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The Effect of Structural System Configuration on the Isolated System Response

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Abstract: **This research paper summarizes the comparative study of isolated structural systems. The comparison depends on the analysis and design criteria defined in Turkish seismic Code 2016 (TBDY_16, Ch14) and ASCE 7-10 document accordingly, the effect of the structural system on the response of isolated system will be investigated to find unwanted and negative influence of using of shear walls in isolated system buildings.**

Keywords: Base isolation design, friction pendulum isolators design, shear walls using effects.

1. INTRODUCTION:

In traditional structures design methods, shear walls are frequently used in structural system of almost all buildings especially in earthquake zones. Due to this habit the same structural system is also being used in "seismically isolated" structures. But this issue creates critical problems in isolation units which are located under shear walls such as "high tension forces" and "buckling phenomena problems". Besides isolation units are subjected to high tension forces which’s considered an undesirable design case for both lead rubber and friction pendulum bearings. On the other hand, high axial loads in lead rubber bearings cause "buckling". So there is an urgent of being able to investigate the optimum structural system that will avoid buckling and tension in the isolation units. To hit the target and obtain the optimum isolation system design case a parametric studies will be performed by considering a shear wall structural system with different dimensions and number of stories.

2. DESCRIPTION THE CONFIGURATION OF THE THREE DIFFERENT STRUCTURAL SYSTEMS:

In this study an original building was selected and modified into a form of three different structural systems. The systems were described as follows:
F.S_ system: Frame system only which has no shear walls in its plan (figure 1).
S.S.W_ system: Short Shear Walls system which has three couple shear walls in the short direction at three different places in its plan (figure 2).
L.S.W_ system: Long Shear Walls system which has three couple shear walls in the long direction at three different places in its plan (figure 3).
In this research above abbreviations will be used to indicate to buildings identifications.

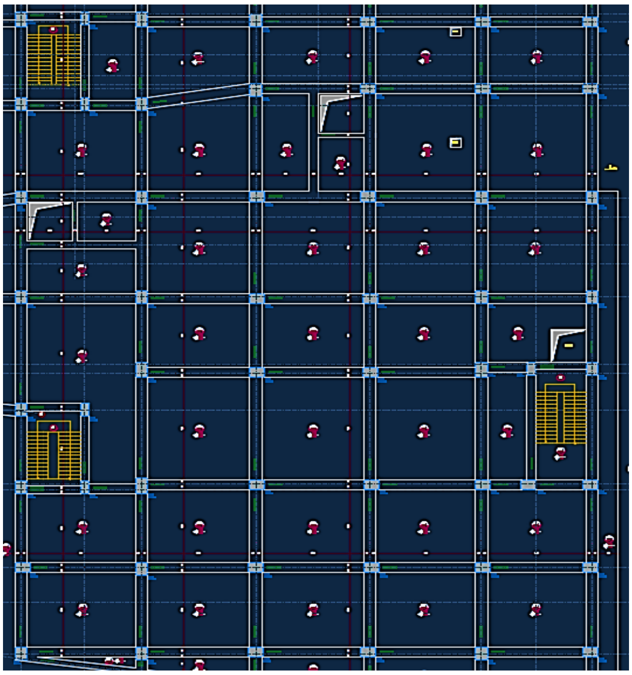

Fig 1: Building Structural system’s plan view.

The buildings have 7 repeated stories, two underground and five repeated story. The ground story’s heights is 4.8 m and the other stories height are 4.5m. Building plan contains 7 axes at X direction and 10 axes at Y direction respectively. The cross section of beams are (B60x70, B60x80, B80x70) in every plan, (C60x100, C80x100, C 60x100, C80x100) sections properties for columns elements, (S20) shell properties for slabs and (W25) shell properties for walls.

In Turkey, the most common used isolation units are the frication Pendulum isolators, so only this type’s units will be included in this research in the three different structural systems. Every unit will be modeled as Linear Link items at first design stage, then their properties will be modified as Non-Linear link properties as second designing stage.

