

# Modelling of Reinforced Concrete Structures

## CASE STUDY #2

### Beam Model vs FE Model



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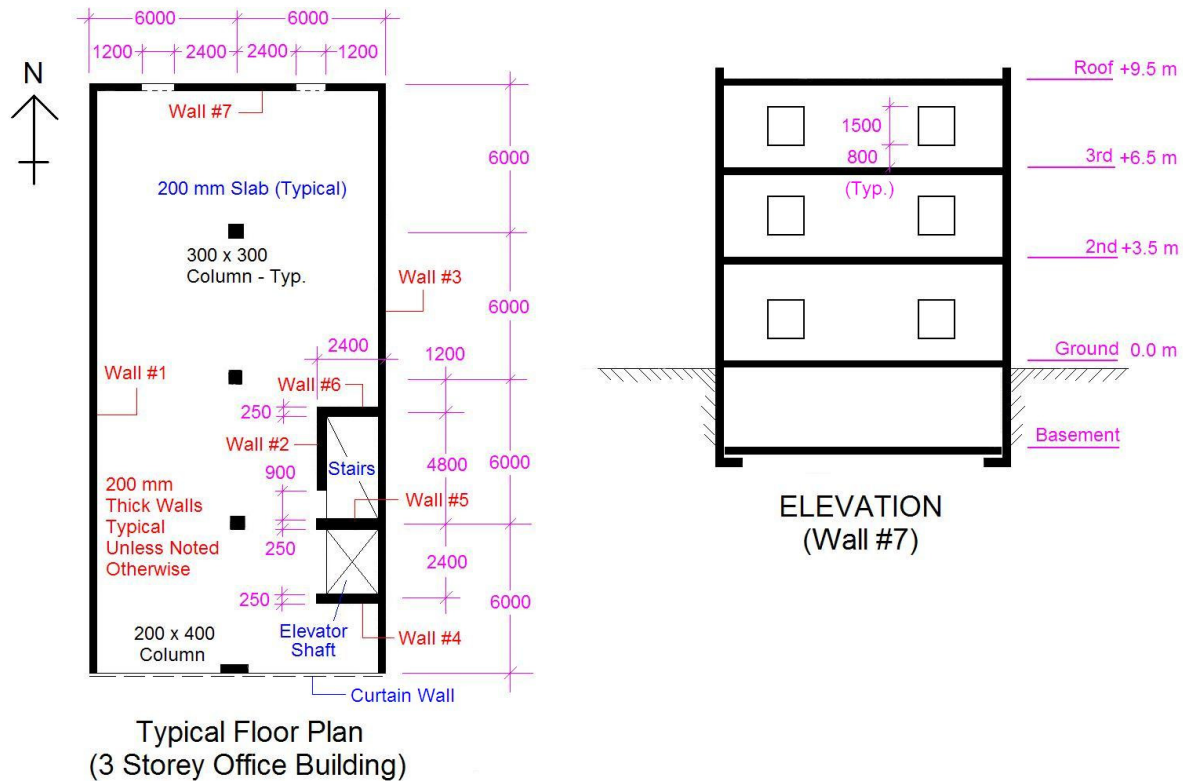
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# CASE STUDY #2

In this study, we will create two S-FRAME<sup>®</sup> models of a three storey office building that has only shear walls in its lateral load resisting system. The first model will consist only of beam type members and the second model will consist only of finite elements – quadrilateral shells. The building will be loaded and the results will be compared.

