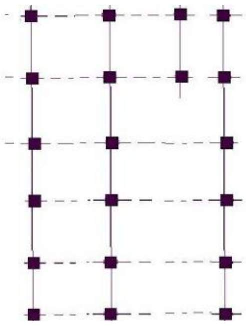


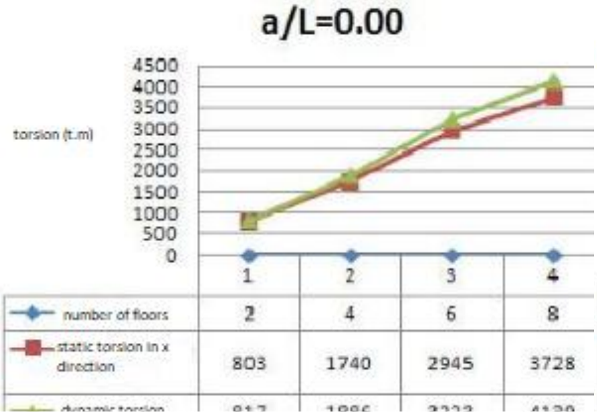
Fig4. *L-shaped plan with ratio a/L= 0.35* **Fig5.** *L-shaped plan with ratio a/L= 0.00*

6. ANALYZED RESULTS CHECK

6.1. Part 1

As previously stated, looking past experiences, the ineffectiveness of equivalent static analysis methods is clarified for irregular buildings with a large number of floors. Therefore, the necessity of using modified methods or dynamic analysis methods for buildings cannot be denied.

So, in order to checking the output values obtained from dynamic and equivalent static analyzes in irregular L-shaped structures, which are the subject of this research, the plans of figures 2 and 5 were modeled according to the specifications of clause 3 and in the number two to eight floors, and were analyzed in two equivalent static and dynamic methods. The results of the equivalent static and dynamic analysis of each of the regular and irregular models above are shown in figures 6 to 9.



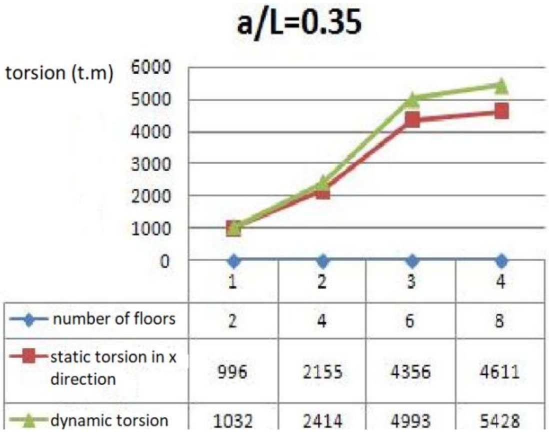
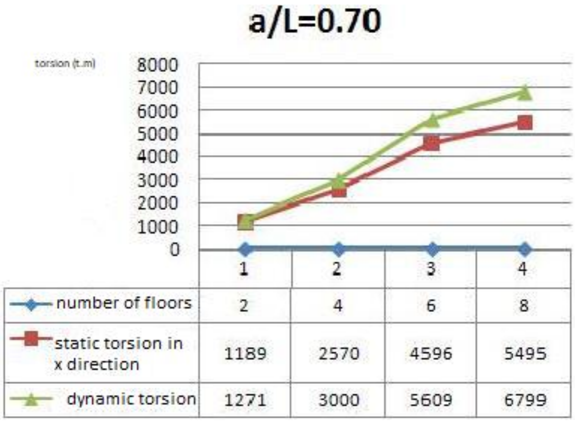


Fig6. *Torsion changes with ratio a/L= 0.00* **Fig7.** *Torsion changes with ratio a/L= 0.35*



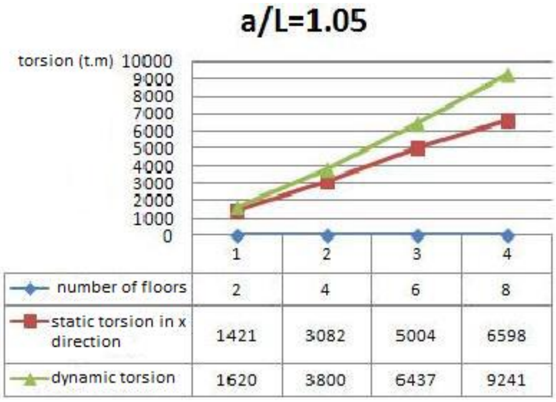


Fig8. *Torsion changes with ratio a/L= 0.70* **Fig9.** *Torsion changes with ratio a/L= 1.05*