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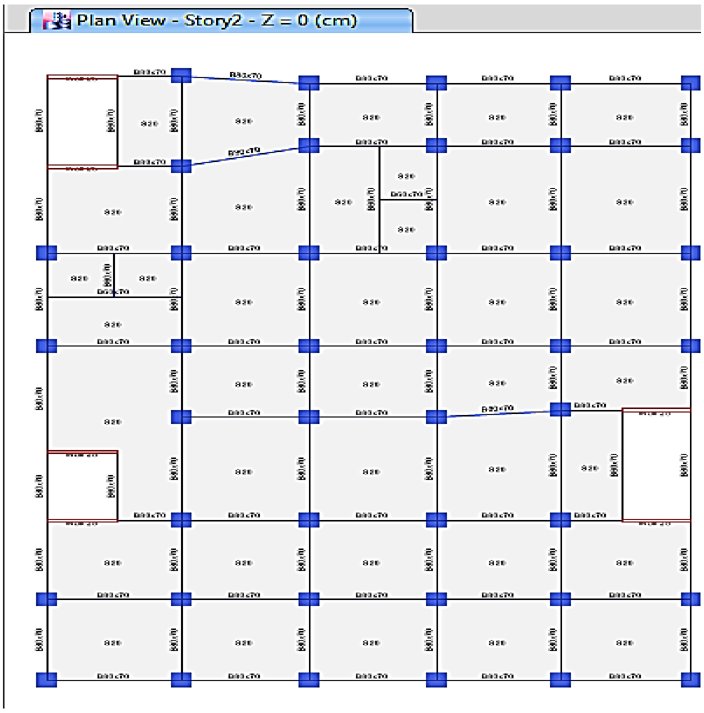

Fig 2: short shear wall system's plan.

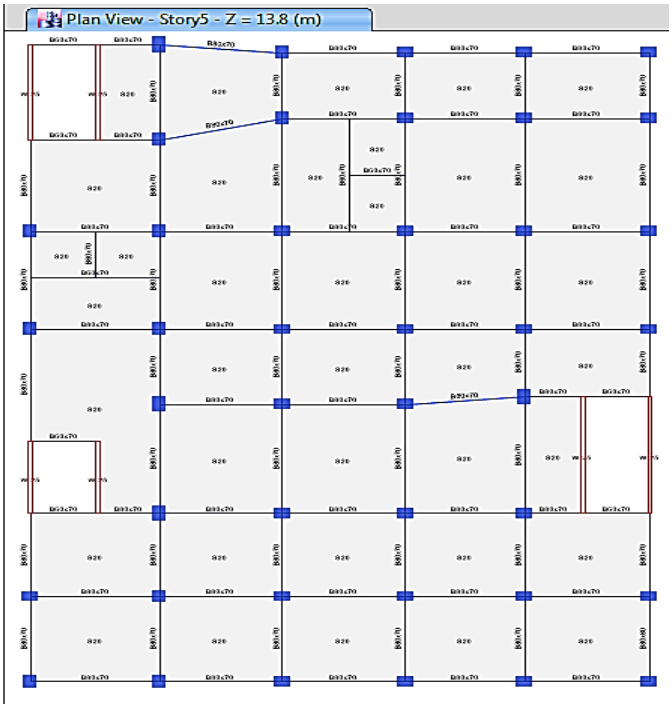

Fig 3: Long shear wall system's plan.

Isolation units located under every column and under every shear wall in the same manner. Depending on shear wall dimension, three or four isolation unit will be placed, one at the beginning, one at the end of every shear wall and the other isolation units will be located on the same row similarly. By this distribution of isolation units, the number of isolators will be different in every model. The number of isolation units in F.S_ system are 54 units, 66 units in S.S.W_system, and 72 units in the L.S.W_system respectively.

3. DESCRIPTION OF FRICITON PENDULUM ISOLATROS MODELING AND THEIR MATERIAL PROPERTIES CALCULATIONS:

Isolators mechanical properties will be calculated based on the new Turkish Seismic Building codes recommendations such as isolation unit's stiffness, effective seismic periods, damping ratio's factor, damping ratio, and maximum later displacement.