## Building Description

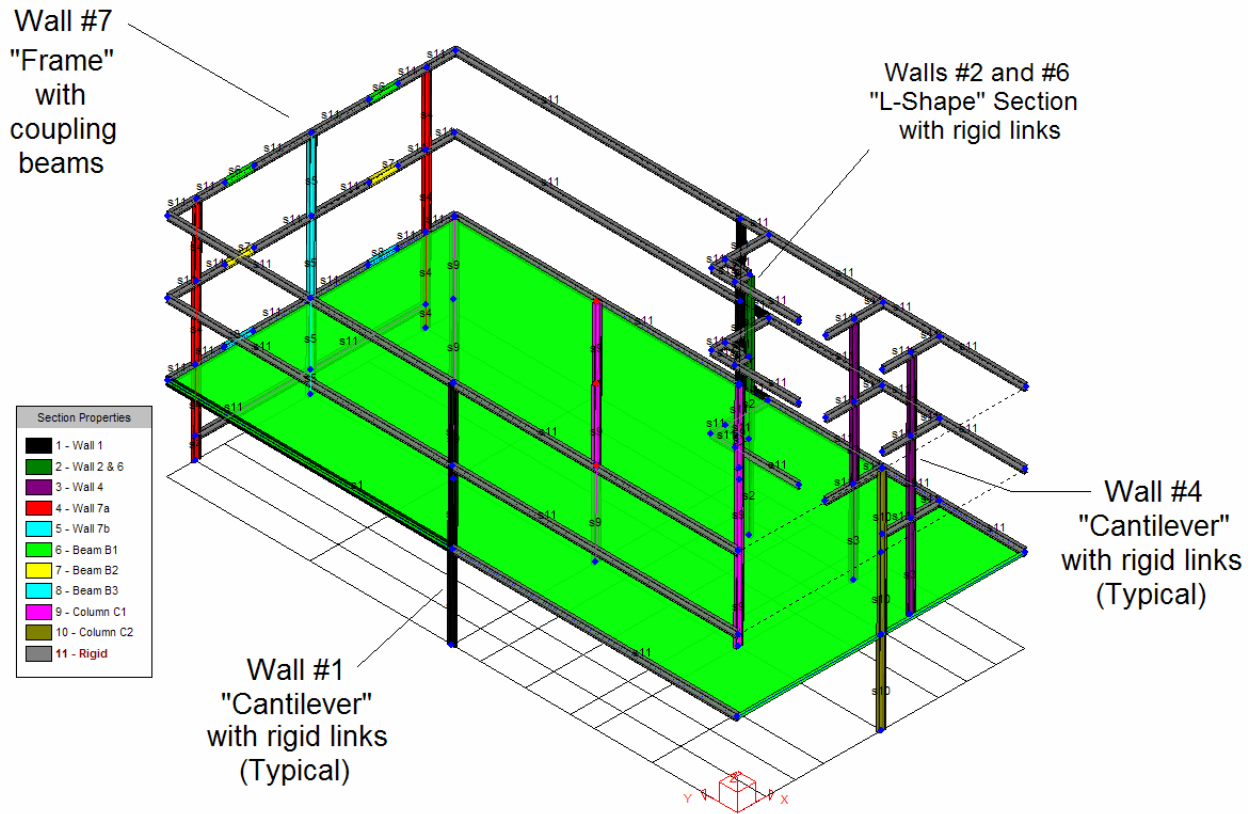


## Distribution of Base Shear, NBCC Clause 4.1.8.11(6)

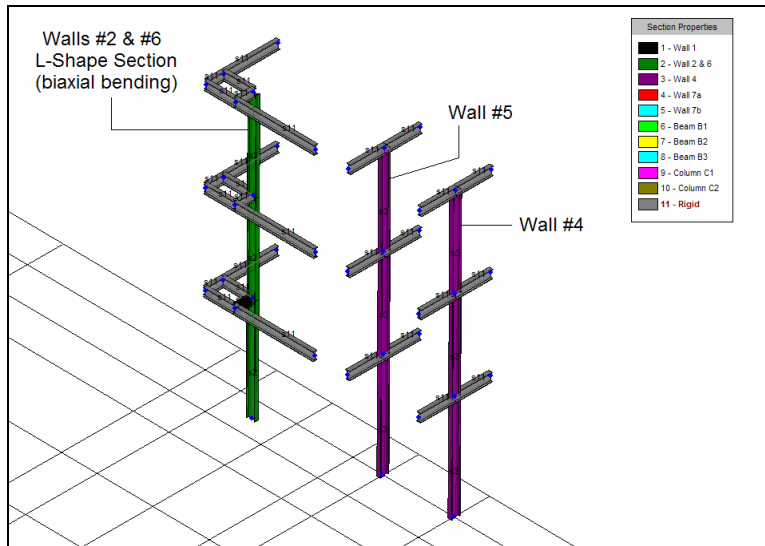
In Case Study #1, the distribution of base shear was computed as follows:

Level	Height $h_x$ (m)	Storey Weight $W_x$ (kN)	$W_x h_x$ (kNm)	Lateral Force $F_x$ (kN)	Storey Shear $V_x$ (kN)
Roof	9.5	2,021	19,199.5	693	693
3	6.5	2,480	16,120	582	1275
2	3.5	2,571	8,998.5	325	1600
		$\Sigma = 7,072$	$\Sigma = 44,318$	$\Sigma = 1600$	