Looking to graph of the torsion changes to the increase in the number of floors for buildings with irregular L-shaped plans but with different protrusion ratios, unlike irregular models, in in which the values of equivalent static (at the critical extension) and maximum dynamic torsion are almost the same in all floors, and there is a slight difference between them, in these irregular models, in floors less than 5 floors, the difference between the values of static and dynamic torsion is high. The results show that there should be some limitations to use the equivalent static method in irregular buildings. This limitation in the case of a one-dimensional examination can be only to the creation of a limit at the maximum height or the maximum number of floors for the equivalent static method. Accurately in the percentages of the difference between the maximum torsion of the equivalent static analysis along the critical point and the maximum torsion of the dynamic analysis presented in table 1, it can be seen that the higher the protrusion ratio (a/L) for irregular L-shaped structures, the difference in the values of the torsion results from two types of analysis increases.

Table1. *The difference percentage between Tes, x and Tdy for different protrusion ratios (a/L) and for different number of floors*

n / a/L	2	4	6	8
0.00	1.7	7.7	8.5	9.9
0.35	3.5	10.7	12.8	15.05
0.70	6.5	14.3	18.1	19.2
1.05	12.3	18.9	22.3	28.6

That means, in order to increase efficiency in analysis, a two-dimensional limit can be created to use an equivalent static method. In this way that by decreasing the protrusion ratio, the maximum height limit or the maximum number of floors increases and vice versa, with the increase in protrusion ratio, the permitted maximum height or the permitted maximum number of floors for the equivalent static method to be reduce.

6.2. Part 2

This part of research, examines the combinational values of the torsions due to the equivalent static analysis and the torsions due to the dynamic analysis. This comparison between the compound of 100% of the value of the torsion due to the equivalent static analysis along the critical extent (Tes, x) plus 30% of the torsion due to the equivalent static analysis along the critical extent (30% Tes, y), with the maximum torsion value of the dynamic analysis (Tdy, max). In other word, taking into account the fact that in all models provided, x-x stretch, the stretch is critical, the comparison is made between values of Tdy=Tdy, max Tm=Tes, x + 0.30 Tes, y. (figs. 10 to 13)