In the first step, seismic maps analyzing procedures should be done according to building geographical coordinates values and ground motions acceleration values. For purpose of assigning the calculated nonlinear properties of every system isolation units, the unique equivalent dynamic force and effective stiffness values in every isolation unit will be included in Etabs program. The following table shows an example of one isolation unit unique values. These values represents hysteresis loop curve points values which identifying friction pendulum isolator properties in X and Y direction respectively into Etabs program. In U2 and U3 directions this design procedure is:

Table 1 hysteresis loop curve points values:

point	Displacement_m	Force_ KN
1	-0.21	-478
2	-0.0025	-314
3	0	0
4	0.0025	314
5	0.21	478

repeated for the other two structural systems respectively. For all different systems, it's been noticed that dynamic period value is sufficiently shifted and bigger than estimated $T = 2{,}966s > T_{design} = 2{,}65\ s$.

Besides the maximum displacement value which include torsion effects is $D = 30{,}60\ cm < 41{,}6\ cm$ smaller than the allowable values mentioned on TBDY_16 recommendation and terms either for all systems.

4. DESCRIPTION OF THE GROUND MOTIONS SETS AND THE NONLINEAR ANALYSIS INSTRCUIONS:

Nonlinear time history analysis is being run according to 7 pair of ground motions records which belongs to different earthquakes records. Firstly Ramp function will be identified and then all the ground motions records in X&Y directions should be entered to the Etabs program. All the ground motions records should be converted into time history function and multiplied by scale factor which is ground acceleration value 9.81m/s.

5. INTRODCTION THE COMPARATIVE ANALYSING RESULTS FOR EVERY STRUCTURAL SYSTEM:

In aim of obtaining the optimum structural system a comparative analyzing by considering these criteria will be run:

i. Maximum Uplifting forces.
ii. Maximum lateral displacement resultant.
iii. Maximum lateral shear forces resultant.
iv. Maximum story drift.
v. Maximum story Acceleration value.
vi. Shear walls participation ratio and maximum base shear forces.

For purpose of evaluating all the results and avoid the repeated calculations and repeated work, only corner isolators results for every system will be specifically studied and verified. By keeping the unique name of every isolator as has been given in Etabs program, we summarize our extended results as follows: The maximum uplifting forces, lateral displacement resultant, and lateral shear forces resultant in every system are compared and introduced in the figures (4,5,6) below in terms of **cm** and **Kn** units respectively. Story drifts and acceleration values of only one system will be discussed here to avoid dealing with all extended results' curves. The allowable story drift values according to TBDY_16 is: 0.005* hi = 0.005*4.5= 0.0225

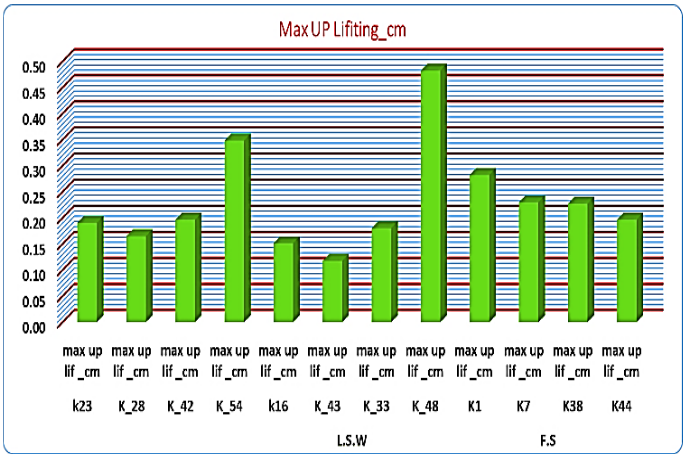

Fig 4: Max uplifting forces in the systems all.

