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Dynamic Analysis of Fourteen Storeyed Y-Shaped High-Rise Reinforced Concrete Building with Shear Walls

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ABSTRACT

The performance of the fourteen storeyed Y-shaped high-rise reinforced concrete building in seismic zone 4 has been investigated using dynamic analysis with response spectrum. The building is designed with dual system containing special moment resisting frame (SMRF) and shear walls. Structural Engineering Software (ETABS) is used for analysis and design of building. The design of superstructure is checked for sliding resistance, overturning effect, P-Δ effect, storey drift and irregularity. Stability check for the structure without shear wall is satisfactory .But, building taller than 10 stories is not adequate to give the lateral stiffness from frame action. Building with core shear wall structure and planar shear walls are proposed. After analyzing and checking for the stability, the results of the three structures with and without shear walls are presented.

KEYWORDS: *RC Building, Core shear wall, Planar shear wall, Design Response Spectrum.*

I. INTRODUCTION

According to Social And Economical Demands, Presently, Mandalay Needs Various Types of Tall Buildings. These Buildings are the Solutions to the Problem of Living Population Growth Rate. in High-Rise Building, it is Important to Ensure Adequate Stiffness to Resist Lateral Forces Induced by Wind or Seismic Effects. Concrete Walls, Which Have High In-Plane Stiffness Placed at Convenient Locations, are often Economically Used to Provide the Necessary Resistance to Horizontal Forces. this Type of Wall is Called a Shear Wall.

The walls may be part of a service core or stairwell, or they may serve as partitions between accommodations. there are three types of shear wall. they are planar shear wall, coupled shear wall and core shear wall. they are usually continuous down to the base to which they are rigidly attached to form vertical cantilevers. shear walls can reduce total deflection and also reduce moment in columns and floor members due to lateral loads. the beams connected to the shear wall need to have the larger member size. shear wall acts as vertical cantilevers and fixed at the base. the thickness of shear wall should be optimum thickness. if the shear wall thickness is more than its requirements, the building weight will increase and then it will not be economical design. shear wall is basically a member that is subjected to cantilever beam action with fixed end at the BASE. therefore, the magnitudes of moment and horizontal shear are found to be maximized at the base and they become less as they become high.

II. PREPARING AND MODELING OF THE PROPOSED BUILDING

A. Case study and Structural System

The structure is composed of shear walls and special moment resisting frame (SMRF). In this structure, response spectrum dynamic analysis is used.

Type of building -	fourteen stories reinforced Concrete building
Type of occupancy -	residential
Shape of building -	y shaped
Height of building Ground floor to first floor	= 12ft
Height of typical floor	= 10ft
Overall height	= 159ft
Maximum length	-136ft
Maximum width	-128ft
Location	- Mandalay (seismic zone 4)

B. Material Properties

The material properties data which are used in structural analysis of the proposed building are as follows:

1. Analysis property data,

Weight per unit volume of concrete	: 150 pcf
Modulus of elasticity	: 3.122×10^6 psi
Poisson's ratio	: 0.2
Coefficient of thermal expansion	: 5.5×10^6in/in per degree F

2. Design property data,

Shear Reinforcement yield stress (f_{ys})	: 50000 psi
Bending Reinforcement yield stress (f_y)	: 50000 psi
Concrete strength (f_c')	: 3000 psi

C. Loading considerations

The gravity loads considered in this design are dead load and live load. The lateral loads of wind load and earthquake load are calculated according to UBC-97.

1 Gravity load: Dead load is defined as the results from the structure and all other permanently attached materials. They have constant magnitude and fixed location throughout the lifetime of the structure. The characteristic feature of dead load is that they are permanent. Live loads are produced by the use and occupancy of the building or other structure and do not include dead load, construction load and environmental loads. Live loads may be either fully or partially in place or not present at all and may also change a position.