**S-FRAME Model A (using Beam Type Members Only and Rigid Diaphragms)**

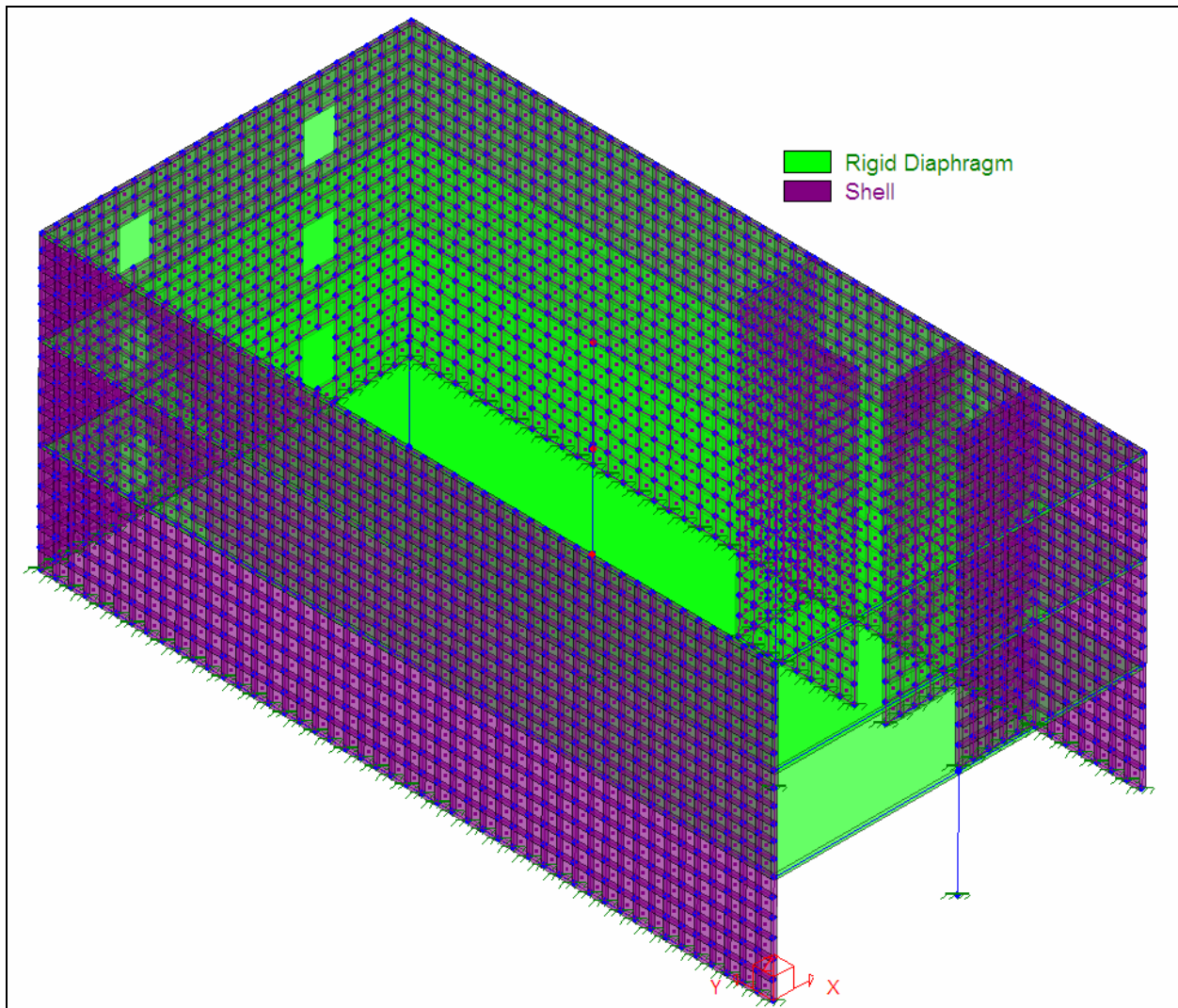


The S-FRAME 3D model of the office building shown here consists only of "beam" type members with rigid diaphragms specified for each floor level. Only the 2<sup>nd</sup> floor diaphragm is displayed above. Section properties for these members may be found in Case Study #1.



Special attention is given to Walls #2 and #6. Walls #2 and #6 is modelled as one column which will be subjected to biaxial bending. The properties of this "column" is given the section properties of an L-Shape (i.e.  $I_x$  and  $I_y$ ). Note that to minimize the amount of torsion that will be attracted to each wall, the torsional constants,  $J$ , for each wall were assigned negligible values.

