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Seismic Analysis of Multistoried Building

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Abstract— The effective design and the construction of earthquake resistant structures have much greater importance in all over the world. In this paper, the earthquake response of symmetric multistoried building is studied by manual calculation and with the help of ETABS 9.7.1 software. The method includes seismic coefficient method as recommended by IS 1893:2002. The responses obtained by manual analysis as well as by soft computing are compared. This paper provides complete guide line for manual as well s software analysis of seismic coefficient method.

***Index Terms*—earthquake, manual calculation, ETABS 9.7.1, IS 1893:2002**

I. INTRODUCTION

ETABS is the present day leading design software in the market. Many design company's use this software for their project design purpose. So, this paper mainly deals with the comparative analysis of the results obtained from the analysis of a multi storey building structure when analyzed manually and using ETABS software separately. In this case, a 22.5m x 22.5m, 8 storey structure is modeled using ETABS software. The height of each storey is taken as 3meter making the total height of the structure 24 meter. Analysis of the structure is done and then the results generated by this software are compared with manual analysis of the structure using IS 1893:2002.

II. PROBLEM DEFINATION

A. Case

A 22.5m x 22.5 m, 8 storey multi storey regular structure is considered for the study. Storey height is 3m. Modeling and analysis of the structure is done on ETABS software.

B. Preliminary Data

Length x Width	22.5m x 22.5m
No. of Storey's	8 (G+7)
Beam	250 mm x 400 mm
Columns	400 mm x 500 mm
Slab thickness	150 mm
Support Condition	Fixed
Thickness External Wall	120mm
Grade of Concrete and steel	M20 and Fe415
Length of each bay	7.5m

C. Loading Consideration

Loads acting on the structure are dead load (DL), Live Load (IL) and Earthquake Load (EL) DL: Self weight of the structure, Floor load and Wall loads

- LL: Live load 3KN/m^2 is considered
- Seismic: Zone: III
- Zone Factor: 0.16
- Soil type: II
- Response reduction factor: R=3
- Importance factor: 1
- Damping: 5%
- Time period: 0.427 sec (calculated as per IS 1893: 2002)

III. ACTUAL ANALYSIS

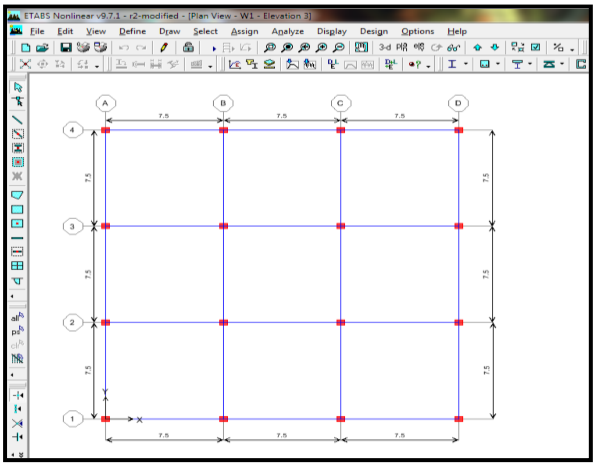

Fig 1: Plan of the structure (ETABS model) (Ref.6)

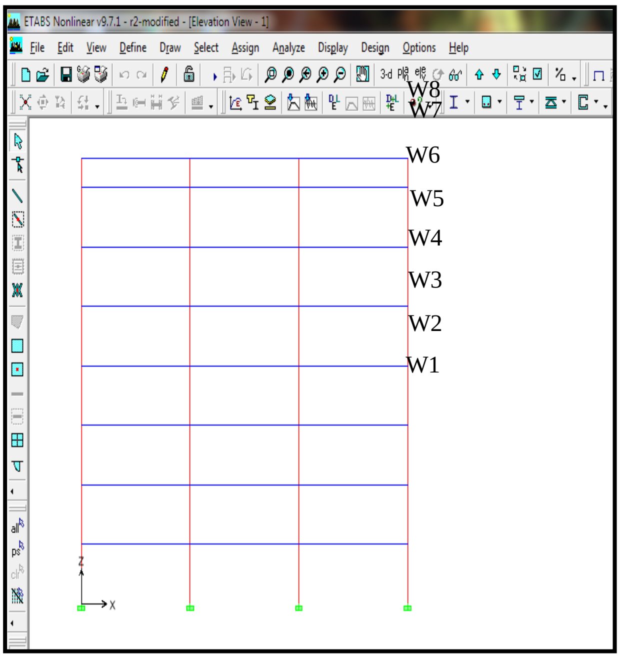

Fig 2: Elevation of structure (ETABS model)

