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Effect of Dimension and Analytical Modelling Technics of U –Shaped Shear Wall on Behavior of RC Buildings

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***Abstract*— U – shaped shear walls are commonly used in buildings to surround elevators and stairs. In process of design of a new building or evaluation of an existing building, analytical model of this type of shear wall is important to estimate reliable results. U – Shaped shear wall can be modelled with shell element or equivalent frame element. It is obvious that using shell element gives closer results, however using shell element increases the analysis duration and long analysis duration is not preferred by the engineers. In this study, effect of U – shaped shear wall with different leg length and using different modelling technics such as shell element and equivalent frame element has been investigated.**

***Keywords*—U – shaped shear wall, reinforced concrete building, modal analysis, frame element, shell element**

I. Introduction

Most of the buildings are generally constructed as reinforced concrete structure (RC) nowadays. Buildings are designed for vertical and horizontal loads. Buildings can resist vertical loads safely however it is important to design buildings safe against the horizontal loads. Earthquake and wind loads are the horizontal loads and they have considerable effect on building's behaviour. Earthquake has more effect on RC buildings than wind loads and RC buildings can have partially damages or totally collapse under a severe earthquake. Previous studies showed that structural damage is caused by large displacement under earthquake. Shear wall has a considerable effect on resisting of horizontal load for a building and it prevents large displacements caused by seismic lateral loads [1], [2], [3]. Properly constructed structural walls can even eliminate the poor seismic response of RC buildings due to the adverse effect of structural irregularities or deficiencies such as soft story, short column, insufficient confinement, poor detailing in beam-column joints, poor material quality etc. [4]. Thus, shear walls should be designed properly to resist horizontal loads and analytical model of shear wall is so important to estimate reliable results.

Shape of shear wall depends on purpose of using buildings or architectural needs. U - Shape shear wall can be widely seen and it is used to surround stairs and elevator. U – Shape shear wall has considerable behaviour in both direction and analytical model of this type of shear wall becomes more complicated.

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A shear wall is analytically modelled as "shell element", "plate element" or "frame element" in a computer aided software program. It is obvious that using a shell element gives very reliable results in analytical modelling. A shear wall, modelled with shell element, is divided into finite elements however for a large system, number of this small pieces gets large stiffness matrix and sometimes it decreases speed of solution and causes long time to estimate the result. Equivalent frame element can be preferred to decrease the time of solution.

The aim of this study is to compare the results of different analytical modelling of U – shaped shear wall. For this purpose, a ten – storey RC frame building with U – shaped shear wall was modelled via SAP 2000 and U – shaped shear wall was modelled with "frame element" and "shell element". The effect of using different modelling technique has been investigated. Also width of leg of U – shaped shear wall was changed and the effect of different leg dimensions has been investigated.

II. Modelling Technics of Shear Walls

A. *Shell Element*

Shear walls can be modelled with shell elements and divided into finite elements. Finite element method (FEM) gives very reliable results for the shear walls when sell element is used. U – Shaped shear wall system can be modelled with shell element and system is divided into a certain number of small elements. Dividing the system into adequate number of finite elements is the important point of the solution and this adequacy will give closer results to the real system. Each point of shell element has 6 degree of freedom [5] and although increasing number of finite elements gives satisfactory results, increase of the number causes long duration of solution. An example of a shell model of a U – Shaped shear wall is given in Fig. 1.

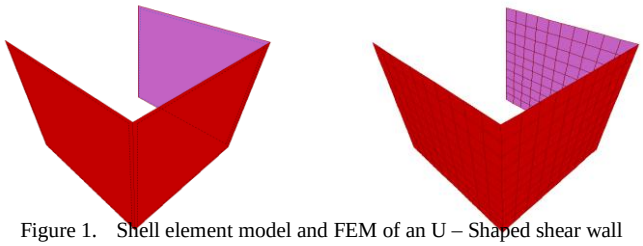

Figure 1. Shell element model and FEM of an U – Shaped shear wall

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B. Equivalent Frame Element Model

In FEM, shell element and the higher number of finite elements cause long analysis duration and if the aim of analysis is to estimate different result than shear wall, frame element can be used rather than shell element. Also, if it is desired to assign a hinge to shear wall manually, frame element should be used instead of shell element. In Fig. 2, schematic view of modelling a shear wall with equivalent frame element is given.

