EFFECT OF IN PLANE SHEARING STIFFNESS OF INFILL WALLS ON RESPONSE OF MOMENT RESISTING FRAMES OF HIGH RISE BUILDINGS UNDER SEISMIC LOADS

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Abstract
The majority of human occupation is catered by residential and office buildings for our living and working purposes. Because of available space restrictions, there is general trend of high rise construction in urban areas which are prone to earthquake forces. The major load resisting structural elements consists of multilevel beam column frames with or without shear walls.

Non structural infill walls constructed of burnt brick masonry are used in almost all concrete frame buildings in Pakistan to serve architectural functions. (A country where seismicity is one of the prime factor to be considered in design) Such masonry infill walls are considered as non-structural elements as these are constructed after completion of concrete frames. Although they are designed to perform architectural functions, masonry infill walls do resist lateral forces with substantial structural action. In addition to this, infill walls have a considerable strength and stiffness and they have significant effect on the seismic response of the structural system. Most of the past researchers concluded that in filled masonry wall frames have the capability to cater greater design forces as compared to frames without it, Since they contribute to shear stiffness of the structure (the property having prime importance in seismic response of a structure) like shear walls.

Keywords- Masonry infill, Shear walls, Lateral stiffness, Seismic response

1 Introduction
The effects of non structural infill walls are not included generally during analysis and design of reinforced concrete structures. However, these infill walls have considerable effect on the structural response as studied by many researchers all over the globe. The brick masonry is used as partitions in most of reinforced concrete construction in Pakistan because of its low cost and locally available skilled labor. Therefore, it is necessary to study the effects of these nonstructural infill walls to response parameters of these structures.

The addition of these nonstructural walls increase the lateral stiffness of the frame structure thus reducing its time period of vibration and shifting the period in the elastic response spectra in such direction that yields higher base and storey shears. Moreover, the increased stiffness of the structure may increase the column shears which creates the plastic hinges at the top of columns that are in contact with infill walls since the structure is designed for a ductile response to design level earthquake.

Furthermore, potentially negative effects also occur such as torsional effects induced by in plan-irregularities, soft-storey effects induced by stiffness irregularities and short-column effects.

In recent past, many researchers did the study of effect of stiffness of infill nonstructural walls on the behavior of the moment resisting frame by using different analysis techniques. Almost all the engineers performed a comparative study between the structures having modeled infill walls and another without it.

In 2007, international journal of science and technology published a paper presented by" Kasım, Armagan, Korkmaz, Fuat Demir and Mustafa Sivri" students of "Suleyman Demirel University, Civil Engineering Department, TURKIYE. They perform the nonlinear analysis on different models of various configurations of infill walls as shown. A three (03) story reinforced frame was considered with different patterns of infill walls. They concluded that the presence of infill masonry walls significantly and positively alters the seismic performance of the structure. However its irregular vertical distribution causes some negative effects including soft story phenomenon.

In 2003, another research work had been carried out by CVR MURTY and SUDHIR K JAIN. The purpose of their research work is to highlight the beneficial effects of non structural masonry walls on the bare moment resisting frames. They carried out their study by on a single story, single bay frame one with infill walls and other without it. After performing the comparative study of the two structures, they concluded that the structure with modeled infill walls have average stiffness of 4.3 times more as compared to structure without infill walls and the stiffness increases to 4 times when reinforced infill masonry was considered. The decrease of stiffness for reinforced masonry was due to increase of mortar thickness. From strength considerations, the unreinforced masonry wall frame has 70% excess strength as compared to frames without it while for reinforced masonry, the ratio decreases to 50%.

So in this study the response of two essentially same structures, with and without consideration of stiffness of in filled walls were evaluated and compared on the basis of different structural parameters listed next.

2 Research Objectives

In this comparative evaluation study, the seismic performance of two multistory reinforced concrete building, one with modeled in filled walls to account for its stiffness and other without it, shall be investigated by Elastic Response Spectrum Analysis using UBC-97.