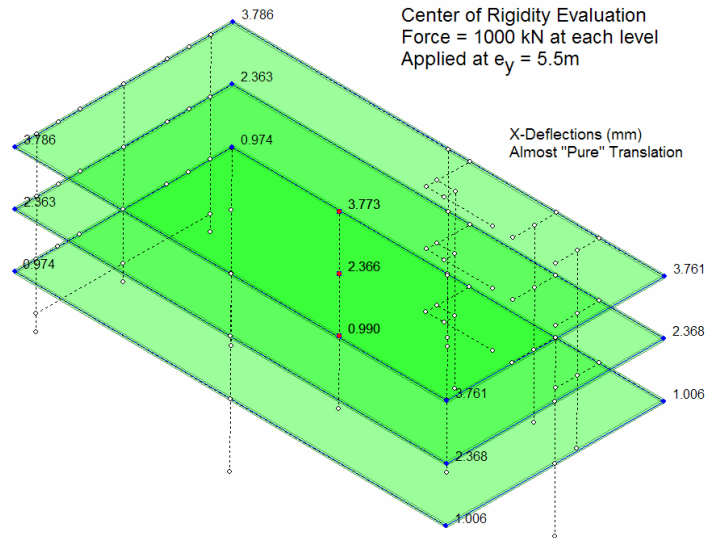
## S-FRAME Model B (using Quadrilateral Shell Elements and Rigid Diaphragms)



In the beam model (A), effective section properties were used. In this case, the effective section properties were equal to approximately “0.62 times” the gross section properties. To generate the equivalent model here using finite elements, the material properties were reduce by the same factor, “0.62”.

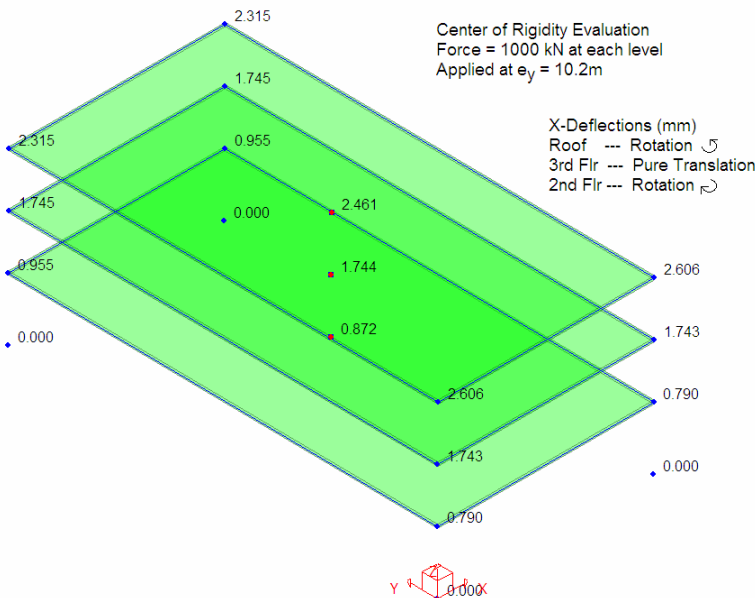
## S-FRAME Model A – Center of Rigidity Evaluation

Using a trial-and-error approach in S-FRAME, we discovered the center of rigidity near  $e_y = 5.5\text{m}$  for this building (as indicated below).



## S-FRAME Model B – Center of Rigidity Evaluation

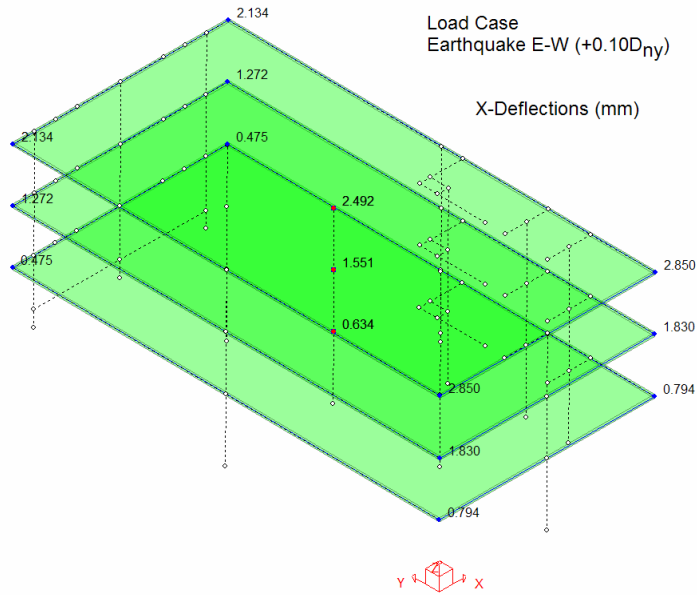
Using a trial-and-error approach in S-FRAME, we discovered the center of rigidity near  $e_y = 10.2\text{m}$  for this building (as indicated below) which is very close to Wall #7.