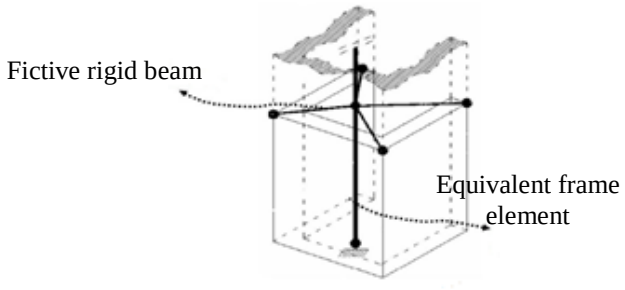

Figure 2. Schematic view of modelling a shear wall with equivalent frame element

Equivalent frame element can be placed in the rigidity center of the shear wall and the frame element is connected to the corner of the shear wall with fictive rigid beams.

III. Analytical Model and Analysis

In this paper, effects of using different technics in the modelling of U – shaped shear walls have been investigated. For this purpose, different buildings, which have different number of stories, and different U – shaped shear walls with different leg dimensions have been considered. Thus a comprehensive study has been done with considering different possible combinations of U – shaped shear walls and buildings. With the consideration of 3 different U – shaped shear walls with different leg width and 3 different buildings with different number of stories, 9 different buildings have been considered within the scope of this study.

A. Considered Buildings

Hypothetical 10 – storey and 20 – storey reinforced concrete frame buildings were considered within the scope of this study and buildings were designed according to Turkish Seismic Code (TSC) 2007 [6]. The concrete with characteristic compressive strength of 30 MPa (C30) was used in the buildings and the steel with characteristic yielding of 420 MPa (S420). Soil class of buildings is C Soil Class and soil classification was made based on USGS [7] classification. C soil Class corresponds to Z3 soil type in TSC 2007. U – Shaped shear wall has been placed to the buildings to surround the elevator. Different shear walls were used with the changing of leg of shear wall.

Plan of the buildings is given in Fig. 3. All column and beam sections are constant for all buildings with 50x50 cm column section and 30x50 cm beam section.

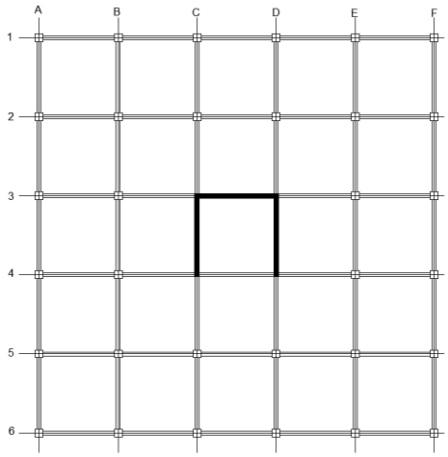

Figure 3. Plan of considered buildigns

B. U – Shaped Shear Wall

3 different U – shaped shear walls using different leg width were considered within the scope of this study. Each shear wall was placed each building. Thus, 6 different buildings were considered with 3 different shear walls and 2 different buildings. Section of shear walls are given in Fig. 4.