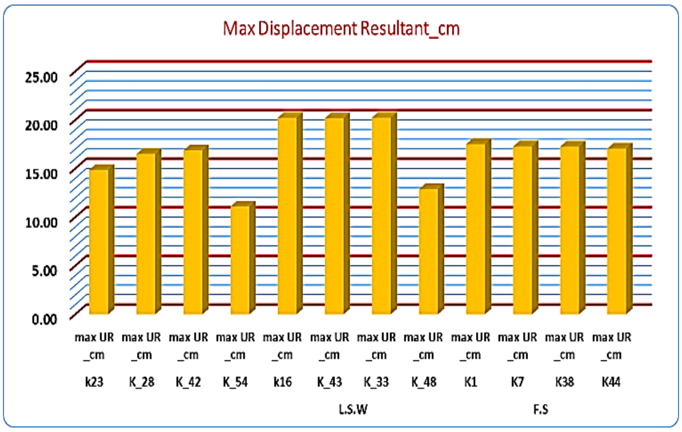

Fig 5: Max lateral displacement resultant in the systems all.

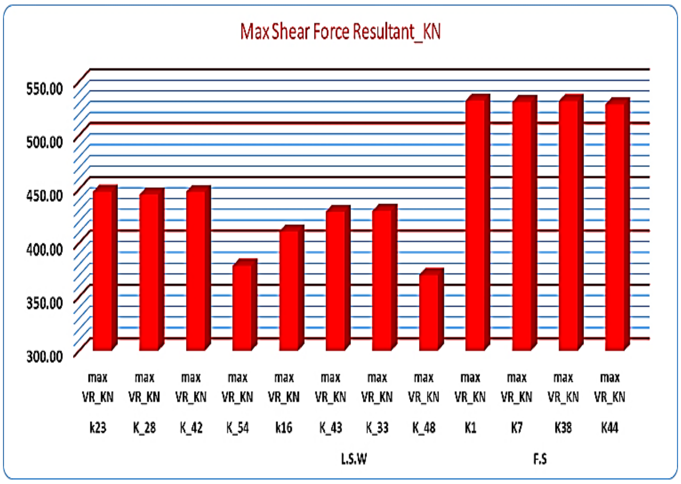

Fig 6: Max lateral shear force resultant in the systems all.

The allowable story drift value is exceeded only in the first next story to isolation system level at both S.S.W and L.S.W systems, and smaller than that value in the F.S system. Story drift values that belongs to every earthquake and related to story number are showed in the figures 6 and figure 7 below for S.S.W system at Y&X_directions respectively. It was noticed that all the acceleration values belongs to S.S.W system are smaller than 1.0g =9.81 m/s value

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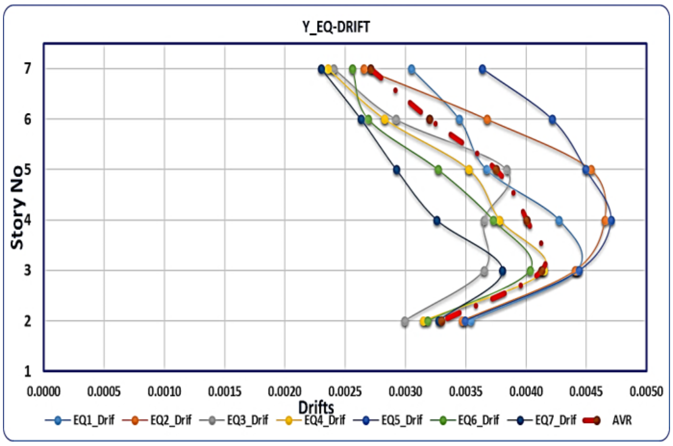

Fig 7: Story drift values in Y_Direction.

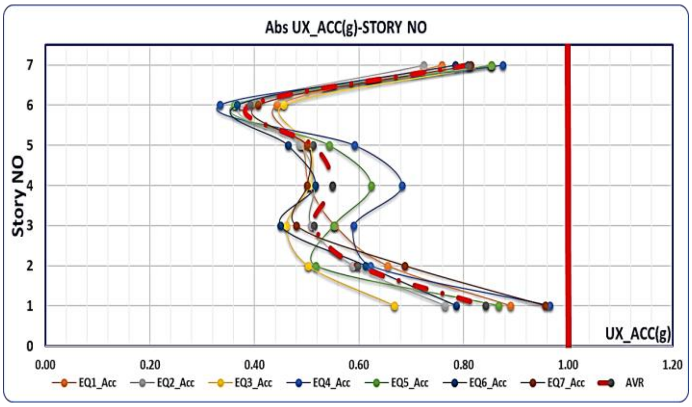

Fig 8: Story Acc values in X_Direction.