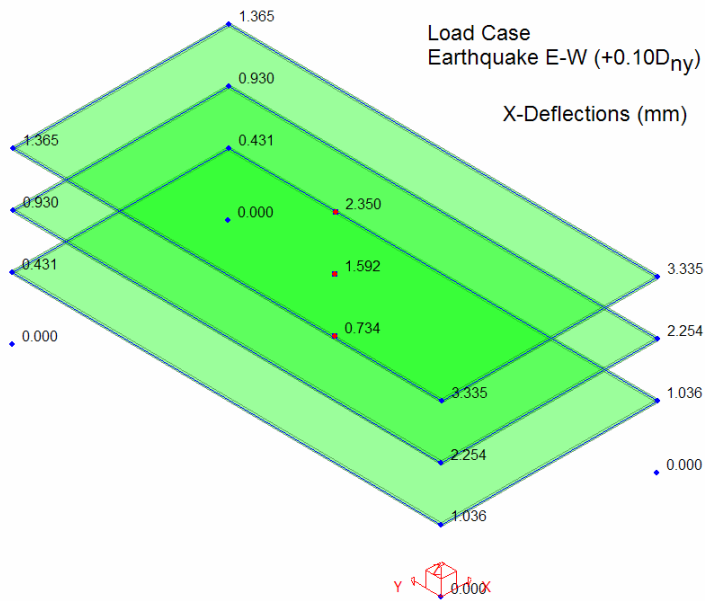
It is interesting to point out that the center of rigidity appears to move from one floor to the next because the 2<sup>nd</sup> Floor and Roof are rotating under these applied loads – in opposite directions. This means that the relative stiffness of each of the walls changes from one floor to the next.

Furthermore, the location of the center of rigidity is much closer to Wall #7 for the FE model (A) as compared to the beam model (B). This means that Wall #7 is relatively much stiffer in the FE model as compared to the beam model. The overall deflections in the FE model are also much smaller as compared to those in the beam model.

