Arrangements of Shear Walls in Control of Lateral Displacement of Concrete Frames

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Abstract: One of the major shortcomings of conventional and rather high-rise structures is increasing lateral displacements arising from lateral forces which finally make the entire project un-economical. In this research, effort has been made to investigate the effect of shear walls arrangements on the lateral displacement of the structure. Two types of structures including 16 and 32-storeys frameswith different arrangements of shear panels were examined. The findings indicate that compared to other frames, the performance of frame no. 1 in both types of structures was poor in controlling the overall displacement of structure. Furthermore, more number of shear panels are not necessarily effective in reducing the overall displacement of structure but the type of arrangement had significant effect. Along the same lines, frames (2) and (3) in both types of structures have been introduced as the best arrangements due to the remarkable effect in reduction overall displacement of structure by 70 to 80%.

Key words: Concrete Frame · Dual System · Lateral Displacement · Shear Arrangements · Shear Walls

INTRODUCTION

In modern civilization tall buildings have rapidly developed worldwide [1]. Tall buildings are symbols of civilized congested and populated society. It is certainty resemble of economic growth, the force and image of a civilization [2]. A tremendous variety of architectural shapes and complex structural layouts are designed. New materials and structural models are built with unique structure with efficient performances as well established tall buildings.Recent literatures have discussed on shear deformations for optimal design, which are used the least amount of structural material to meet the stiffness requirements a well structured buildings [3]. The impact of different geometric configurations of the structural members on the material-saving economic design is also discussed and recommendations for optimal geometries are made. The design strategies discussed here will contribute to constructing built environments using the minimum amount of resources [4, 5]. Reinforcement of conventional and rather high-rise structures against lateral forces is a fundamental issue in design of structures [6, 7]. Selection of structural system of tall buildings which has significant importance and the most controlling issues for the huge lateral displacement and optimization of materials used in the structure skeleton [8-10]. Use of conventional structural systems in the above-mentioned buildings may count for our needs somewhat and they are able to tolerate different lateral forces such as wind and earthquake [11, 12]. Controlling the above forces gained through embracing for steel structures and by shear wall for reinforced concrete structures [5, 13, 14]. One of the most fashionable types of end (lateral) stiffenersin reinforced concrete structures with a rather high altitude is use of dual system (specific moment-resisting frame plus shear wall of specific reinforced concrete) [11, 15]. In present article the behavior of the above-cited system with the arrangements of shear panels in control of lateral displacements effect by earthquake forces is investigated.

Features of Sampling Frames: Inpresent study, analysis on two types of reinforcement concrete frames was carried out., The first reinforcement concrete frame work was a 16-storey frame with the altitude of each frame 3m and 8 spans each 4m. In addition, the second frame work was a 32-storey frame with the altitude of each frame 3m. and 8 spans each 4m. Both frame work with geometric models are displayed in Figure 1.

The size of beams and columns of both frames followed primary analysis and the summary of results are given in Tables 1 and 2 [16, 17]. Shear panels enjoying the width equal to the thickness of beams of the same storey and an altitude is equal to the altitude of each storey.

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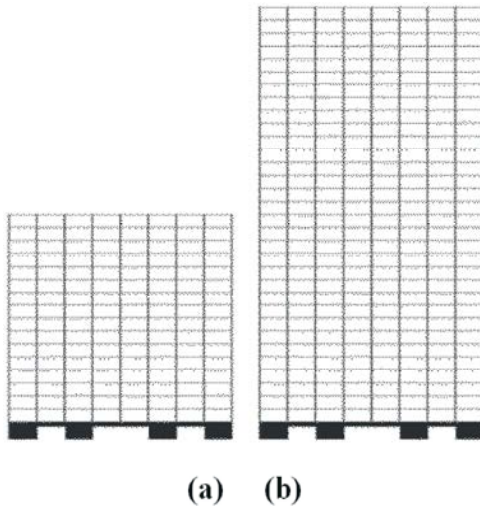Islamic Azad University, Mahabad, Iran.