The objectives of the study are summarized in following:

1. To study effect of in filled walls on the performance of the high rise ductile moment resisting frames under seismic loads and to get a quantitative idea of this effect based on different structural parameters like but not limited to:

   a-) Time Period

   b-) Base Shear

   c-) Story Drifts

   d-) Relative Story Displacements

   e-) Support Reactions

   f-) Member End Forces (Shears, Moments, Torsion etc)

   by comparing it with another same structure but without modeling the infill walls.

2. To understand the need to account the stiffness of infill walls.
3. To ensure and understand the need of proper designing of in filled Non structural walls against lateral seismic forces in order to ensure its serviceable performance level without extensive cracking so that its stiffness contribution should remains there.

3 Case Study Buildings

To study the effect of in plane stiffness of infill walls as prescribed earlier in methodology of research, we will analyze a high rise moment resisting frame building, with and without modeling of infill walls. So for this purpose we model a sample structure having 90ft x 90ft plan dimensions dividing in 6 bays each of 15ft in both principles direction. The total height of building is taken as 109ft having 10 numbers of stories. The height of plinth level is taken as 10ft and a typical story height of 11ft is taken above plinth level comprising of 9 stories.

In first model as shown, loads of masonry in fill walls 9" thick of full story height are applied as member load on all external beams and only on those internal beams situated at grid 'D' and '4'. In second model, infill walls are modeled at prescribed locations using material properties of masonry walls as shown. The brief description of these models and graphical views are given below.