**S-FRAME Model A – Deflections for Load Case E-W (+0.10D<sub>ny</sub>)**

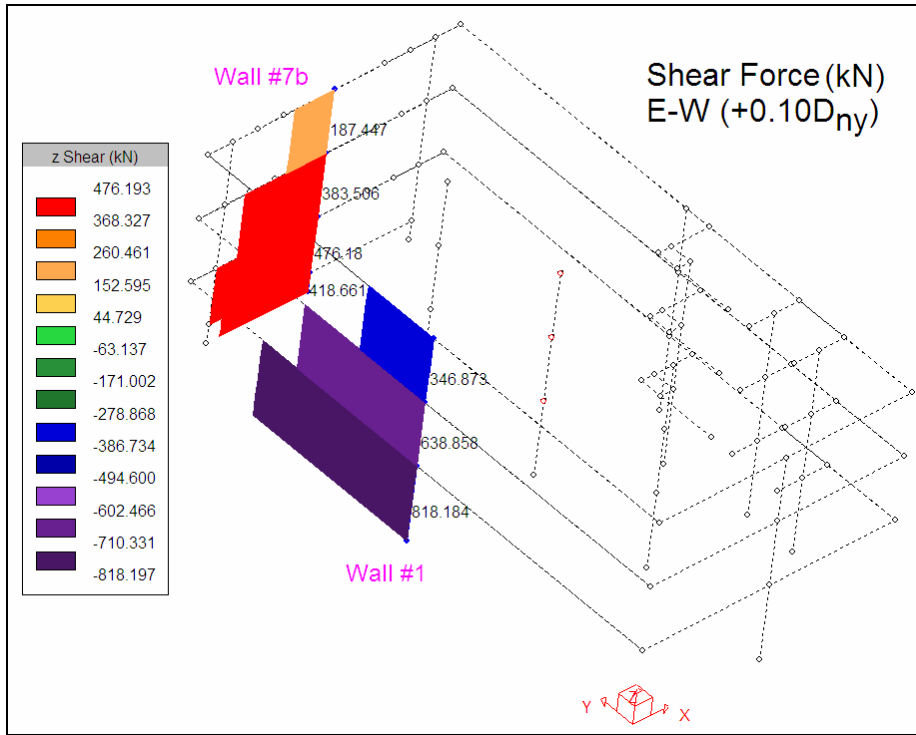


**S-FRAME Model B – Deflections for Load Case E-W (+0.10D<sub>ny</sub>)**

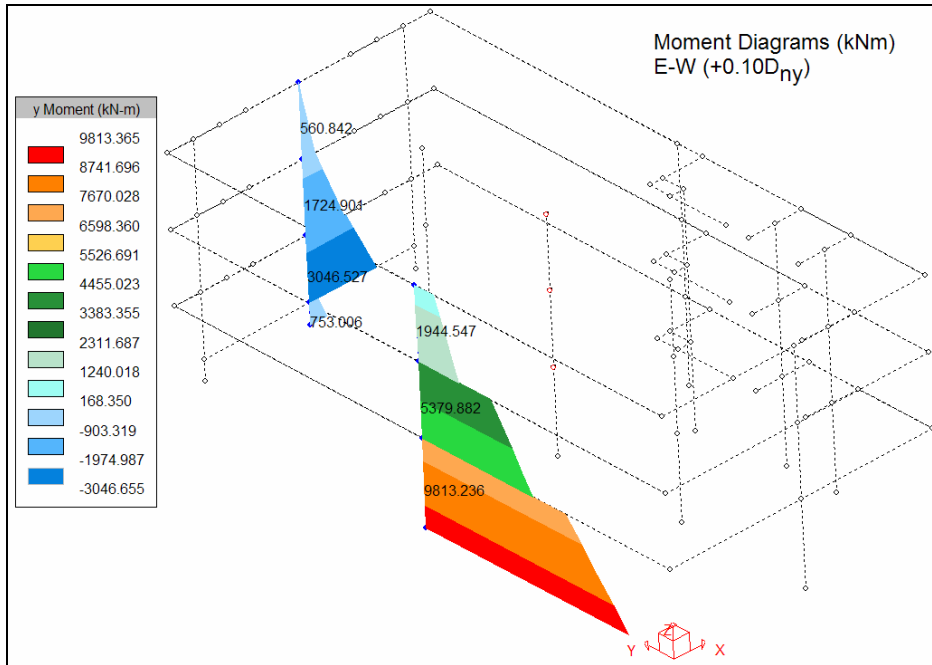


When comparing the results of the two models, Model B is twisting a significantly more than Model A for the same loading conditions. Eventhough Model B (FE) is more stiff than Model A (beams), Model B is more sensitive to torsional loading because of its larger eccentricity in the y-direction ( $e_y = 10.2\text{m}$ ).

**S-FRAME Model A – Shear Force Diagrams for Load Case E-W (+0.10D<sub>ny</sub>)**

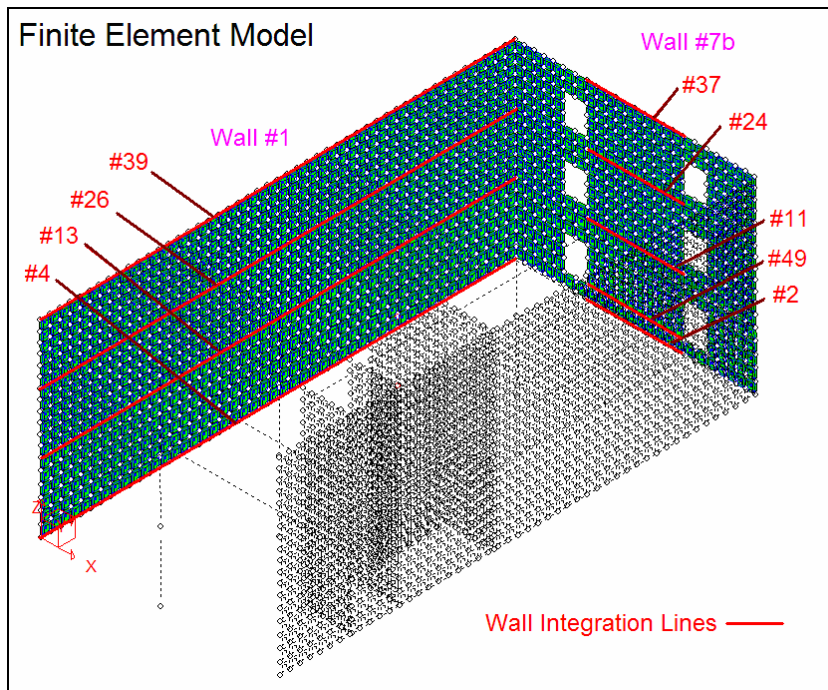


**S-FRAME Model A – Moment Diagrams for Load Case E-W (+0.10D<sub>ny</sub>)**



## S-FRAME Model B – Wall Integration Lines

S-FRAME has the capability to integrate the finite element stresses along a given wall integration line to generate sectional forces. The following “Wall Integration Lines” have been defined for Wall #1 and Wall #7b in Model B.