A. Dead Load (D. L.) per floor

Items	SIZE(LBH) m3	No.	Density(kN/ m3)	Dead Load (kN)
Beam	0.25×0.4×7.5	24	24	432
Column	0.5×0.4×3	16	24	230.4
Slab	22.5×22.5× 0.15	1	24	1822.5
Wall	22.5×0.12×3	4	20	648
			SUM	3132.9

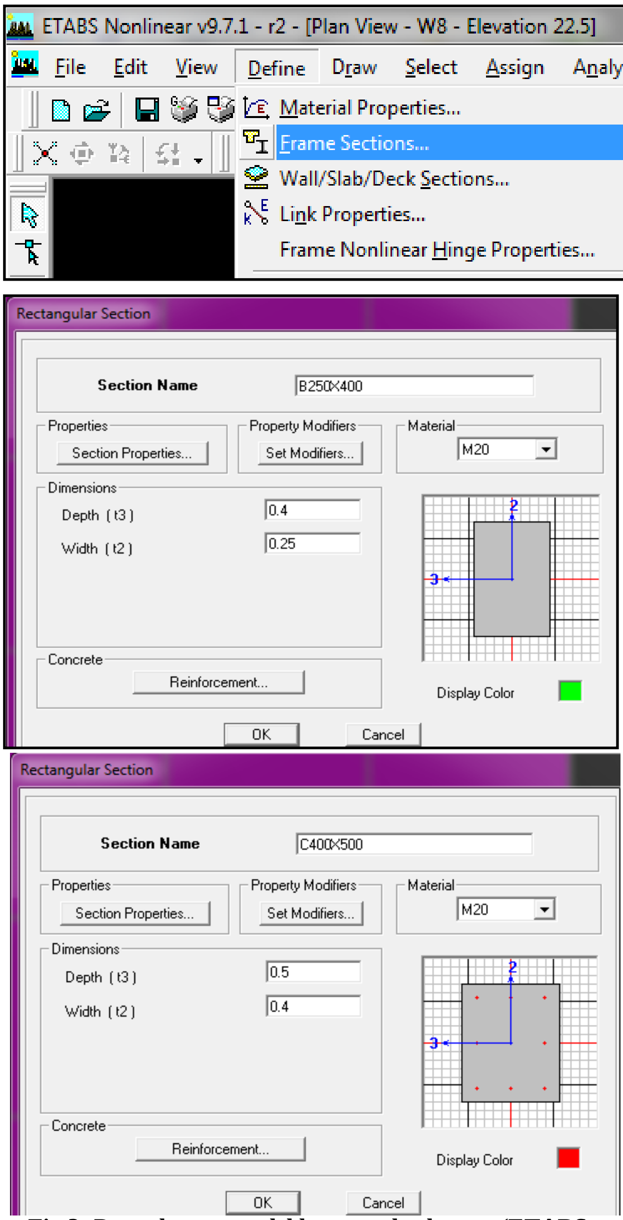

Fig 3: Procedure to model beam and columns. (ETABS model) (Ref.6)

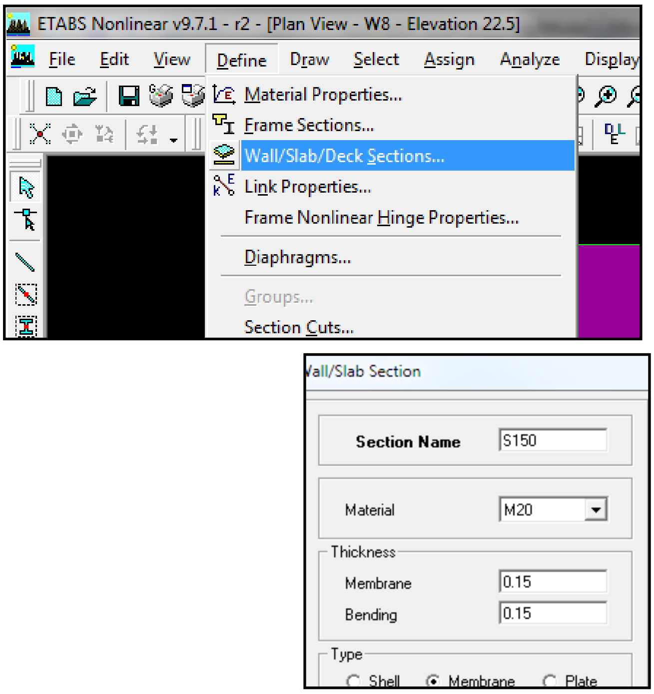

Fig 4: Procedure to model slab (ETABS model)

B. UDL due to wall:

Wall is not modulated only UDL is due to wall on beam is considered.