These situation is dominant at F.S system either(figures 9,10,11), however some values are bigger than 1.0g at L.S.W in both Y&X_Directions similarly.

At the same location, in straight of two different axes, two shear walls are selected, typically each wall results will be discussed in the same manner previously those two walls obviously different in the length and number of isolators under each of them. Again only one shear wall results are discussed here, keeping in mind that the other comparisons will take place in the same manner for all other shear walls.

The other compare aspect is shear wall participation ratio according to total base shear forces. By calculating the shear force resisted by walls proportioned to total maximum base shear force in base level at X&Y_ directions either (figure15).

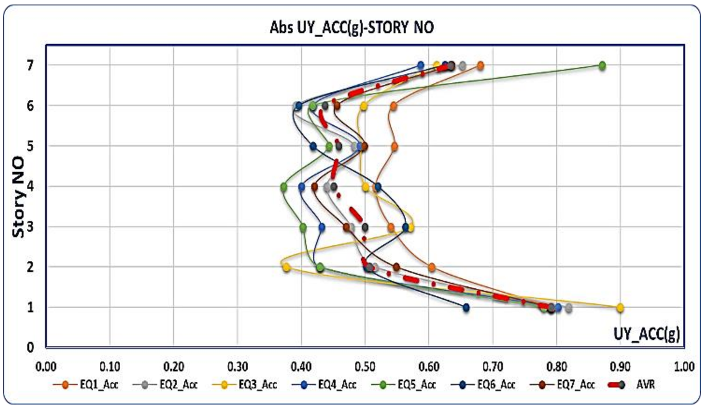

Fig 9: Story Acc values in Y_Direction.

To be efficiently specified and more selective between L.W.S and S.S.W_system.

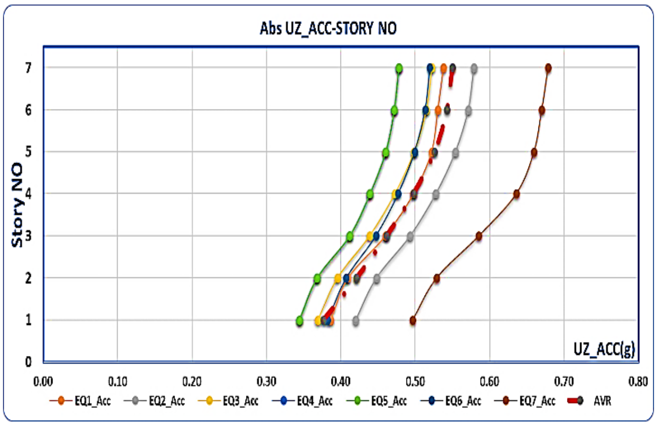

Fig 10: Story Acc values in Z_Direction.

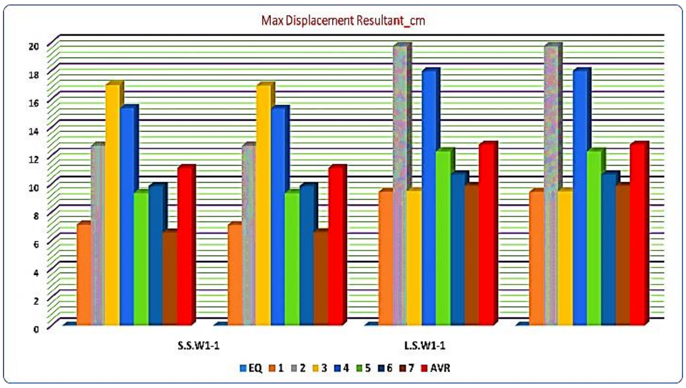

Fig 11: Max displacement resultant values for two different shear wall.