Fig. 1: Reinforced concrete geometric models a. 16-storey frame workb. 32-storey frame work

Table 1: The Size of beam and column sections (16-storey frame type)

16-storey frame type	Column (m)	Beam (m)
1-4	0.50 × 0.90	0.50 × 0.50
8-5	0.50 × 0.80	0.50 × 0.50
12-9	0.70 × 0.50	0.50 × 0.50
16-13	0.50 × 0.60	0.50 × 0.50

Table 2: The Size of beam and column sections (32-storey frame type)

32-storey frame type	Column (m)	Beam (m)
4-1	1.00 × 0.50	0.50 × 0.50
12-5	0.50 × 0.90	0.50 × 0.50
20-14	0.80 × 0.50	0.50 × 0.50
32-21	0.50 × 0.70	0.50 × 0.50

Table 3: Specifications of Materials Engineering

Compressive Strength of Concrete Feature	f'c = 300 k/cm²
Concrete Elasticity Modulus	E = 273860 k/cm²
Concrete Poisson's Ratio	= 0.15 υ
Volume Unit Weight	W= 2400 k/m³

Table 4: Static Seismic Loading Hypotheses

A region of the most probable for earthquake	A = 0.35
Land / Type of I	T_0= 0.10, S=1.50 Ts=0.40
Structure with too much importance	I = 1.40
Specific Reinforced Concrete Structure in Dual System	R = 11

The materials consumed in both types of frames were reinforced concrete, the specification of material used summarized in Table 3.

Hypotheses of Loading Test Analysis
Gravitational Loading: The Values of respectively 0.5 Ton/m and 1 Ton/m imposed on beams on each storey in a linear fashion extensively and equally[18].

Horizontal Loading: Static Seismic loading (for preliminary analysis) attained based on the 3rd Edition Iranian Standard No. 2800 [19] with the hypotheses mentioned in Table 1.

Dynamic seismic loading were extracted based on Iranian Standard No. 2800 [19] with the above hypotheses.

Structural Analysis: Structural analysis was carried out by means of well known computer program ETABS which isused for the linear structural analysis of buildings subjected to static loads and dynamic earthquake loads, is documented. Efficient model formulation and problem solution is achieved by idealizing the building as a system of frame and shear wall substructures inter-connected by floor diaphragms. The extended capabilities of the enhanced program are explained taking into consideration of the effects of P-Δ and combining modes using fully quadratic combinationmethod (CQC) resulted in beams, columns and walls stiffness of 0.35 Ig, 0.70 Ig, 0.35 Ig,respectively [19].

Frames Movement Axial Deformation: In evaluation of frames' movement axial deformation parts was dispensed.

Supports and Face Deformation: Supports are fixed in kind and their face deformation was dispensed.

Suggested Figures for Arrangement of Shear Panels: The following shear panels arrangements were suggested for both types of 16-Storey Frames and 32-Storey Frames (Figure 2) and for the entire models the numbers of panels are equal and on each storey two shear panels are drawn.

Models Analysis and Evaluation of Moment-resisting Frames: Tables 5 and 6, in addition Figures 3 to 17 display values and diagrams for lateral displacement of frames with different arrangements of shear panels, respectively. Tables 7 and 8 display the percentage of decrease in lateral displacement of frames compared to frame number1 for both types of 16-storey and 32-storey frames. Moreover, Figures 17 and 18 display the difference between lateral deformations and the amount of convergence for both types of 16-Storey and 32-Storey

Table 5: The Values of lateral displacements 16-Storey frame on the basis (cm)

Storey	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7
1	0.10	0.10	0.10	0.10	0.10	0.10	0.10
2	0.18	0.10	0.10	0.10	0.10	0.10	0.10
3	0.28	0.20	0.20	0.20	0.20	0.20	0.10
4	0.48	0.20	0.20	0.20	0.30	0.30	0.20
5	0.66	0.30	0.30	0.30	0.40	0.40	0.30
6	0.95	0.30	0.30	0.40	0.48	0.48	0.38
7	1.25	0.40	0.38	0.50	0.48	0.68	0.60
8	1.53	0.50	0.38	0.58	0.48	0.78	0.68
9	1.80	0.50	0.58	0.58	0.60	0.88	0.78
10	2.10	0.58	0.58	0.68	0.60	0.98	0.88
11	2.40	0.58	0.58	0.78	0.68	1.05	0.98
12	2.68	0.68	0.68	0.88	0.78	1.15	1.05
13	3.06	0.68	0.68	0.88	0.88	1.05	1.05
14	3.35	0.68	0.68	0.88	0.88	0.98	1.05
15	3.65	0.68	0.68	0.88	0.88	0.88	1.05
16	3.93	0.68	0.78	0.88	0.88	0.78	1.05

Table 6: The Values for Lateral Displacements 32-Storey Frames on the basis (cm)