Gravity Load Data

Unit weight of concrete	:150 lb/ft^3
4½" thick wall weight	:50 lb/ft^2
9" thick wall weight	:100 lb/ft^2
Superimposed dead load	:20 psf
Weight of elevator	:2 tons
Live load on residential area	:40 lb/ft^2
Live load on roof	:30 lb/ft^2
Live load on stair case	:100lb/ft^2
Weight of water	:249.6 psf

2 Wind Load: Every building or structure and every portion shall be designed and constructed to resist the wind effects. Wind shall be assumed to come from any horizontal direction. No reduction in wind pressure shall be taken for the shielding effect of adjacent structures.

Wind Load Data

Exposure type	:Type B
Basic wind velocity	:80 mph
Important factor	:1
Windward coefficient	:0.8
Leeward coefficient	:0.5
Method used	:Normal force method

3 Earthquake Load: Seismic force on a building depends on zone factor, soil types, source types, near source factor, response modification factor, important factor and, seismic response coefficient.

Earthquake Load Data

Location	:Mandalay
Seismic zone	:Zone 4
Zone factor, Z	:0.4
Soil type	:S_D
Importance factor, I	:1.0
Response modification factor, R	:8.5
Seismic coefficient, C_a	:0.44 N_a
Seismic coefficient, C_v	:0.64 N_v
Near source factor, N_a	:1.0
Near source factor, N_v	:1.0
Analysis types	:Dynamic Analysis

III. Analysis and Design of Rc Building with Shear Wall Structure

A fourteen storey R.C building is modeled for the analysis. The height of the base is 12 feet. Other storeys are 10 feet height. The stair roof storey is 7 feet. Total height is 159 feet.

A. Analysis of Shear Wall Structures

Model (1) represents core shear wall in stair case & lift. Six different locations of planar shear walls and core shear wall are placed in the previous model. Model (2) represents six planar shear walls are resisted in both X and Y directions and core shear wall in stair case & lift.

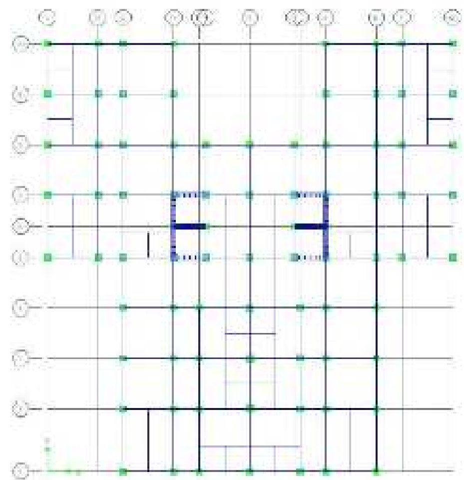

Figure1. Plan of the core shear wall proposed building Model (1)

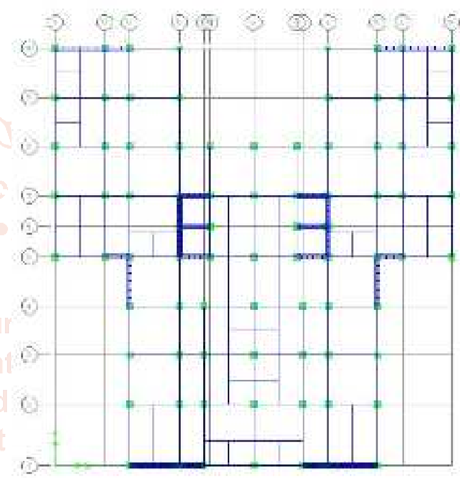

Figure2. Plan of the core and planar shear wall proposed building Model (2)

B. Design Results for beams

The beams used in these buildings are 10"×12", 10"×14", 10"×16", 10"×18", 12"×16", 12"×18", 12"×20", 14"×18"and 14"×20". The ratio of longitudinal steel area to gross concrete cross sectional area of the beams are within the ranges from the minimum steel ratio (ρ_{min}) to the maximum steel ratio (ρ_{max}).

C. Design Results for columns

The columns used in these buildings are 12"×12", 14"×14", 16"×16", 18"×18", 19"×19", 20"×20", 22"×22",24"×24" and 26"×26". The ratio of longitudinal steel to gross concrete cross sectional area of the columns are within the ranges from 0.01 to 0.06 to acquire the seismic design specifications.