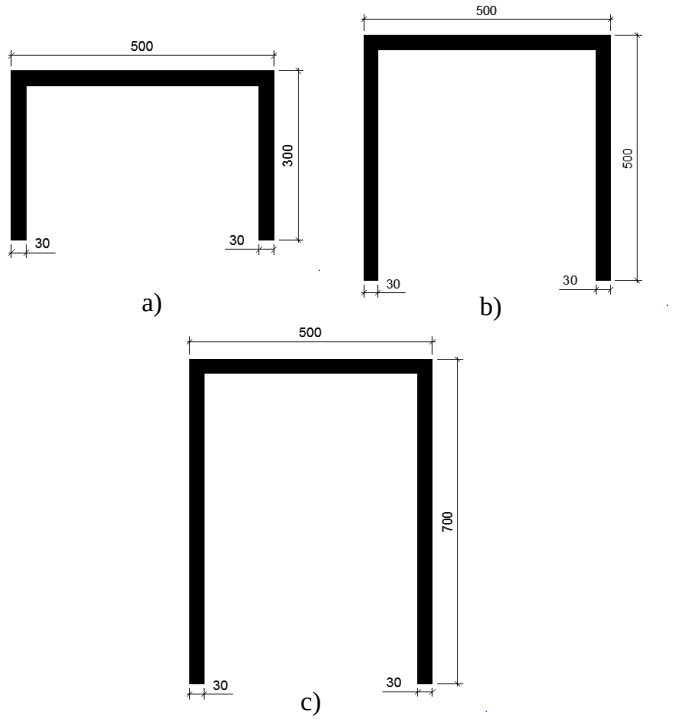

Figure 4. Sections of U – Shaped shear walls

Firstly, shear walls were modelled with shell element and secondly they were modelled with equivalent frame element.

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C. *Analytical Model*

All the buildings were modelled via ETABS v16 [8] and ETABS model view is given in Fig. 5.

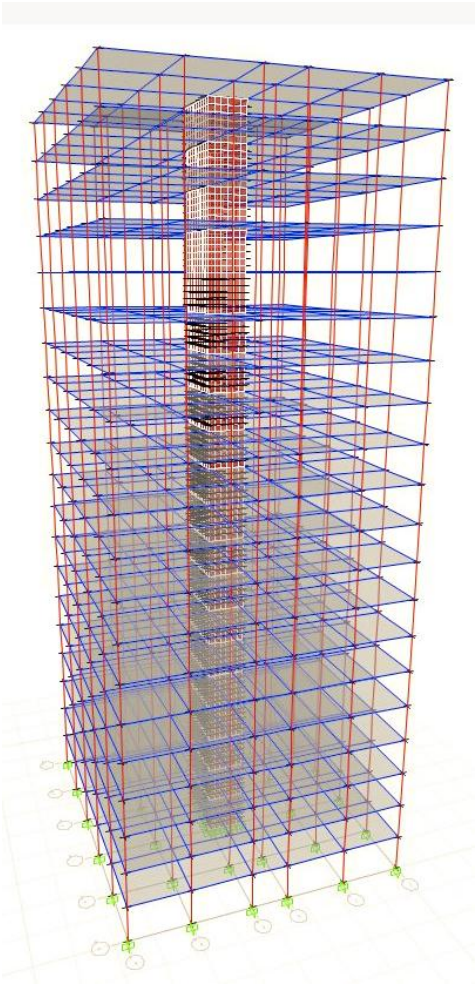

Figure 5. ETABS model of 20 – storey building

U – Shaped shear walls were modelled with shell element and equivalent frame element. A schematic view of equivalent frame element is given in Fig. 6.

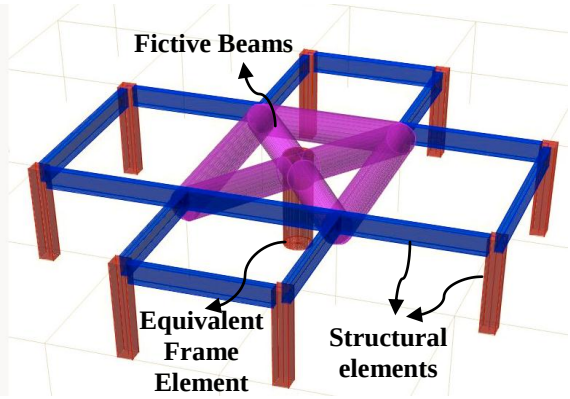

Figure 6. ETABS model of a shear wall with equivalent frame element

Equivalent frame element is a circular columns with 100 cm diameter and section details were modified to achieve the details of considered U – shaped shear wall. These details are moment of inertia, shear area, polar moment of inertia and these details were estimated for both orthogonal directions. Fictive rigid beams given in Fig. 6 have circular section, too. Circular section provides equal moment of inertia in all directions and it is right to use such a section in equivalent frame element model. Their section details were increased to estimate more rigid element since fictive rigid beams are be able to transfer the loads directly from equivalent frame element to beams connected to the shear wall.

