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Perusal of Multi Storey Light Frame Shear Wall by Manual Check and Finite Element Method

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Abstract*: Shear walls are a structural system which gives solidness or stability to structures from lateral loads like wind, seismic loads. The structural systems are fabricated by reinforced concrete, plywood/timber unreinforced, reinforced masonry at which these systems are subdivided into coupled shear walls, shear wall frames, shear panels and staggered walls. The present paper work was made in the interest of studying and analysis of various research works involved in enhancement of shear walls and their behaviour towards lateral loads. In SAP2000 analysis we found that when we apply lateral force between the stories the amount of compression and tension force between the stories obtained is equal to the manual analysis .In STAAD.PRO, we analyzed the light frame shear wall for seismic analysis. The estimated results for light frame shear wall with one storey, shear wall with two storey and shear wall with three storey shown similar to the results which are obtained by using FEM software like STAAD and SAP2000.

***Index Terms*: Shear Wall, Storey, SAP2000, Seismic, Shear Panels**

I. INTRODUCTION

Shear wall is a vertical structural element used to resist the horizontal forces such as wind force, seismic force. These forces act parallel to the plane of the wall. Shear walls are generally used in high rise buildings where effect of wind forces and seismic forces is more & provides large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. The finite element models could provide accurate results, but in some cases become too time intensive for the analysis of entire buildings [1]. On the other hand, this type of modelling not only simulates displacements induced from openings and cracks in the sheathing material but also from tensile and compression support reactions [2, 3]. Another paper [4] investigates and outlines the effect of door and window openings in timber framed shear walls.Previous feasible studies of structural systems have been conducted to analyse the effect of the lateral forces [3,4, 5]. Therefore, the author adapted a new approach to account for the different loading conditions by introducing alternative FEM software as analysing tool for the proposed model under study.

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TYPES OF SHEAR WALLS

1. Reinforced Concrete Shear Wall.
2. Concrete Block Shear Wall.
3. Steel Shear Wall.
4. Plywood Shear Wall.
5. Mid-Ply Shear Wall.

LOADS

Lateral Loads: loads which act horizontal to structures are known as lateral loads.

Earthquake Loads: when two layer of earth or plates of earth strikes or slides with each other, they released certain energy in form of waves which attack horizontal to structures. These types of loads are known as earthquake loads. These loadings result from the structure's distortion caused by ground motion and lateral resistance to structures. Effects Earthquake loading depends upon amount and ground acceleration, mass and stiffness of structures, intensity of earthquake waves and bearing capacity of soil etc. Earthquake load can be calculated by EQ=ZIKCSW

Z = seismic zone coefficient (varies from 1/8 to 1).
I = occupancy important factor (varies from 1.5 to 1.25).
K = horizontal force factor (varies from 0.67 to 2.5).
T = fundamental natural period.
S = soil profile coefficient (varies from 1.0 to 1.5).
W = total dead load of the building.

$$C = \frac{1}{15\,T} \leq 0.12$$

Wind loads: when structure blocks the flow of wind, the wind's kinetic energy is converted into potential energy of pressure, which causes a wind loading. The effect of wind load on a structure depends upon density, velocity of air, angle of incidence, shape and stiffness of structure and roughness of its surface.

Wind load or wind pressure on structure
$q=1/2\ e\ V^2$
e is Density of air and
V is velocity of air

II. METHODOLOGY

Manual Design for 1st storey:
Width, b=4
Height, h=10
Force, p=v=1000lbs
Tension, T=C=V*h/b
=1000lbs*10'/4'
=2500lbs