D. Design Results for Shear Wall

The cross sectional dimensions of beams, columns and slabs are the same with the previous non-shear wall structure. The material properties, loading and other data for wind and seismic forces are the same as the non-shear wall structure. The thicknesses of shear walls are:

Shear walls (Base to 2nd floor) - 14"
Shear walls (3st floor to 7th floor) - 12"
Shear walls (8th floor to Roof floor) - 10"

IV. Check for Stability of the Structure

A. Overturning Moment

The distribution of earthquake forces over the height of a structure causes structure to experience overturning effects. The summation of moment due to the distributed lateral-forces is the overturning moment. The factor of safety for overturning moment is the ratio of the resisting moment to overturn-in moment and it must be greater than 1.5. The proposed structure is capable of resisting overturning effect. The checking for overturning moment is illustrated in Table II.

B. Sliding

The ratio of the resistance due to friction to sliding force is called factor of safety for sliding and it must be greater than 1.5. There is no sliding occur in the structure. The checking for sliding is illustrated in Table II.

C. Torsional Irregularity

The maximum drift at one end of the structure transverse to its axis is not more than 1.2 times the average storey drifts of both ends. The effect of horizontal torsional moment can be neglected in the proposed structure. The checking for torsional irregularity is illustrated in Table II.

D. Storey Drift

The storey drifts are checked in order to determine whether the structure is stable or not by using UBC- 97 formula. According to the UBC-97 Code, the storey drift limit must be lower than 0.02h. The checking for storey drift is illustrated in Table II.

$\Delta_M = 0.7\ R\Delta s = 0.7 x 8.5\Delta s = 5.95\Delta s \leq \Delta_{limit}$

where,

Δ_M = Maximum storey drift

Δs = Story drift obtained from the analysis

R = Response modification factor = 8.5

Δ_{Limit} = Storey drift limitation = 2.0% of storey height for T ≥ 0.7 sec

Period, T $= C_t (H)^{3/4}$

$= 0.03 \times (159)^{3/4}$

$= 1.34 > 0.7$ sec

E. P-Δ effect

Based on the UBC-97, P-Δ effect does not exist when the ratio of storey drift to storey height (storey drift ratio) does not exceed 0.02/R in seismic zone 3 and 4. Since 0.02/R = 0.02/8.5 =0.00235, P-D effect is not needed to consider in the proposed building.

TABLE I CHECK FOR STORY DRIFT AND TORSIONAL IRREGULARITY

Model	Storey Drift			Torsional Irregularity		
	Actual Value(in)		Δ_{Limit} (in)	Actual Value		All: Value
	X direction	Y direction		X direction	Y direction	
1	1.188096	0.84252	2.4	1.1	1	1.2
2	0.90678	0.80682	2.4	1.1	1	1.2

TABLE II CHECK FOR OVERTURNING AND SLIDING

Model	Overturning			Sliding		
	Actual Value		Safety Factor	Actual Value		Safety Factor
	X dire:	Y dire:		X dire:	Y dire:	
1	7.5	10.4	1.5	4	3.1	1.5
2	7.3	7.9	1.5	3	3	1.5

V. Comparison of Analysis Results

Comparison of storey drift, storey shear and storey moment are presented between core shear wall structure and structure with core shear wall and planar shear wall .The analysis results for members are carried out 30 types of load combinations based on ACI 318-02. Results of story drift, story shear and story moment for both directions are taken from earthquake loads. The compared results are presented with Table III, IV, V, IV, VII, and VIII and Figure 3, 4, 5, 6, 7, and 8 as below.