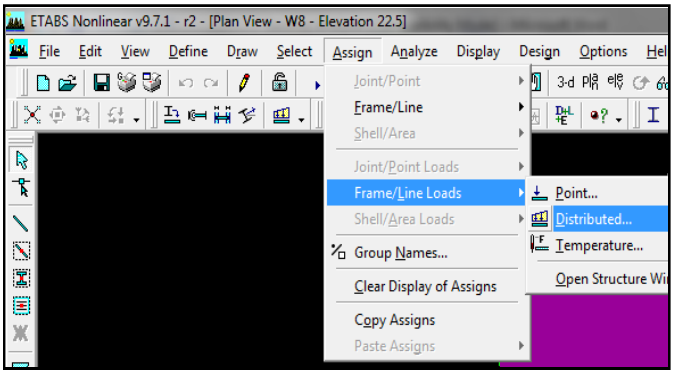

Fig 5: Procedure to assign UDL to beam (ETABS model) (Ref.6)

UDL OF WALL = 0.12(thickness) × 3(height of wall) ×20 (brick density) = 7.2 kN/m

C. Live load on floor area

As mentioned in II.C, Live load is considered 3kN/m^2 on each floor. Each floor has dimension 22.5m x 22.5m.
Live load on each floor is

3x22.5x22.5 = 1518.75 KN

As per IS 1893:2002 (pg no. 24) Clause no. 7.3.1, Table no.8, only 25% live load is considered in seismic weight calculations.

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Volume 4, Issue 9, March 2015

25% of live load = 0.25x 1518.75 = 379.6875 KN.