Checking forces by using SAP 2000 software for 1st storey

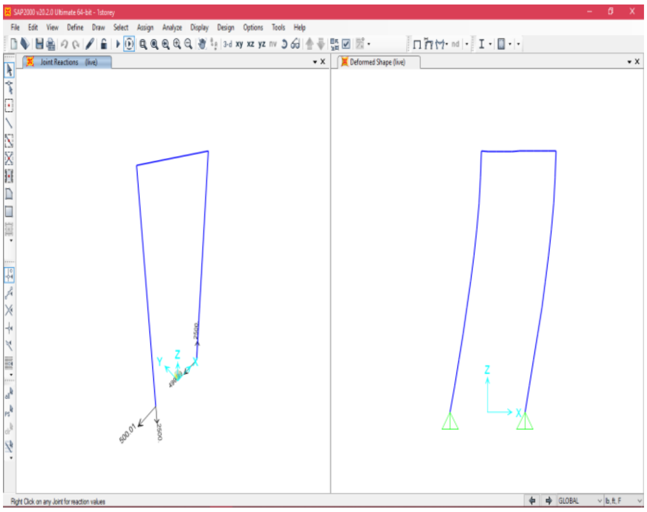

Figure 1: support reactions and forces for 1st storey

Manual Design for 2nd storey

Width, b=4'

Height, h=10'

Force, $P_1=V_1=1000$lbs

$P_2=V_2=1500$lbs

Tension, $T_2=C_2=V_2*(h/b) + V_1*(h/b)$

=1500lbs*(10'/4') + 1000lbs*(10'/4')

=6250lbs

Checking forces by using SAP 2000 software for 2nd storey

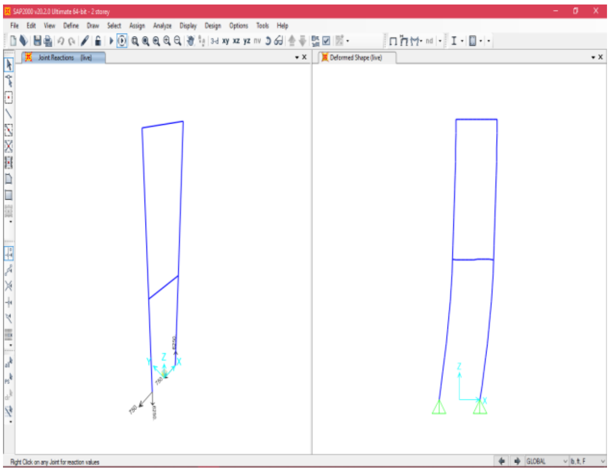

Figure 2: support reactions and forces for 2nd storey

Manual design for 3rd storey

Width, b=4'

Height, h=10'

Force, $P_1=V_1=1000$lbs

$P_2=500$ lbs, $V_2=1500$lbs

$P_3=500$ lbs, $V_3=2000$ lbs

Tension, $T_3=C_3=V_3*(h/b) + V_2*(h/b)$

=2000lbs*(10'/4') + 1500lbs*(10'/4')