A. Comparison of Storey Drift

The comparative study of storey drift values in X and Y directions for two models are represented in Table , Table III and Figure 3, Figure 4. Structure with core shear wall has the greatest values 0.001664 in X-direction at story 8 and 0.00118 in Y-direction at story 10. Structure with core shear wall and planar shear wall has the greatest value 0.00127 in X-direction at story 12 and 0.00113 in Y-direction at story 11. The storey drift values of core shear wall structure is 2.1 times higher than those of core shear wall and planar shear wall structure in X-direction at story 1. The storey drift values of core shear wall structure is 1.14 times higher than those of core shear wall and planar shear wall structure in Y-direction at story 1. Shear wall can reduced significantly the story drift of each level. It can resist lateral loads. The less story drift values, the more the structure is stable. Thus, the story drift in structure with core shear wall and planar shear wall (Model 2) has the smallest value in both directions for all models.

TABLE III STOREY DRIFTS IN X DIRECTION OF MODEL 1 AND 2

Story	Storey Drifts in X Direction	
	Model 1	Model 2
Roof	0.001413	0.00125
13	0.001498	0.001264
12	0.001541	0.00127
11	0.001586	0.001269
10	0.001642	0.001261
9	0.00165	0.001238
8	0.001664	0.001198
7	0.001614	0.001136
6	0.001569	0.00106
5	0.001487	0.000971
4	0.001392	0.000861
3	0.001236	0.000733
2	0.001048	0.000574
1	0.000811	0.00039
GF	0.000404	0.000183

TABLE IV STOREY DRIFTS IN Y DIRECTION OF MODEL 1AND 2

Story	Storey Drifts in Y Direction	
	Model 1	Model 2
Roof	0.001138	0.001108
13	0.001162	0.001114
12	0.001173	0.001125
11	0.001179	0.00113
10	0.00118	0.001129
9	0.00117	0.001117
8	0.001145	0.001091
7	0.001091	0.001039
6	0.001029	0.00098
5	0.000958	0.000908
4	0.000868	0.000819
3	0.000761	0.000711
2	0.000621	0.000572
1	0.000486	0.000425
GF	0.000265	0.000224

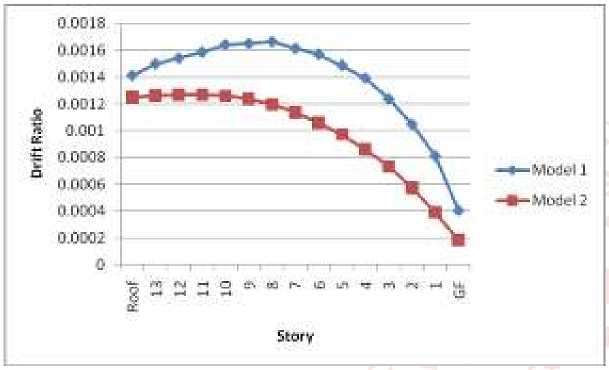

Figure.3 Comparison of Story Drift in X-direction

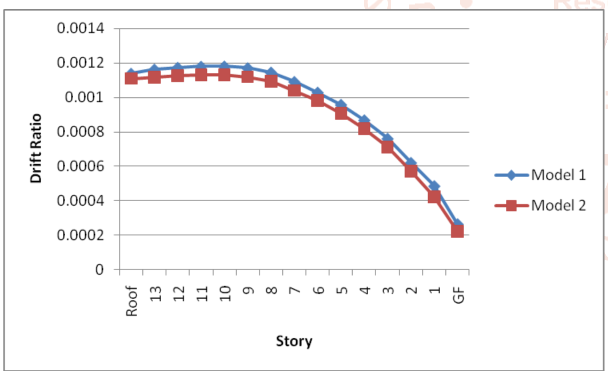

Figure4. Comparison of Story Drift in Y-direction

B. Comparison of Storey Shear

In comparison of story shear in both directions, shears are increased steadily and maximum story shears are found in ground floor. Story shear is corresponding to the seismic dead load at the base. Seismic dead load is the largest at the base. Seismic dead load is the total dead load and applicable portions of other loads. The weight of the structure with structure with core shear wall and planar shear wall (Model 2) is greater than the structure with core shear wall. The storey shear values of the core shear wall structure is 1.49 times slightly less than that of core shear wall and planar shear wall structure in X -direction at ground floor. The storey shear values of the core shear wall structure is 1.2 times slightly less than that of core shear wall and planar shear wall structure in Y-direction at ground floor. Structure with core shear wall and planar shear wall (Model 2) has the greatest story shear.