Storey	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7
1	0.15	0.15	0.15	0.10	0.10	0.15	0.15
2	0.20	0.20	0.15	0.10	0.10	0.20	0.15
3	0.50	0.30	0.30	0.20	0.20	0.40	0.20
4	0.70	0.40	0.40	0.30	0.30	0.70	0.30
5	1.10	0.50	0.40	0.40	0.40	0.80	0.40
6	1.35	0.60	0.50	0.50	0.60	1.15	0.50
7	1.75	0.75	0.60	0.60	0.80	1.35	0.60
8	2.25	0.80	0.70	0.80	1.00	1.50	0.60
9	2.60	0.90	0.80	0.90	1.30	1.75	0.80
10	3.10	1.00	0.90	1.10	1.50	2.00	1.00
11	3.55	1.10	1.00	1.30	1.70	2.30	1.35
12	4.00	1.20	1.20	1.60	1.90	2.70	1.65
13	4.50	1.35	1.30	1.80	1.90	3.00	1.95
14	5.10	1.45	1.60	2.00	2.00	3.30	2.20
15	5.60	1.55	1.80	2.25	2.00	3.55	2.50
16	6.10	1.75	2.10	2.40	2.10	3.85	2.80
17	6.55	1.85	2.10	2.60	2.20	3.95	3.00
18	7.15	2.00	2.25	2.80	2.30	4.10	3.25
19	7.60	2.25	2.35	3.10	2.40	4.30	3.55
20	8.15	2.40	2.65	3.40	2.60	4.50	3.85
21	8.55	2.50	2.65	3.60	2.80	4.70	4.15
22	9.05	2.70	2.75	3.94	3.00	4.90	4.40
23	9.50	2.83	2.80	4.15	3.30	5.10	4.70
24	9.90	3.20	2.90	4.25	3.60	5.20	5.00
25	10.40	3.30	3.00	4.30	3.90	5.10	5.15
26	10.80	3.35	3.00	4.45	4.00	5.00	5.40
27	11.25	3.45	3.15	4.45	4.20	5.00	5.55
28	11.65	3.55	3.30	4.45	4.25	4.90	5.75
29	12.00	3.65	3.40	4.45	4.35	4.85	6.00
30	12.45	3.65	3.45	4.45	4.35	4.80	6.15
31	12.80	3.75	3.65	4.50	4.35	4.75	6.45
32	13.20	3.85	3.75	4.50	4.35	4.70	6.65

Table 7: The Percentage of decrease in Lateral Displacements 16-Storey Frames compared to Frame 1 (Base Frame)

16-Storey Frames	Lateral Displacement Upper -Part of Structure (cm)	The Percentage of decrease in Lateral Displacements Upper - Part of Structure (%)
Frame 1	3.93	0.00
Frame 2	0.68	82.65
Frame 3	0.78	80.15
Frame 4	0.88	77.61
Frame 5	0.88	77.61
Frame 6	0.78	82.65
Frame 7	1.05	73.2

Table 8: The Percentage of decrease in Lateral Displacements 32-Storey Frames compared to Frame 1 (Base Frame)

16-Storey Frames	Lateral Displacement Upper - Part of Structure(cm)	The Percentage of decrease in Lateral Displacements Upper - Part of Structure (%)
Frame 1	13.20	0.00
Frame 2	3.85	70.83
Frame 3	3.75	71.59
Frame 4	4.50	65.91
Frame 5	4.35	67.05
Frame 6	4.70	64.39
Frame 7	6.65	49.62
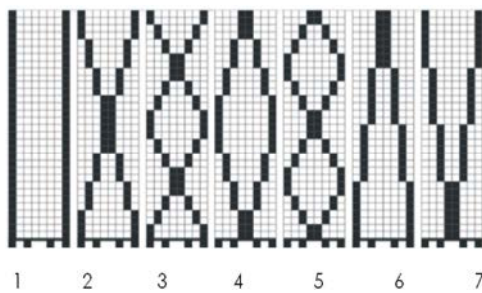
Fig. 2: Different figures of shear panel arrangements
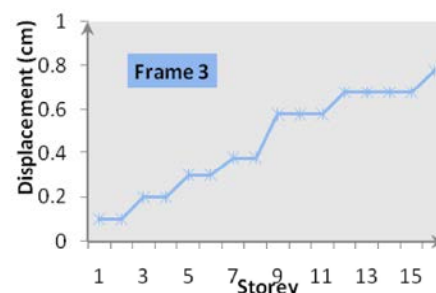
Fig. 5: Diagram of Displacement for 16-Storey Frame - Type 3