=11250lbs

Checking forces by using SAP 2000 software for 3rd storey

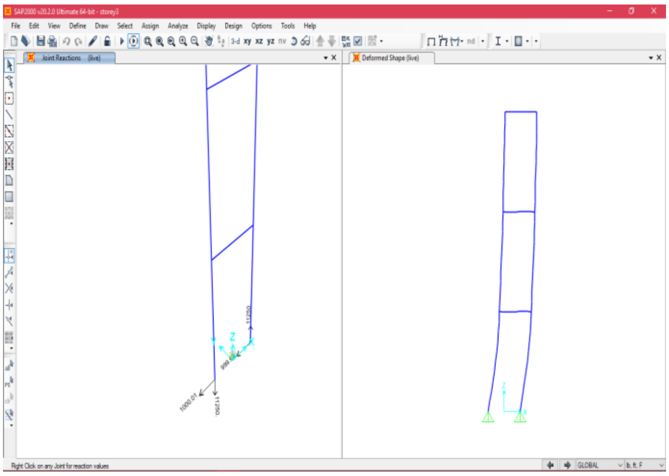

Figure 3: support reactions and forces for 3rd storey

Seismic Analysis of light frame shear wall by Using STAAD.PRO Software

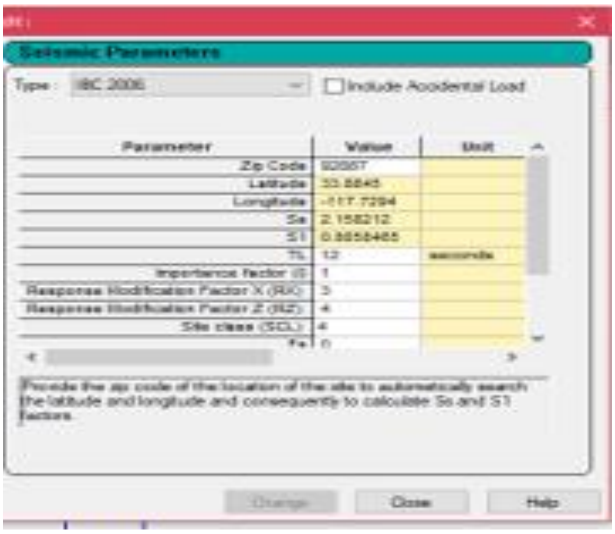

Figure 4: Assigning seismic parameters for light frame shear wall

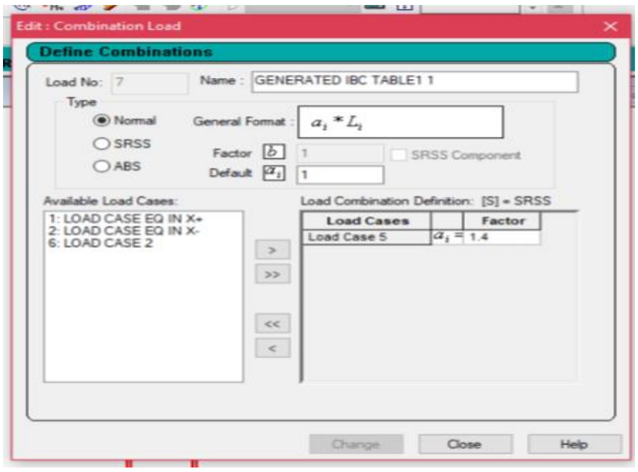

Figure 5: Applied load combinations for light frame shear wall

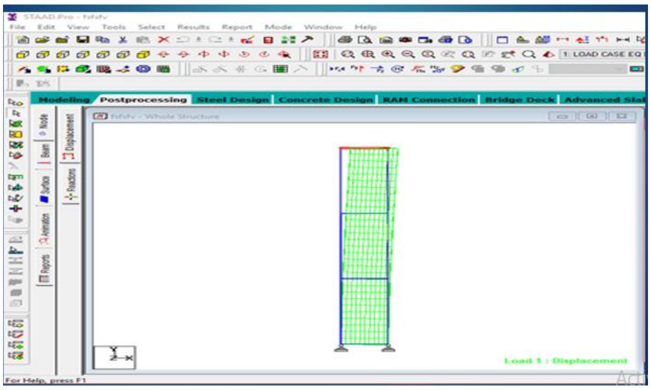
Figure 6: Deformed shape for light frame shear wall

MANUAL CALCULATION FOR SEGMENTED APPROACH

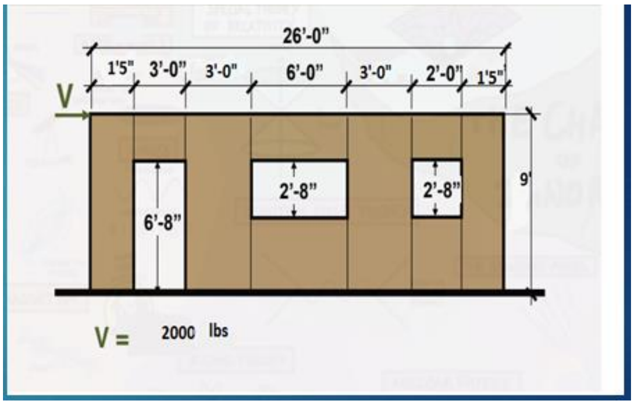

Figure 7: light frame shear wall for segmented approach

Fig-7 represents the layout for the study of segmented approach. In this we had prepared the panels according to their respective dimensions and are analyzed for the study of shear forces manually.