### Numerical Results – Wall Forces

Wall No	Ld Case No	Fx Below kN	Fz Below kN	My Below kN-m	Fx Above kN	Fz Above kN	My Above kN-m
2	1	0.0000	0.0000	0.0000	408.3932	6.0729	872.9527
49	1	408.3932	6.0729	634.7233	509.7126	6.4867	958.3414
11	1	327.1309	4.8997	175.0152	408.1684	4.6962	467.4458
24	1	343.6110	2.9336	-61.2465	272.8140	2.4181	179.5129
37	1	238.1582	0.4041	-123.4017	0.0000	0.0000	0.0000
4	1	0.0000	0.0000	0.0000	961.5495	304.4491	12,945.2139
13	1	966.7015	202.5519	8,346.2188	1,123.7723	185.7966	8,145.1543
26	1	1,125.8951	91.4022	3,637.0574	846.3495	76.7147	3,460.8062
39	1	846.9073	4.9983	59.9791	0.0000	0.0000	0.0000

Wall #7b

Wall #1

Shear   
  Axial   
  Moment  
 (Below Line)

Shear   
  Axial   
  Moment  
 (Above Line)

Note: Sectional forces generated by “Wall Integration Lines” in S-FRAME can be directly exported to S-CONCRETE I-Shapes.

## **S-FRAME Model A versus Model B – Sectional Forces**

Wall #7b				
Level	Model A – Shear (kN)	Model B – Shear (kN)	Model A – Moment (kNm)	Model B – Moment (kNm)
3 <sup>rd</sup>	187	273	561	180
2 <sup>nd</sup>	384	344	1725	467
1 <sup>st</sup>	476	510	3047	958

For Wall #7b, there's a very large difference in the computed bending moments (at all levels) but the shear forces are approximately the same.

Wall #1 (Squat Wall)				
Level	Model A – Shear (kN)	Model B – Shear (kN)	Model A – Moment (kNm)	Model B – Moment (kNm)
3 <sup>rd</sup>	347	847	1945	3461
2 <sup>nd</sup>	639	1126	5380	8145
1 <sup>st</sup>	818	967	9813	12,945

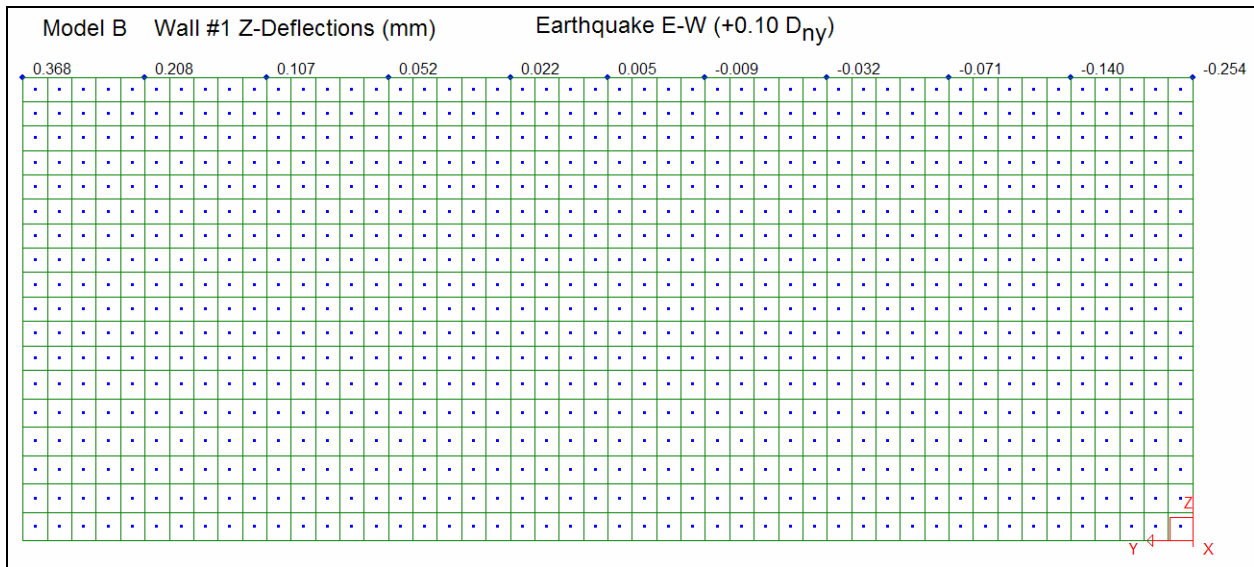
For Wall #1, there's a significant difference in the computed shear forces and bending moments – at all levels. Shear in Model B appears to be constant along the entire height of the wall.