Fig. 3: Diagram of Displacement for 16-Storey Frame - Type 1
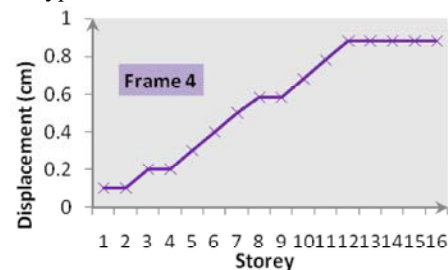
Fig. 6: Diagram of Displacement for 16-Storey Frame - Type 4

Fig. 4: Diagram of Displacement for 16-Storey Frame - Type 2
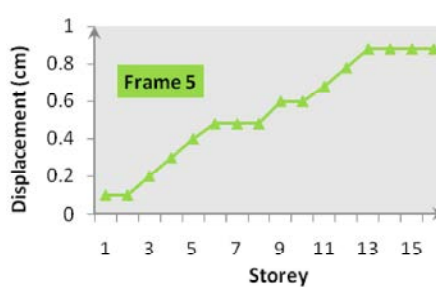
Fig. 7: Diagram of Displacement for 16-Storey Frame - Type 5
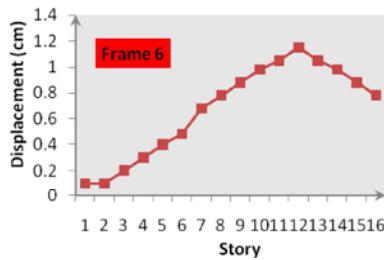
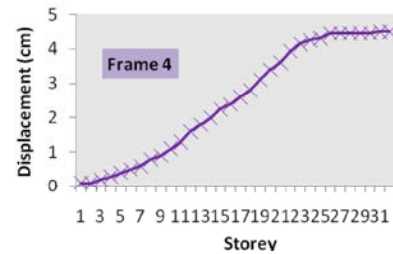Fig. 8: Diagram of Displacement for 16-Storey Frame - Type 6
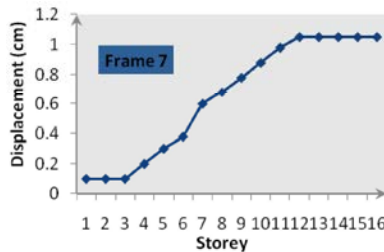

Fig. 9: Diagram of Displacement for 16-Storey Frame - Type 7
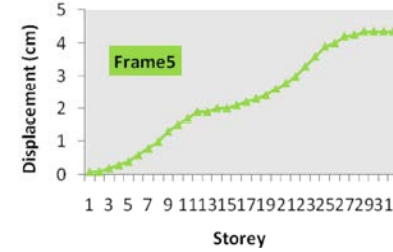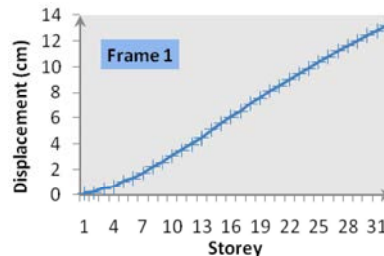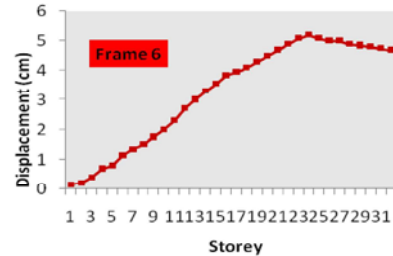

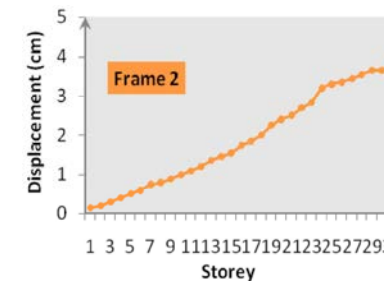Fig. 10: Diagram of Displacement for 32-Storey Frame - Type 1