1. Unit shear
   V = V/L =2000/9 =222.22 lbs/ft.
2. Allowable shear 1'-5'' walls
   V allowable = 380*0.88 = 334.4 lbs/ft.
3. Allowable shear 4' walls (2:1 h: w).
   V allowable = 260 lbs /ft > 222.22 lbs/ft.
4. Hold-down forces
   H = v*h =222.22*9 = 1999.98 lbs.

MANUAL CALCULATION FOR PERFORATED SHEAR WALL APPROACH

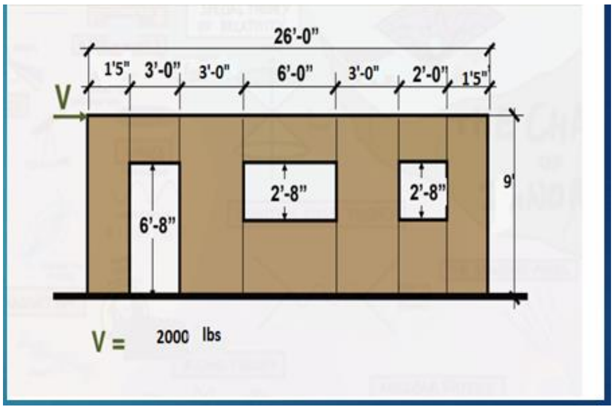

Figure 8: light frame shear wall for perforated shear wall approach

Fig-7 represents the layout for the study of perforated shear wall approach. In this we had prepared the panels according to their respective dimensions and are analyzed for the study of shear forces, shear resistance and shear anchorage manually.

1. Unit shear in the wall
   v = 2000/9 = 222.22 lbs/ft.
2. Percent of Full-Height Sheeted
   9/20 = 0.45 (45%).
3. Maximum opening height
   2H/3 = (2*9)/3 =6 ft.
4. Co – shear Resistance Adjustment Factor
   Co =0.55
5. Adjusted Shear Resistance
   $V_{allowable}$ = 490*0.88*0.55 =237.16 > 222.22 lbs/ft.
6. Uplift at Perforated shear wall ends (hold downs)
   H = (222.22/0.55)*9 =3636.32 lbs.
7. In plane Shear Anchorage
   H = 222.22/0.55 =404.036 plf

III. RESULTS & DISCUSSION

Results for 1st Storey in SAP 2000

From Table I, Table II, Table III, we observed that the assembled joint masses, joint displacements& joint reactions are to be tabulated and at a distance of 5.833mts there is sum accelerated mass source of 2.13 Lb-s2/ft. The joint displacements for the first storey for the linear static condition are obtained as 11.831 radians. The joint reactions for the first storey are obtained as 2500lb.

Table I: Assembled joint masses

Joint	Mass Source	U1	U2	U3	Center X	Center Y	Center Z
Text	Text	Lb-s2/ft	Lb-s2/ft	Lb-s2/ft	Ft	Ft	Ft
1	MSSSRC1	0.44	0.44	0.44	-2	0	0
2	MSSSRC1	0.62	0.62	0.62	-2	0	10
3	MSSSRC1	0.44	0.44	0.44	2	0	0
4	MSSSRC1	0.62	0.62	0.62	2	0	10
Sum Accel UX	MSSSRC1	2.13	0	0	0	0	5.8333
Sum Accel UY	MSSSRC1	0	2.13	0	0	0	5.8333
Sum Accel UZ	MSSSRC1	0	0	2.13	0	0	5.8333

Table II: Joint displacements

Joint	Output Case	Case Type	U1	U2	U3	R1	R2	R3
Text	Text	Text	Ft	Ft	Ft	Rad	Rad	Rad
1	Live	Lin Static	0	0	0	0	11.83	0
2	Live	Lin Static	83.64	0	0.04	0	1.423	0
3	Live	Lin Static	0	0	0	0	11.83	0
4	Live	Lin Static	83.64	0	-0.04	0	1.423	0

Table III: Joint reactions

Joint	Output Case	Case Type	F1	F2	F3	M1	M2	M3
Text	Text	Text	Lb	Lb	Lb	Lb -ft	Lb -ft	Lb -ft
1	Live	Lin Static	-500.01	0	-2500	0	0	0
3	Live	Lin Static	-499.99	0	2500	0	0	0

Results for 2nd Storey in SAP2000 Software

From Table IV, Table V, Table VI, we observed that the assembled joint masses, joint displacements& joint reactions are to be tabulated and at a distance of 10.833mts there is sum accelerated mass source of 4.26 Lb-s2/ft is obtained which will be double the value observed in the case of first storey. The joint displacements for the second storey for the linear static condition are obtained as 18.346 radians.