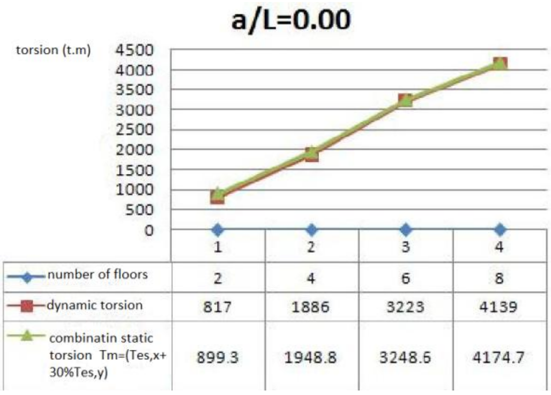


Fig10. *Torsion changes with ratio a/L= 0.00*

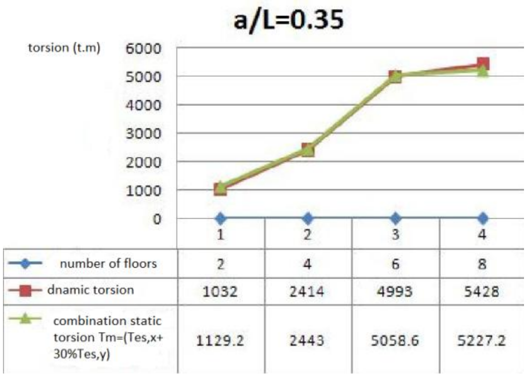


Fig11. *Torsion changes with ratio a/L= 0.35*

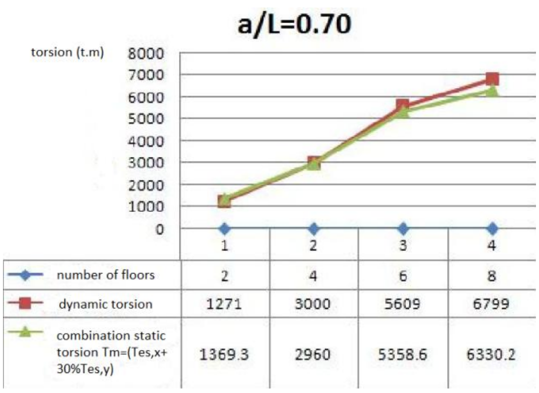


Fig12. *Torsion changes with ratio a/L= 0.70*

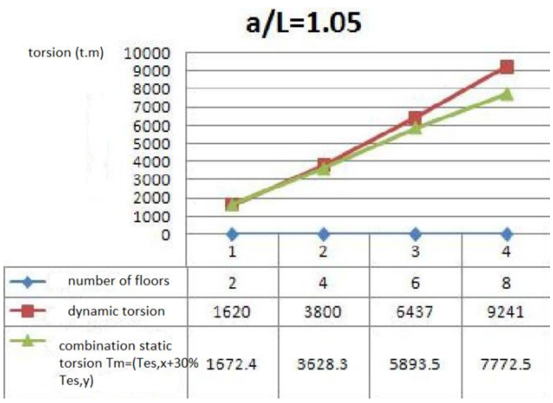


Fig13. *Torsion changes with ratio a/L= 1.05*

As seen from this equation, the combined sum of the torsion(Tm) is very close to the maximum torsion due to the dynamic analysis (Tdy), which in many cases causes their graphs to match the same.

With precision in table 2 and comparison of the values of the difference between the maximum dynamic torsion (Tdy) and the static composite torsion (Tm) , for different protrusion ratios (a/L) and number of different stories (n) , the amount of static torsion for the number of floors less than 5 floors is often greater than the value of the dynamic torsion and for floors of more than 5 floors, this difference is negligible and of course, as the protrusion ratio of the number of the floors (or height from the base level) increases, this percentage difference increases. (Table 2)

Table2. *The percentage difference between (Tm) and (Tdy) for different protrusion ratios and the number of different stories*

n / a/L	2	4	6	8
0.00	10.10	3.3	0.7	0.9
0.35	-9.4	-1.2	-1.3	3.7
0.70	-7.7	1.3	4.5	6.9
1.05	-3.2	4.5	8.4	15.9

From what was said and the values of table 2 shows that by choosing good combination of varying degree of static torsion in two orthogonal directions, one in a critical direction and the other in the orthogonal direction with critical direction, we can modify or adjust the elevation constraints for irregular buildings.

In any case, comparison of the values of table 2 and graphs shows in the event dynamic analysis cannot be provided for an irregular L-shaped structure, by performing a static analysis in two orthogonal directions and creating the above numerical combination (Tm), the maximum dynamic torsion can be approximated and as the ratio of this irregularity (ratio a/L) and the number of floors (n) is lower, these static torsional values of dynamic torsion.

7. Conclusion

In this study, the functions of irregular L-shaped structures with irregular layout (different protrusion ratios) and with variable number of floors from 2 to 8 were investigated. According to the presented content and within the range of models examined, the following results can be presented:

1. In regular buildings, the values of the torsion results from the equivalent static analysis in the critical direction, with the values of the maximum torsion resulting from dynamic analysis in buildings of different stories is approximately the same. In other word, the use of any equivalent static or dynamic method leads to the same results for the torsion and there is no limit for the use of each within the standard building height.
2. Unlike irregular buildings, with the equivalent static (along the critical extent) and maximum dynamic torsion values, almost all of the models with different number of floors were almost identical, in irregular L-shaped structures, this is not the case. As in the case of irregular L-shaped models, if the number of modeled building floors is less than 5 floors, a slight different is found between the values of the equivalent static torsion (along the critical extent) and the maximum dynamic torsion, which, of course, can be ignored. But with increase in the number of floors to the above mentioned limit, this variation of torsion from two equivalent static and dynamic analyzes will increase and the greater number of floors, the greater difference. Therefore, the use of equivalent static method for irregular L-shaped structures, if the number of floors is less than 5 floors, results in almost the same results with the dynamic method, however, with increasing the number of building floors to above, the values of the torsion due to the static analysis are not acceptable.
3. In irregular L-shaped structures, there should be some limitations to use the equivalent static analysis method. This limitation can only be considered at the maximum height of the irregular L-shaped structures or the maximum number of its floors.
4. By making suitable combinations of the values of the torsion obtained by equivalent static analysis in two main orthogonal directions, the maximum torsion values obtained from the dynamic analysis can be obtained. These compounds can be used incases which dynamic analysis is not

possible, because it leads to the same results with the torsion caused by dynamic analysis. One of those acceptable compounds, which can be pointed out, is a combination, which is derived from the some of the convolutions resulting from an equivalent static analysis at continental perpendicular along critical extent. Reviewing the results of table 2 shows that the torsion of this compound is almost the same as the maximum dynamic torsion from irregular L-shaped structures. Of course, the less number of floors and the less irregularity, the more precision will be.

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Citation: *Morteza Soltani. et.al, "The Influence of L-Shaped Structures on their Behavior against Earthquakes", International Journal of Constructive Research in Civil Engineering, 4(4), pp. 1-8. DOI: http://dx. doi.org/10.20431/2454-8693.0404001*