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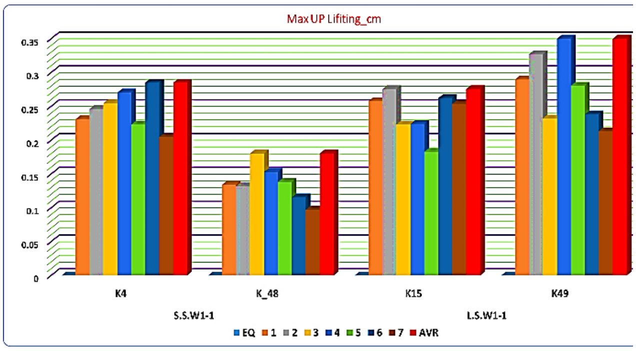

Fig 12: Max Uplifting values for two different shear wall.

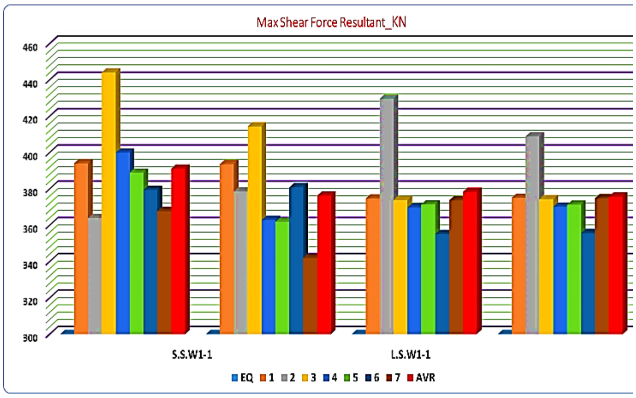

Fig 13: Max Shear force resultant values for two different shear wall.

Finally the essential comparative criteria in the table and their graphics are showed as follows:

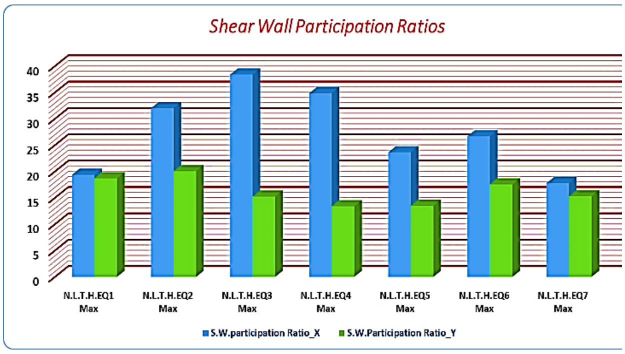

Fig 14: Shear wall participation values.

Table 2: the essential comparative criteria

Strc.sys	only frames	short shear wall system	long shear wall system
MAX Up Lifting Displacement_cm	0.283	0.404	0.4824
Max Horizental Disp Resultant_cm	17.511	16.875	20.246
Max Shear Force_KN	532.542	447.840	429.990
α_x(%)	10.154	10.425	9.512
α_y(%)	10.709	8.512	10.694

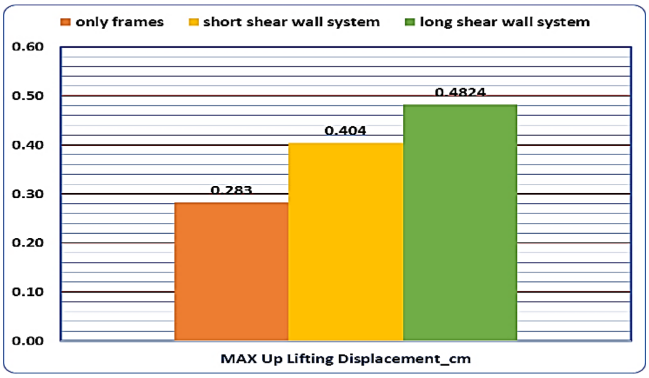

Fig 15: Max uplifting displacement comparative scheme.

α_X&Y here is the transmitted building weight ratio to its base as a shear forces. In the isolated base building this ratio should be smaller than %10 otherwise isolation system using not highly recommended in this structure, in other meaning isolation system using efficiency will be ineffective as much as expected.