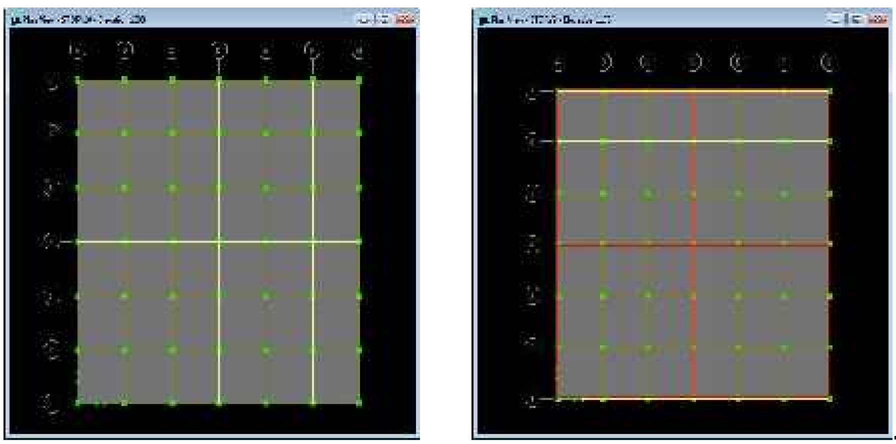


Figure 1 Plan views

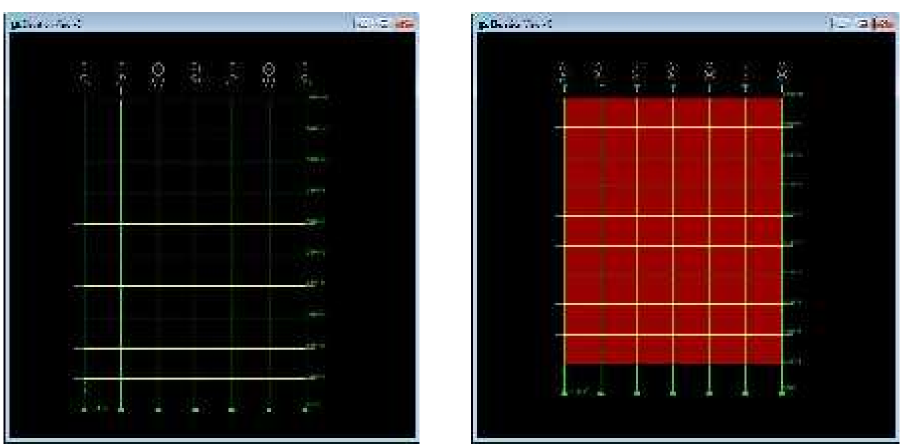


Figure 1 Elevation views

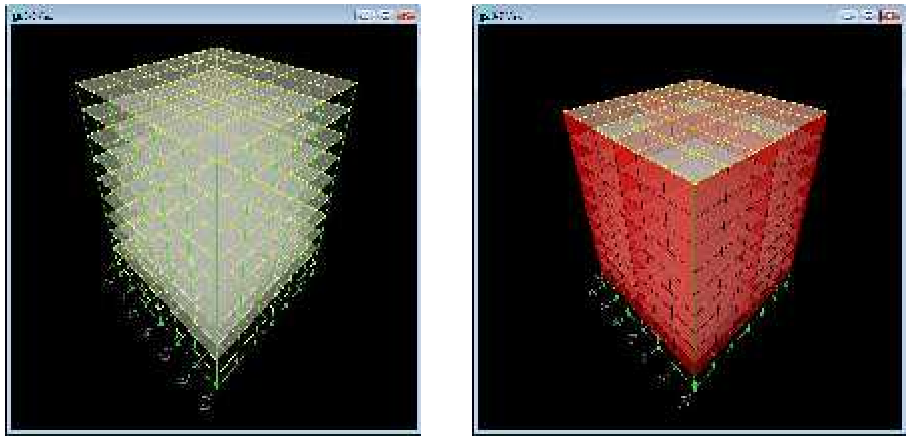


Figure 3: 3D views

4 Method of Analysis

Dynamic analysis is performed using Response Spectrum method of analysis by using standard UBC Response Spectra whose peak values corresponds to Ca and Cv values used for Zone 2b as per UBC. Eigen vectors analysis type is used to generate different possible number of modes.

In modal analysis, SRSS (square root of sum of squares) technique is used for modal combinations in which 8 no of modes are taken for combination since mass participation appears to be 99% for 8th mode in both principle directions.

SRSS (square root of sum of squares) technique is also used for Directional combinations.

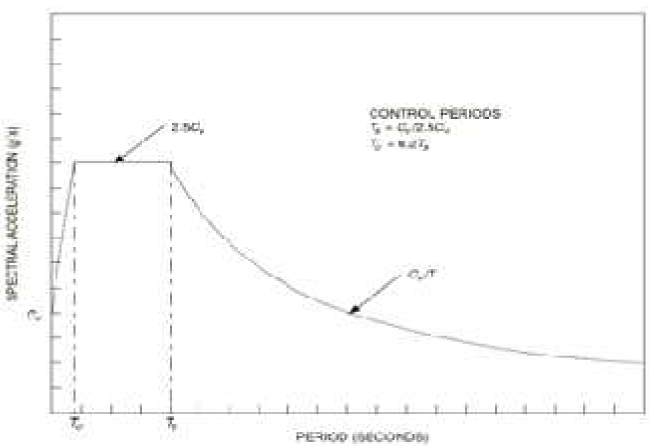


Figure 4: UBC response spectra

5 Results and Discussion

After performing the dynamic analysis of the two structures, their behavior will be analyzed and compared in terms of the following parameters.

1- Modal Time Periods

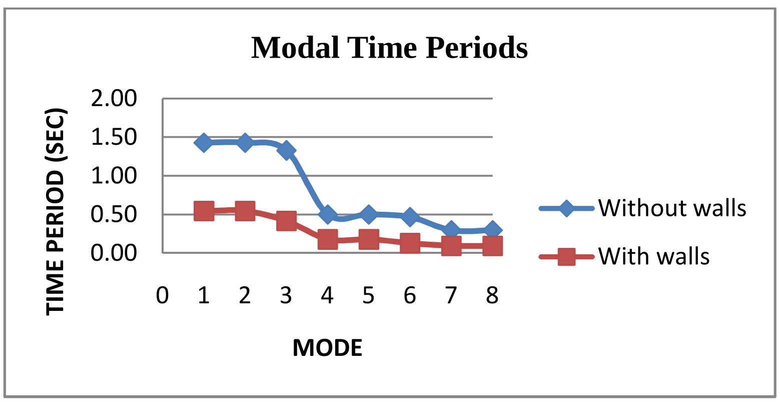
2- Storey Shears
3- Storey Displacements
4- Support Reactions
5- Reinforcement %age of Columns

The comparison of results on the basis of above parameters will be made in terms of Tables and Graphs in the proceeding sections.