The joint reactions for the second storey are obtained as 6250lb.

Table IV: Assembled joint masses

Joint	Mass Source	U1	U2	U3	Center X	Center Y	Center Z
Text	Text	Lb-s2/ft	Lb-s2/ft	Lb-s2/ft	Ft	Ft	Ft
1	MSS SRC1	0.44	0.44	0.44	-2	0	0
2	MSS SRC1	1.07	1.07	1.07	-2	0	10
3	MSS SRC1	0.62	0.62	0.62	-2	0	20
4	MSS SRC1	0.44	0.44	0.44	2	0	0
5	MSS SRC1	1.07	1.07	1.07	2	0	10
6	MSS SRC1	0.62	0.62	0.62	2	0	20
Sum Accel UX	MSS SRC1	4.26	0	0	5.207E-17	0	10.8333
Sum Accel UY	MSS SRC1	0	4.26	0	5.207E-17	0	10.8333
Sum Accel UZ	MSS SRC1	0	0	4.26	5.207E-17	0	10.8333

Table V: Joint displacements

Joint	Output Case	Case Type	U1	U2	U3	R1	R2	R3
Text	Text	Text	Ft	Ft	ft	Radians	Radians	Radians
1	Live	Lin Static	0	0	0	0	18.346	0
2	Live	Lin Static	131.464	0	0.114	0	2.734	0
3	Live	Lin Static	166.983	0	0.141	0	0.894	0
4	Live	Lin Static	0	0	0	0	18.346	0
5	Live	Lin Static	131.462	0	-0.114	0	2.734	0
6	Live	Lin Static	166.980	0	-0.141	0	0.894	0

Table VI: Joint reactions

Joint	Output Case	Case Type	F1	F2	F3	M1	M2	M3
Text	Text	Text	Lb	Lb	Lb	Lb-ft	Lb-ft	Lb-ft
1	Live	Lin Static	-750	0	-6250	0	0	0
4	Live	Lin Static	-750	0	6250	0	0	0

Results for 3rd storey in SAP2000 software

From Table VII, Table VIII, Table IX, we observed that the assembled joint masses, joint displacements& joint reactions are to be tabulated and at a distance of 10.833mts there is sum accelerated mass source of 4.26 Lb-s2/ft is obtained which will be double the value observed in the case of first storey. The joint displacements for the second storey for the linear static condition are obtained as 18.346 radians. The joint reactions for the second storey are obtained as 6250lb.

Table VII: Assembled Joint Masses

Joint	Mass Source	U1	U2	U3	Center X	Center Y	Center Z
Text	Text	Lb-s2/ft	Lb-s2/ft	Lb-s2/ft	ft	Ft	Ft
1	MSSSRC1	0.44	0.44	0.44	-2	0	0
2	MSSSRC1	1.07	1.07	1.07	-2	0	10
3	MSSSRC1	1.07	1.07	1.07	-2	0	20
4	MSSSRC1	0.62	0.62	0.62	-2	0	30
5	MSSSRC1	0.44	0.44	0.44	2	0	0
6	MSSSRC1	1.07	1.07	1.07	2	0	10
7	MSSSRC1	1.07	1.07	1.07	2	0	20
8	MSSSRC1	0.62	0.62	0.62	2	0	30
Sum Accel UX	MSSSRC1	6.4	0	0	3.47217	0	15.8333
Sum Accel UY	MSSSRC1	0	6.4	0	3.47217	0	15.8333
Sum Accel UZ	MSSSRC1	0	0	6.4	3.47217	0	15.8333