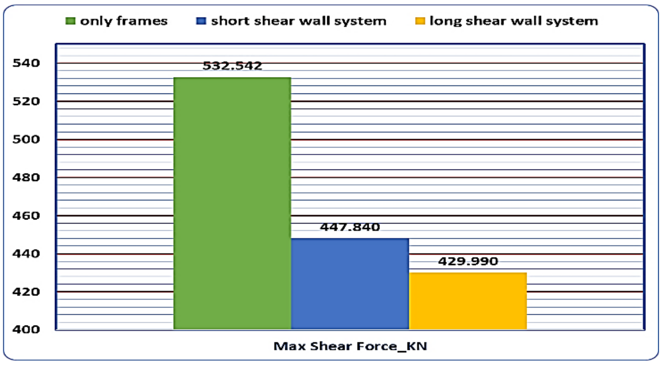

Fig 16: Max shear forces comparative scheme.

α_X&Y ratio maximum values near to allowable once which considered acceptable in this design issue.

6. CONCLUSION:

- There is no effect for changing the shear walls' dimension and direction on story acceleration values between both system which has an approximate values.

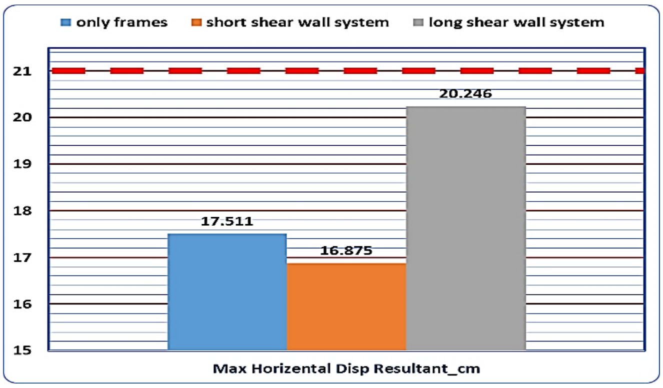

Fig 17: Max horizontal displacement comparative scheme.

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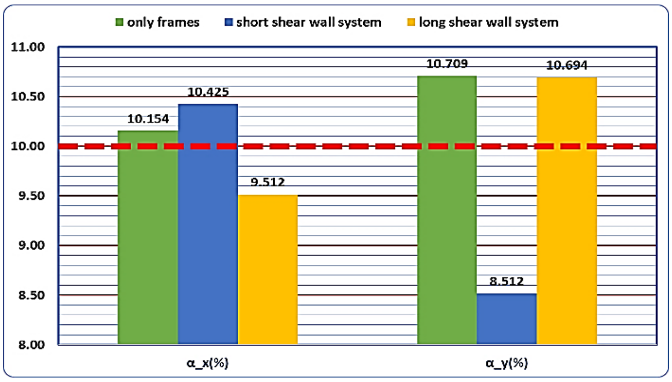

Fig 18: α_X&Y ratio comparative scheme.

- The biggest lateral displacement in the isolation unit is 0.484 cm at L.S.W_system, and the smallest value is 0283 cm at F.S_system. That means if there is no sufficient gap for isolation units to be slipped laterally during the earthquake happening, F.S_system is considered the suitable system used.
- Biggest shear force in isolation units occurs at F.S_system and the lowest value at L.S.W_system, which means, using no shear wall at structural system makes the isolation unit extra-loaded in compare with others.
- It's been noticed a clear difference in shear wall participation ratio in the L.W.S and S.S.W_system. That shows the noticeable role of long shear wall using in seriously isolated building.
- It has been noticed that all story drift values did not exceed the allowable once only and only in the next first story after isolation units layer. And the smallest values have been noticed in F.s-system building.
- The maximum uplifting displacement takes a place in again L.S.W_system results from big dimension of shear walls and the number of isolation units located under it. This values approximately the same in the other two systems.
- It has not been possible to discuss all calculated results, so in aim of avoiding repeating works, we have summarized the into only one comparative model, commenting on the selected once from engineering visualized perspective.

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