5.1 Modal Time Periods

Table 1: Model time periods

Modal Time Periods (Sec)		
Mode	**T sec (Without walls)**	**T sec (With walls)**
1	1.43	0.54
2	1.43	0.54
3	1.33	0.42
4	0.50	0.18
5	0.50	0.18
6	0.47	0.13
7	0.30	0.09
8	0.30	0.09

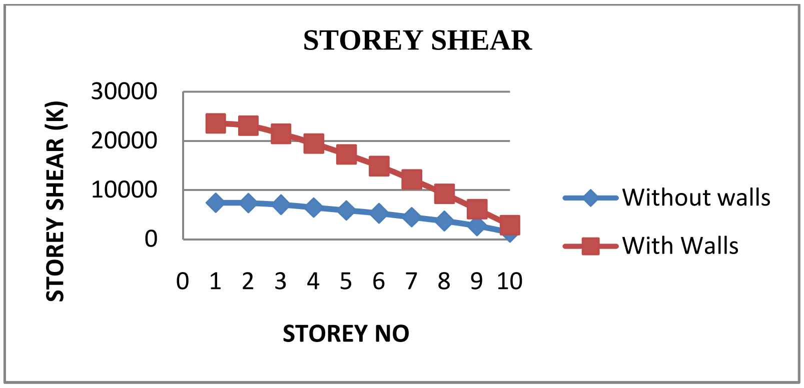


5.2 Storey Shears

Table 2: Storey shear

Storey Shear		
Storey Id	**Vx (Kip) without walls**	**Vx (Kip) with walls**
Storey1	7435.8	23565.83
Storey2	7361.45	23085.51
Storey3	6993.22	21437.16
Storey4	6452.62	19451.49
Storey5	5864.94	17262.38

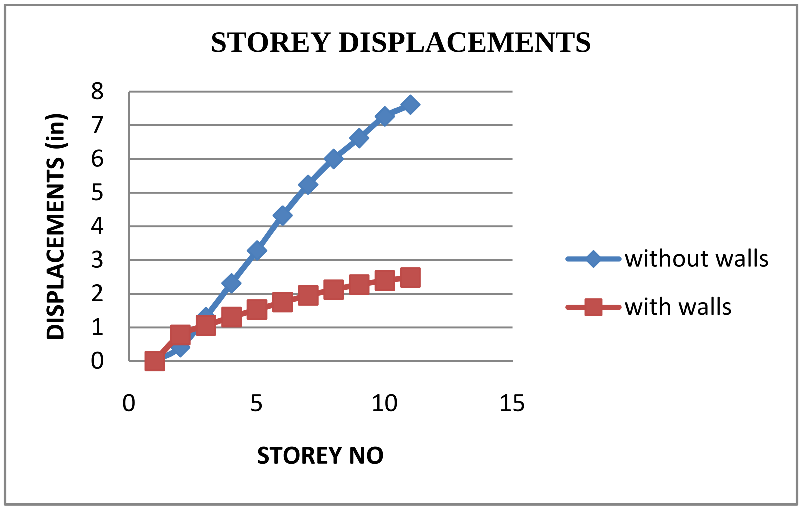
Storey6	5233.98	14868.86
Storey7	4511.8	12193.17
Storey8	3673.43	9239
Storey9	2710.85	6130.33
Storey10	1376.65	2885.54