IV. Analysis Results

The considered buildings with U – shaped shear wall were modelled via ETABS and effect of leg length of shear wall and

A. *Modal Analysis Results*

Modal analysis results are given in Table 1 – Table 3 and Table 4 – Table 6 for 10 – storey building and 20 – storey building, respectively.

TABLE I. MODAL VALUES FOR 20 – STOREY BUILDING WITH 3 M SHEAR WALL

Mode	*Modelling with shell element*		*Modelling with equivalent frame element*	
	T (sec)	Mode Direction	T (sec)	Mode Direction
1	1.77	Y - Y	1.71	Y - Y
2	1.66	Torsion	1.64	Torsion
3	1.45	X - X	1.47	X - X

TABLE II. MODAL VALUES FOR 20 – STOREY BUILDING WITH 5 M SHEAR WALL

Mode	*Modelling with shell element*		*Modelling with equivalent frame element*	
	T (sec)	Mode Direction	T (sec)	Mode Direction
1	1.73	Torsion	1.70	Torsion
2	1.56	Y - Y	1.59	Y - Y
3	1.39	X - X	1.50	X - X

TABLE III. MODAL VALUES FOR 20 – STOREY BUILDING WITH 7 M SHEAR WALL

Mode	*Modelling with shell element*		*Modelling with equivalent frame element*	
	T (sec)	Mode Direction	T (sec)	Mode Direction
1	1.80	Torsion	1.64	Torsion
2	1.39	Y - Y	1.38	Y - Y
3	1.34	X - X	1.37	X - X

TABLE IV. MODAL VALUES FOR 10 – STOREY BUILDING WITH 3 M SHEAR WALL

Mode	*Modelling with shell element*		*Modelling with equivalent frame element*	
	T (sec)	Mode Direction	T (sec)	Mode Direction
1	0.81	Torsion	0.91	Torsion
2	0.76	Y - Y	0.75	Y - Y
3	0.61	X - X	0.61	X - X

TABLE V. MODAL VALUES FOR 10 – STOREY BUILDING WITH 5 M SHEAR WALL

Mode	*Modelling with shell element*		*Modelling with equivalent frame element*	
	T (sec)	Mode Direction	T (sec)	Mode Direction
1	0.83	Torsion	0.84	Torsion
2	0.64	Y - Y	0.64	Y - Y
3	0.57	X - X	0.59	X - X

TABLE VI. MODAL VALUES FOR 10 – STOREY BUILDING WITH 7 M SHEAR WALL

Mode	*Modelling with shell element*		*Modelling with equivalent frame element*	
	T (sec)	Mode Direction	T (sec)	Mode Direction
1	0.85	X - X	0.87	Torsion
2	0.54	Torsion	0.55	Y - Y
3	0.53	Y - Y	0.52	X - X

According to the results, using equivalent frame element instead of shell element does not affect mode shape. If we look from the viewpoint of torsional mode, equivalent frame element shorten the periods especially for 7 m U – shaped shear wall in 20 – storey building. However frame element does not have significant effect for 10 – storey buildings in terms of torsional mode. It can be said that using equivalent frame element does not have significant effect in terms of torsional mode for relatively buildings with short period. If we look from the viewpoint of mode shapes of orthogonal directions, there is no difference between 10 – storey buildings with shell and frame elements, however a considerable difference occurs for 20 – storey buildings when shell or frame elements are used. This effect can be the reason of fictive rigid beams because rigidity of the fictive beams is not constant and a proper rigidity should be estimated. Secondly, Effect of fictive beams on the rigidity of relatively rigid buildings decreases and effect of these fictive elements is considerable for 20 – storey buildings.

B. Shear Force and Moment Results

Shear force and moment at the bottom of shear walls are given in Table 7 – Table 9 for design earthquake loads in X and Y directions. In tables, V is shear force and M is moment.