TABLE V STOREY SHEARS IN X DIRECTION OF MODEL 1AND 2

Story	Storey Shears in X Direction (Kips)	
	Model 1	Model 2
RF	234.7	313.67
13	412.56	584.84
12	537.53	784.71
11	631.98	938.23
10	710.61	1064.6
9	779.35	1175.54
8	842.94	1278.68
7	906.7	1380.42
6	973.47	1483.46
5	1041.42	1584.99
4	1108.92	1682.92
3	1173.03	1771.51
2	1228.92	1844.57
1	1270.6	1897.28
GF	1278.03	1907.97

TABLE VI STOREY SHEARS IN Y DIRECTION OF MODEL 1AND 2

Story	Storey Shears in Y Direction (Kips)	
	Model 1	Model 2
RF	279.95	311.92
13	511.08	582.32
12	683.87	786.02
11	815.51	943.65
10	922.31	1072.29
9	1014.78	1183.89
8	1100.28	1287.36
7	1184.6	1388.79
6	1271.32	1491.11
5	1359.23	1592.92
4	1446.72	1692.93
3	1529.07	1785.06
2	1600.42	1863.6
1	1655.9	1924.81
GF	1666.76	1939.42

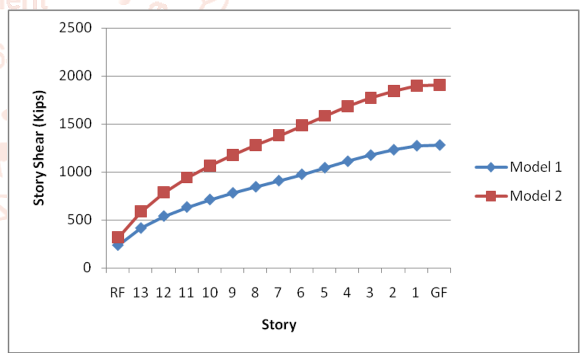

Figure 5.Comparison of Story Shear in X-direction

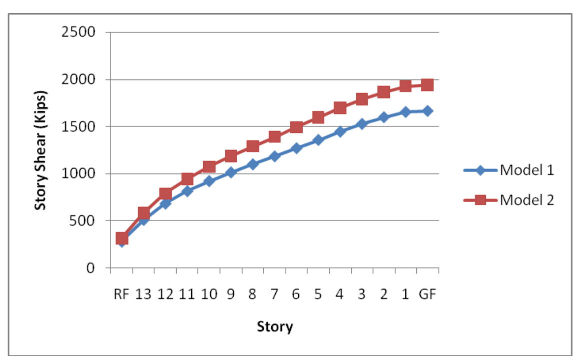

Figure 6 Comparison of Story Shear in Y-direction

C. Comparison of Storey Moment

The comparative study of storey moment values in X and Y directions for three models are represented in Table XIV, Table XV and Figure 10, Figure 11. In comparison of story moment in both directions, moments are increased steadily and maximum story moments are found in ground floor. The story moment is depending on the seismic load. So, the story moment is the largest at base. The storey moment values of the non-shear wall structure is 1.56 times slightly less than that of core shear wall structure and 1.83 times less than those of core shear wall and planar shear wall structure in X-direction at ground floor. The storey moment values of the non-shear wall structure is 1.22 times slightly less than that of core shear wall structure and 1.87 times less than those of core shear wall and planar shear wall structure in Y-direction at ground floor. Structure without shear wall has the least story moment and structure with core shear wall and planar shear wall (Model 3) has the greatest story moment.