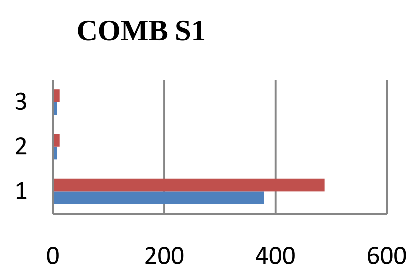
5.3 Storey Displacements

Table 3: Storey displacement

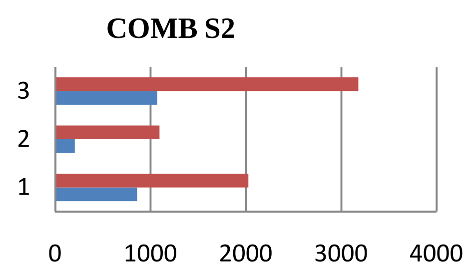
Storey Displacements		
Storey ID	**Ux (inch) without walls**	**Ux (inch) with walls**
Base	0	0
Storey1	0.41	0.77
Storey2	1.31	1.06
Storey3	2.30	1.31
Storey4	3.28	1.53
Storey5	4.32	1.75
Storey6	5.23	1.95
Storey7	6.00	2.12
Storey8	6.61	2.27
Storey9	7.26	2.39
Storey10	7.60	2.48



5.4 Support Reactions

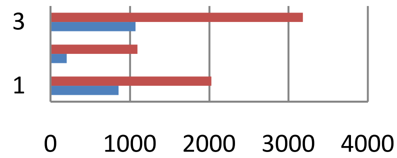


	1	2	3
WITH WALLS	488.08	12.272	12.259
WITHOUT WALLS	378.45	7.726	7.726



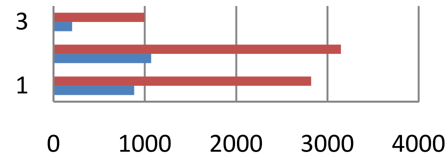
	1	2	3
WITH WALLS	2025.48	1092.79	3180.155
WITHOUT WALLS	857.07	203.546	1070.17

COMB S3



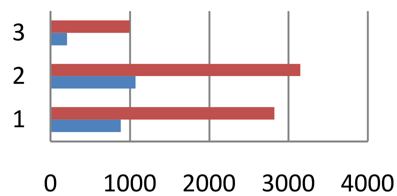
	1	2	3
WITH WALLS	2025.48	1092.79	3180.155
WITHOUT WALLS	857.07	203.546	1070.17

COMB S4



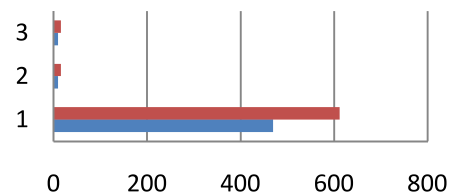
	1	2	3
WITH WALLS	2822.72	3148.794	997.005
WITHOUT WALLS	882.62	1070.227	203.853

COMB S5



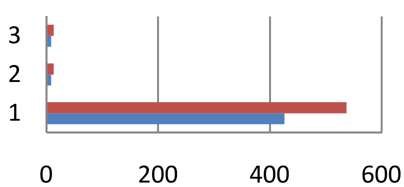
	1	2	3
WITH WALLS	2822.72	3148.794	997.005
WITHOUT WALLS	882.62	1070.227	203.853

COMB F1



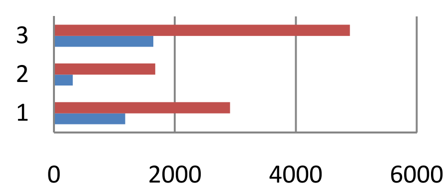
	1	2	3
WITH WALLS	611.75	15.64	15.634
WITHOUT WALLS	469.38	9.528	9.528

COMB F2



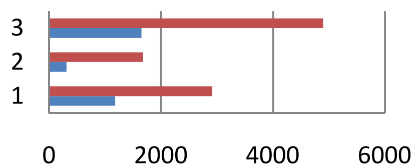
	1	2	3
WIITH WALLS	537.06	13.048	13.027
WITHOUT WALLS	425.84	8.811	8.811

COMB F3



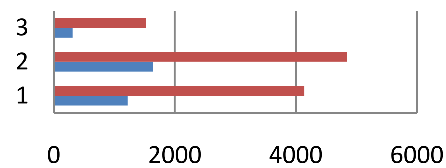
	1	2	3
WITH WALLS	2913.37	1677.497	4893.345
WITHOUT WALLS	1179.5	310.987	1646.121