According to the results, there is considerable difference between shell and frame element moments in Y direction for 10 - storey and 20 – storey buildings. The legs of U – shaped shear walls lie in Y direction and that means equivalent frame element model has considerable effect in the direction where legs lie down. The difference of moments in X direction is lower than moments in Y direction. On the contrary, using shell or frame element has considerable effect in X direction for shear force.

TABLE VII. M AND V VALUES FOR 3M SHEAR WALL UNDER DESIGN EARTHQUAKE LOAD

	10 – Storey Building		*20 – Storey Building*	
	Shell	Frame	Shell	Frame
V_x (kN)	3366	4251	3987	4514
V_y (kN)	4663	4735	5094	5174
M_x (kNm)	91187	92949	185988	189276
M_y (kNm)	76018	83798	138938	160200

TABLE VIII. M AND V VALUES FOR 5M SHEAR WALL UNDER DESIGN EARTHQUAKE LOAD

	10 – Storey Building		*20 – Storey Building*	
	Shell	Frame	Shell	Frame
V_x (kN)	4045	4781	4148	5020
V_y (kN)	5858	5806	6224	6164
M_x (kNm)	114933	113585	220634	218076
M_y (kNm)	79733	93820	142309	173366

TABLE IX. M AND V VALUES FOR 7M SHEAR WALL UNDER DESIGN EARTHQUAKE LOAD

	10 – Storey Building		*20 – Storey Building*	
	Shell	Frame	Shell	Frame
V_x (kN)	4140	5352	4330	6210
V_y (kN)	7270	6799	7720	7750
M_x (kNm)	143606	135334	265286	272631
M_y (kNm)	81230	106811	147790	211436

V. Conclusions

The aim of this study is to determine the effect of the dimension of a U – Shaped shear wall and using different modelling technics such as sell element and equivalent frame element. For that purpose, 10 – storey and 20 – storey RC frame buildings were designed and 3 different U – shaped shear walls with 3 m, 5 m and 7 m leg length were placed to the buildings.

According to the results, modelling element type of shear wall has considerable effect on behaviour of building and section forces. Following conclusions can be drawn considering the results of this study:

- For 20 – storey buildings, equivalent frame element shorten the period of torsional mode. For the increasing length of leg of shear wall periods becomes shorter. Also using equivalent frame element or shell element effects mode shapes in orthogonal directions.

- Using equivalent frame element or shell element does not have significant effect on mode shape of 10 – storey buildings.
- Using equivalent frame element instead of shell element yields very different results in terms of section forces in the direction that shear wall legs lie down.
- It is important to estimate a proper rigidity for fictive beams since it is clear that fictive beams significantly affect the behaviour of buildings.

It is needed to say that these results were estimated for the buildings considered in this study. Different results can be seen for different types of buildings.

References

[1] M. Fintel, "Shear wall-an answer for seismic resistance," Concrete International, vol. 13, pp. 48-53, 1991.

[2] S. G. Satpute and D. B. Kulkarni, "Comparative study of reinforced concrete shear wall analysis in multistoreyed building with openings by nonlinear methods," International Journal of Structural & Civil Engineering Research, vol. 2, pp. 183-193, 2013.

[3] O. Gorgulu and B. Taskin, "Strength reduction factor variation in school buildings retrofitted by RC infill walls," 8th National Conference on Earthquake Engineering, Istanbul, May, 2015.

[4] O. Avsar and O. Tunaboyu, "Influence of structural walls on the seismic performance of RC buildings during the May 19.2011 Simav earthquake in Turkey," Journal of Performance of Constructed Facilities, vol. 28, 04014016, 2014.

[5] E. L. Wilson, Three Dimesional Static and Dynamic Analysis of Structures, A Physical Approach with Emphasis on Earthquake Engineering, Computers and Structures, USA, 2002.

[6] TSC, Turkish Seismic Code, Specification for Buildings to be Built on Seismic Areas, Turkish Ministry of Public Works and Settlement, Ankara, 2007.

[7] USGS, United State Geological Survey, https://www.usgs.gov/

[8] ETABS, Structural Software for Building Design, CSI, Computers and Structures, California, 2016.