Fig. 11: Diagram of Displacement for 32-Storey Frame - Type 2

Fig. 12: Diagram of Displacement for 32-Storey Frame - Type 3

Fig. 13: Diagram of Displacement for 32-Storey Frame - Type 4

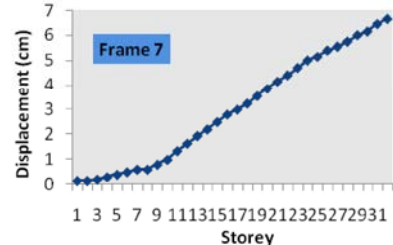Fig. 14: Diagram of Displacement for 32-Storey Frame - Type 5

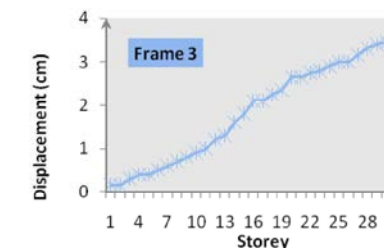Fig. 15: Diagram of Displacement for 32-Storey Frame - Type 6

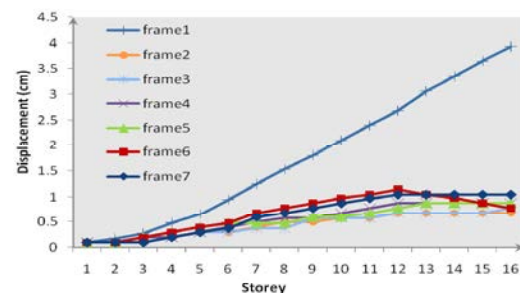Fig. 16: Diagram of Displacement for 32-Storey Frame - Type 7

Fig. 17: Convergent Diagram of lateral displacement for 16-Storey Frame Group
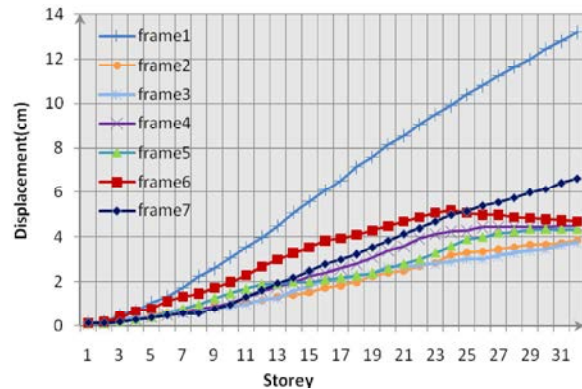
Fig. 18: Convergent Diagram of lateral displacement for 32-Storey Frame Group
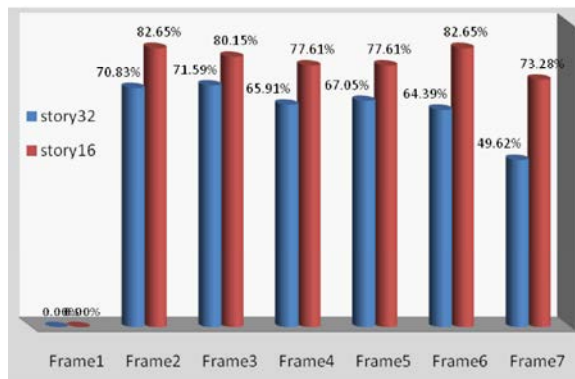

Fig. 19: The Percentage of decrease in lateral displacement for Frames No. 2 to 7 compared to Frame No. 1 for both 16-Storey and 32-Storey Types

frames, respectively. Figure 19 displays a comparison between the effect of increasing stories on decreasing the amount of lateral displacements.

CONCLUSION

Based on present investigation the following conclusions are drawn:

- Based on conclusions the analysis displayed in Tables 7 and 8, there are remarkable difference were observed in both 16-storey and 32-Storey frames concerning overall displacements between frames 2 to 7 with respect to frame 1. These changes wereresulted in 16-Storey frames with a decrease of displacement by 70-80% and in 32-Storey frames an increase in displacement buy 50-70%.
- For both frames types, frame nos. 2 and 3 compared to other frames have less displacements and from the above matter it was concluded that the above frames enjoying a kind of truss performanceindicating better transferring of forces during bracing; consequently more force absorption by the above elements.

- In a general point of view, for both mentioned frames, the performance of frames panels no. 1 was compared to other frames concerning controlling displacement of overall structure seems to be poor.
- The conclusion indicates that more section panels did not cause necessarily displacement of structures but the type of arrangement had important criteria as well.
- On the strength of Figures 17 and 18 the most notable conclusion was that the more stories are reduced, the replacement frames diagrams due to the lateral forces have more overlapping on each others.

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