Table VIII: Joint Displacements

Joint	Output Case	Case Type	U1	U2	U3	R1	R2	R3
Text	Text	Text	Ft	Ft	Ft	Radians	Radians	Radians
1	Live	Lin Static	0	0	0	0	24.644	0
2	Live	Lin Static	177.108	0	0.206	0	3.828	0
3	Live	Lin Static	232.073	0	0.290	0	1.953	0
4	Live	Lin Static	263.848	0	0.316	0	0.927	0
5	Live	Lin Static	0	0	0	0	24.644	0
6	Live	Lin Static	177.107	0	-0.206	0	3.828	0
7	Live	Lin Static	232.072	0	-0.290	0	1.953	0
8	Live	Lin Static	263.845	0	-0.316	0	0.927	0

Table IX: Joint Reactions

Joint	Output Case	Case Type	F1	F2	F3	M1	M2	M3
Text	Text	Text	Lb	Lb	Lb	Lb-ft	Lb-ft	Lb-ft
1	Live	Lin Static	-000.01	0	-11250	0	0	0
5	Live	Lin Static	-999.99	0	11250	0	0	0

Results from STAAD PRO

IBC 2006 SEISMIC LOAD ALONG X-:
*CT= 0.020 CU= 1.400
*TIME PERIODS:
* Ta0.625T =0.121 Tusers =0.000
* TIME PERIOD (T) =0.121
* Cs LIMITS: LOWER = 0.013 UPPER = 2.225
* LOAD FACTOR = -1.000
* DESIGN BASE SHEAR = -1.000*0.480*233.18
= -111.84 KN
IBC 2006 SEISMIC LOAD ALONG X+:
* CT= 0.020 CU= 1.400
* TIME PERIODS:
* Ta0.625T =0.121 Tusers =0.000
* TIME PERIOD (T) =0.121
* Cs LIMITS: LOWER = 0.013 UPPER = 2.225
* LOAD FACTOR = 1.000
* DESIGN BASE SHEAR = 1.000*0.480*233.18
=111.84 KN

From the results obtained from the STAAD PRO, design base shear along X positive and X negative is obtained as 111.84KN for the applied conditions. The maximum displacement is obtained as 128.92mm under the application of live load for node 7.

Table X: Maximum Displacements

Dead Load		Live Load	
Maximum	At Node	Maximum	At Node
X = -1.95180E-03	27	X=1.28929E+02	7
Y=-3.22002E-02	7	Y=1.21391E+01	253
Z=0.00000E+00	0	Z=0.00000E+00	0
RX=00000E+00	0	RX=00000E+00	0
RY=00000E+00	0	RY=00000E+00	0
RZ=-2.72556E-04	1	RZ=-7.52827E-02	7

IV. CONCLUSION

- In SAP2000 analysis we applied lateral forces on each storey and we compared amount of lateral force on each storey with each other and concluded that top storey as more lateral force.
- We observed that the tension and compression values of the 1st storey are 2500 lbs by using software analysis and manual analysis.
- We observed that the tension and compression values of the 2nd storey are 6250 lbs by using software analysis and manual analysis.
- We observed that the tension and compression values of the 3rd storey are 11250 lbs by using software analysis and manual analysis.
- In STAAD analysis we observe that the maximum displacements and deflections by giving seismic load, dead load, and live load to the structure.
- We observed that, maximum displacement is Y=-3.22 at node 7, reaction is RZ=-2.725 at node 1 when dead load is applied to the structure.
- We observed that, maximum displacement is X=1.289 at node 7, reaction is RZ=-7.528 at node 7 when live load is applied to the structure.
- We observed that, manual analysis for segmented approach and perforated shear wall approach the maximum unit shear value is 222.22 lbs/ft.
- From the above results and discussion the shear wall which is to be considered under the study has been observed from Assembled joint masses, Joint displacements, Joint reactions and maximum displacements under the effect of seismic forces by manual check and by using some advanced Finite Element Method of study by using software's like SAP2000 and STAAD PRO.

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