### **Conclusions**

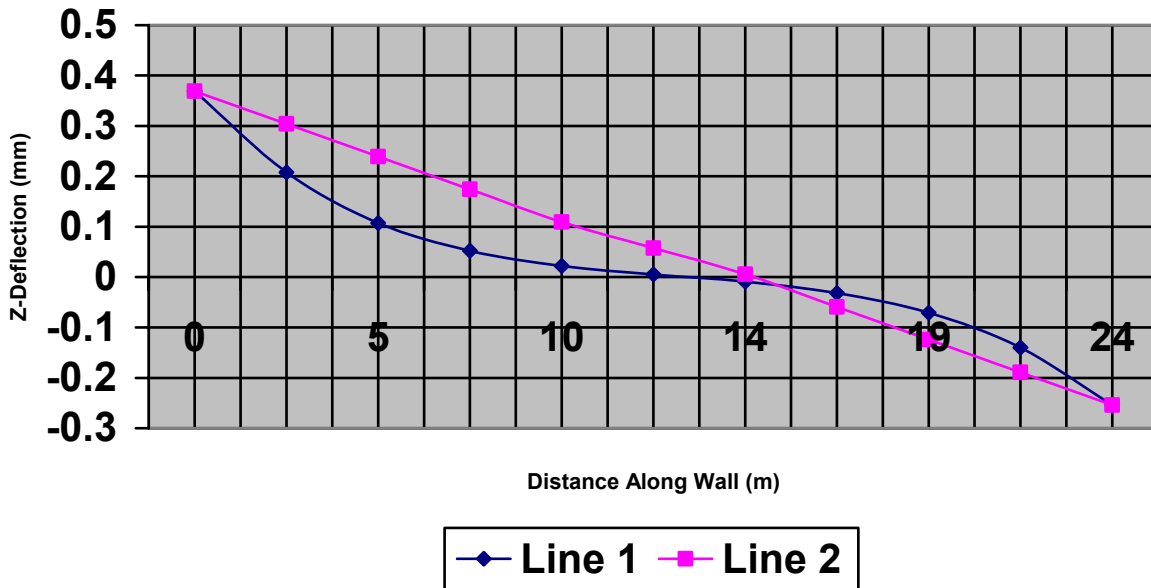
There appears to be significant differences in results between the two models. The difference in stiffnesses in the two models may account for some of these differences in terms of how the lateral loads are distributed among the lateral load resisting elements. However, it cannot account for all the differences. For Wall #7, using rigid links between window openings (“coupled-wall system”) in Model A may have “artificially” forced the wall to deflect in a flexural manner because of the underlying theory behind beam type members.

When using “beam theory”, the basic assumption in this theory is that plane sections remain plane. Model A uses beams to model walls that have height to width ( $h_w/L_w$ ) ratios approximately equal to 2.0 (Wall #7b) and much less than 2.0 (Wall #1). In fact, the window openings in Wall #7 appear to have little influence on its behaviour. For such walls (#7 & #1), using beams to model the behaviour may not be appropriate. Overall, Model B probably generates reasonable and more accurate design forces and moments as compared to Model A – especially when for certain walls, beam theory does not apply.

A plot of the vertical deflections at the top of Wall #1 will indicate how the wall is behaving in Model B (FE). The plot is displayed below.



Wall #1 - Vertical Deflections



“Line 1” represents the vertical deflections at the top of Wall #1 (results from S-FRAME).  
 “Line 2” represents the vertical deflections assuming that plane sections remain plane.  
 Clearly “beam theory” does not apply to Wall #1 (squat wall).

The purpose of this case study is to alert the reader that significant differences may arise between models. S-FRAME has the ability to generate these models but the engineer must exercise reasonable judgment when generating models and interpreting the results.