COMB F4



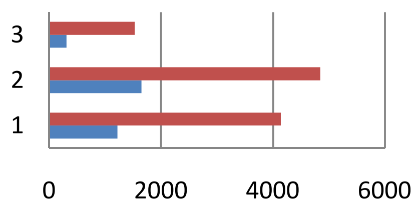
	1	2	3
WITH WALLS	2913.37	1677.497	4893.345
WITHOUT WALLS	1179.5	310.987	1646.121

COMB F5



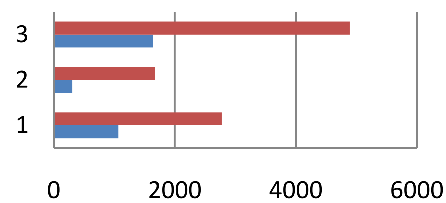
	1	2	3
WITH WALLS	4141.61	4845.01	1529.95
WITHOUT WALLS	1218.86	1646.21	311.46

COMB F6



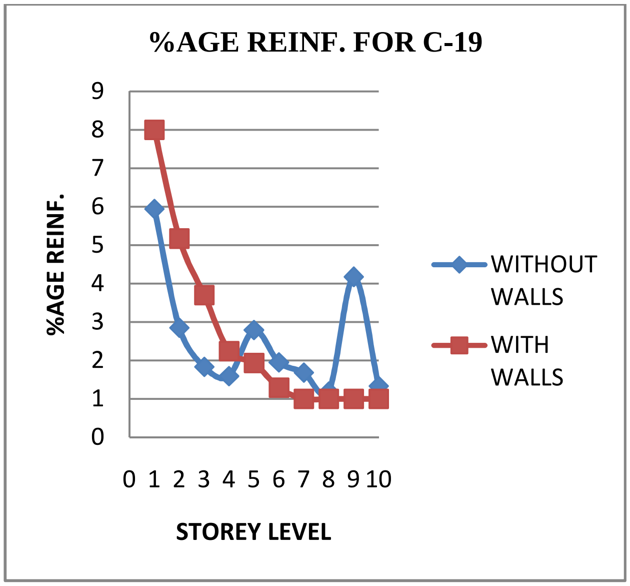
	1	2	3
WITH WALLS	4141.61	4845.01	1529.95
WITHOUT WALLS	1218.86	1646.21	311.46