TABLE VII STOREY MOMENT IN X DIRECTION OF MODEL 1 AND 2

Story	Storey Moment in X Direction(Kips-in)	
	Model 1	Model 2
Roof	35679.7	39633.5
13	96781.78	109221.9
12	178124.1	202609.1
11	274062.1	313517.7
10	380828.1	437708.8
9	496124.7	572508
8	618765.9	716520.2
7	748367.5	869285.2
6	885111.5	1030870
5	1029432	1201523
4	1181758	1381516
3	1342280	1570850
2	1510790	1769083
1	1722373	2017216
GF	1904053	2229866

TABLE VIII STOREY MOMENT IN Y DIRECTION OF MODEL 1AND 2

Story	Storey Moment in Y Direction (Kips-in)	
	Model 1	Model 2
Roof	30010.13	40187.16
13	79225.29	110069.1
12	142720.8	203283.2
11	216070.7	313450.7
10	296805.1	436462.7
9	383542.3	569890.9
8	475568.6	712505.2
7	572717.6	863939.7
6	675279	1024343
5	783738.3	1193985
4	898512.2	1373055
3	1019804	1561397
2	1147510	1758397
1	1308283	2004447
GF	1446626	2214870

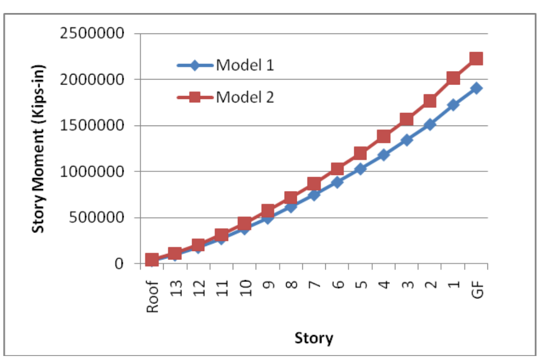

Figure 7.Comparison of Story Moment in X-direction

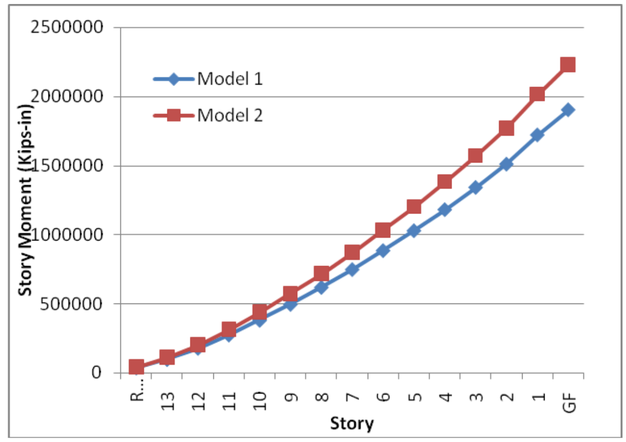

Figure 8.Comparison of Story Moment in Y-direction

DISCUSSIONS AND CONCLUSIONS

In this study, the analysis of fourteen storeyed Y-shaped high-rise reinforced concrete building with shear walls in seismic zone 4 is done by ETABS v 9.7.1 software using response spectrum analysis. In this study, the stability checking is satisfied for each model. Storey drift and torsional irregularity effect are checked by using UBC – 97 specifications. And then it is checked for overturning and resistance to sliding. The structural elements are designed by using American Concrete Institute (ACI 318-02). Shear wall are provided for lateral stability of reinforced concrete structure. From the results of analysis, the influence of shear wall location on the selected irregular building is more stable by providing the location of shear walls in the symmetric side.

It can be concluded that storey drift of structure without shear wall decreased slightly from ground floor to story 1 and fell dramatically at story 2 and then declined steadily from story 2 to roof floor in X and Y-directions. Storey drift values of model (1) and (2) are slightly increased from ground floor to story 10 and then a little decreased to roof floor in both directions. For all structures, ground floor has the greatest values of shear force and roof floor has the least values of shear force in both directions. Structure with core shear wall and planar shear wall has the greatest values of shear force for all stories in both X and Y-direction. The story moments values of structure with core shear wall and planar shear wall are greater than other structures for all stories in X and Y directions. Based on the analysis results, it can be concluded that the proposed building with core and planar shear wall is the most suitable structure.

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