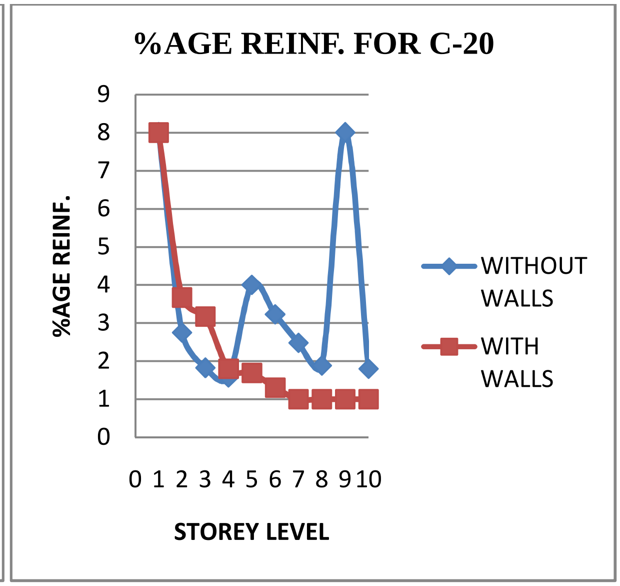
COMB F7

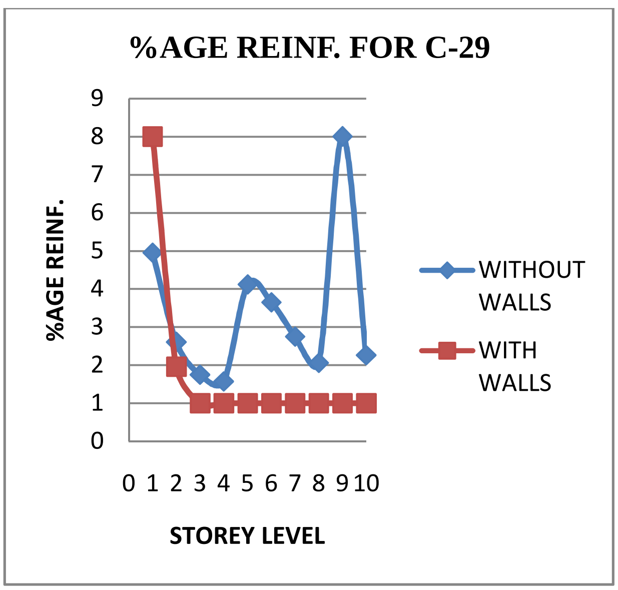


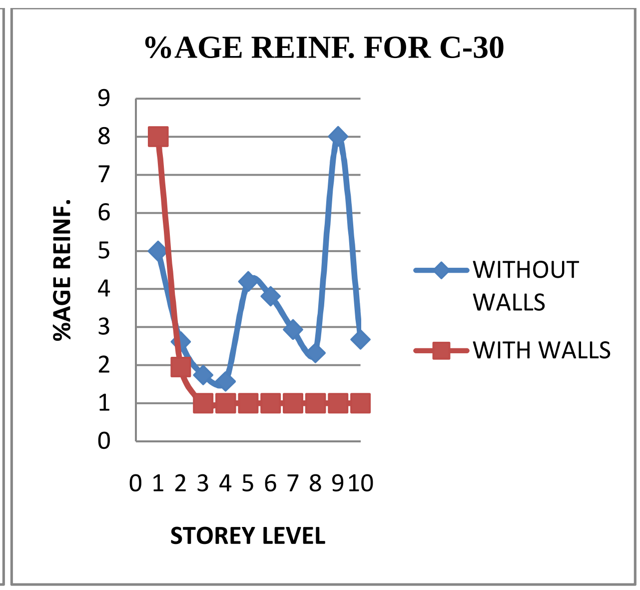
	1	2	3
WITH WALLS	2777.16	1674.289	4890.137
WITHOUT WALLS	1068.97	308.661	1643.795

5.5 Reinforcement %Age of Columns









6 Conclusions

- Time periods of the model with modeled infill walls are lower than the model without infill walls. It happened because the infill walls increase the overall stiffness of the structure and hence tries to lower the time periods.
- Storey shear of the structure with modeled infill walls are quite larger than the structure without modeled in fill walls since Time periods of the model with modeled infill walls are lower than the model without infill walls as explained. Hence keeping in view of the above results, it can be suggested that stiffness of infill walls should be considered for design since it represents a true picture of the behavior of structure.
- Storey displacements in the structure with modeled infill walls are much lower than the structure without infill walls except at 1rst story level. It might be due to reason that the infill walls adds the significant stiffness to the structure which results in the lowering of story displacements and hence moments.
- However at 1rst storey level the displacement behavior of the structure is reversed since it creates the well known effect of “Soft Storey” as is called by UBC. A soft storey effect appears to occur in the structure at storey level where the difference of storey stiffness of the two adjacent stories are more than 20% as prescribed by UBC. Since the infill non structural walls are not present beneath the plinth level, hence it creates the difference between the storey stiffness of plinth and 1rst level which in turns give rise to the soft storey phenomenon and producing large deflections and hence moments at that level as will be seen in later stages. Keeping in view, it can be suggested that the true behavior of the structure will be presented only when we consider the stiffness of infill walls or proper consideration should be given to soft storey phenomenon.
- The column reinforcement of the structure in which stiffness of infill walls are considered are less comprehensively showing the fact that stiffness of walls gives beneficial in terms of economy to the structure.
- The reinforcement in the plinth column is much higher i.e. 8% in the same structure showing the negative effects of soft story phenomenon and hence its importance to consider in design.

7 References

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