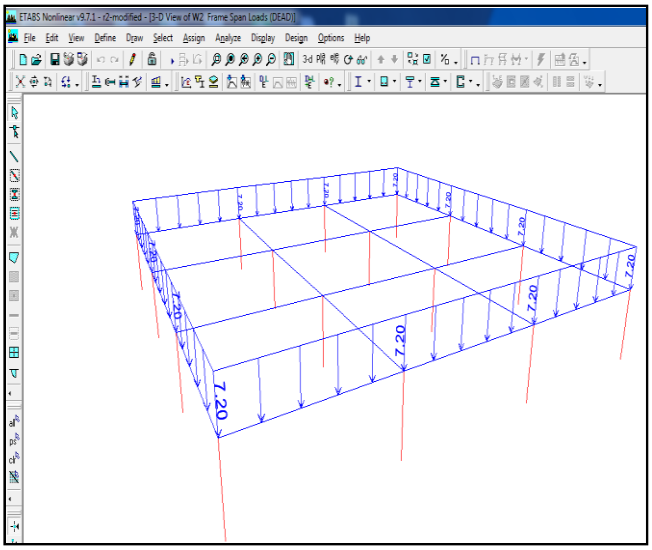


Fig 6: 7.2kN/m UDL applied to beam on each floor

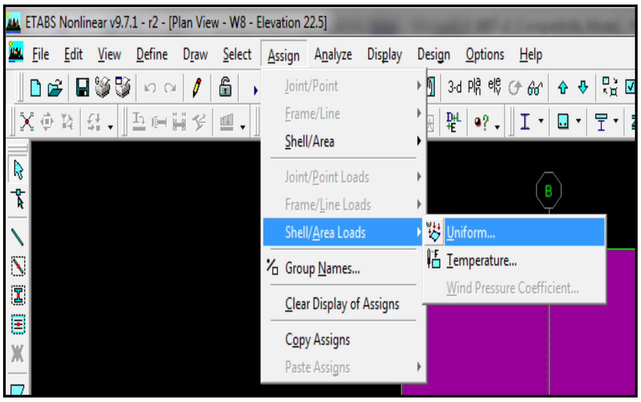


Fig 7: Procedure to assign live load on floor

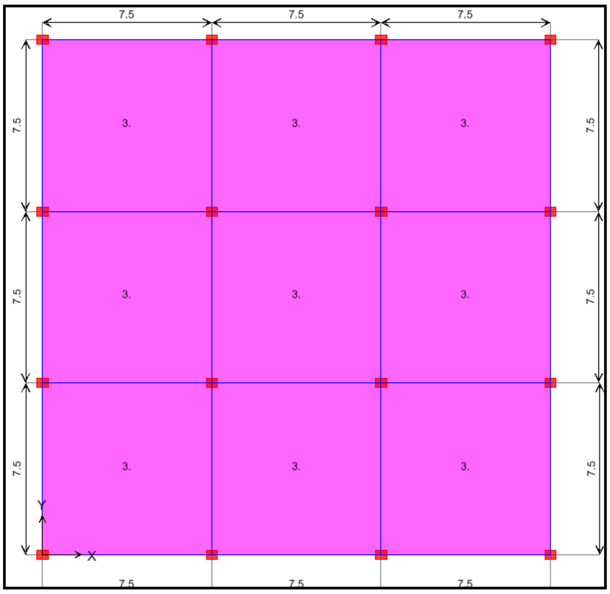
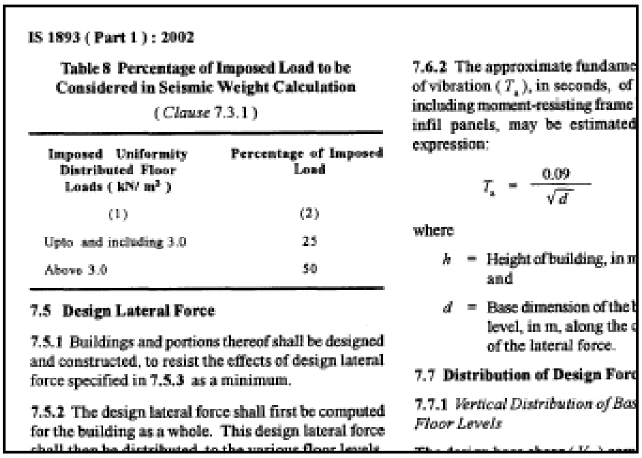


Fig 8: Applied live load on each floor (3 kN/m^2)



IS 1893 (Part 1) : 2002

Table 8 Percentage of Imposed Load to be Considered in Seismic Weight Calculation
(*Clause* 7.3.1)

Imposed Uniformity Distributed Floor Loads (kN/ m²)	Percentage of Imposed Load
(1)	(2)
Upto and including 3.0	25
Above 3.0	50

7.5 Design Lateral Force

7.5.1 Buildings and portions thereof shall be designed and constructed, to resist the effects of design lateral force specified in 7.5.3 as a minimum.

7.5.2 The design lateral force shall first be computed for the building as a whole. This design lateral force shall then be distributed to the various floor levels

7.6.2 The approximate fundame of vibration (T_a), in seconds, of including moment-resisting frame infill panels, may be estimated expression:

$$T_a = \frac{0.09}{\sqrt{d}}$$

where

h = Height of building, in m and

d = Base dimension of the b level, in m, along the d of the lateral force.

7.7 Distribution of Design Forc

7.7.1 *Vertical Distribution of Bas Floor Levels*

Fig 9: Live load reduction clause as per IS 1893:2000 (Ref.5)

D. Load combination

As per IS 1893:2000, the load combination Dead load + Live Load becomes,

DL + 25% LL.

DL = 3132.9, 25% LL = 379.687

DL+ 25% LL = 3572.5875 kN per each floor.

This live load reduction is defined by a command mass source in ETABS 7.1.

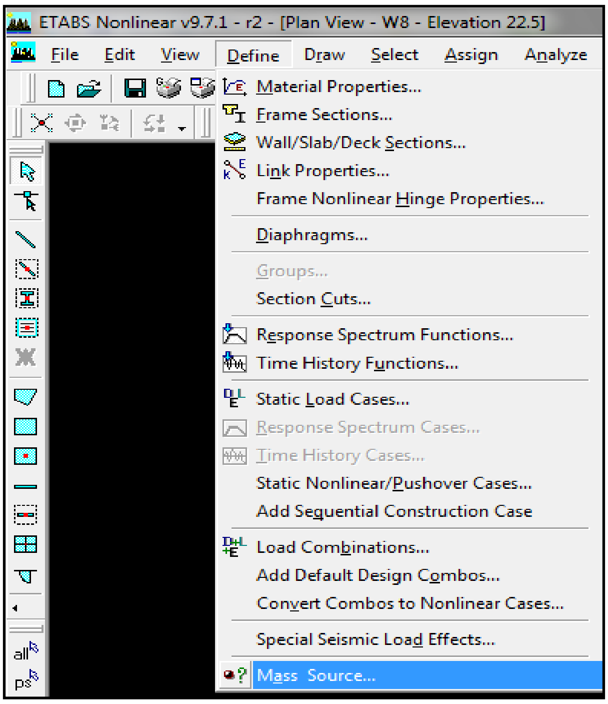


Fig 10: Procedure to define Mass Source (ETABS model) (Ref.6)

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International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 9, March 2015

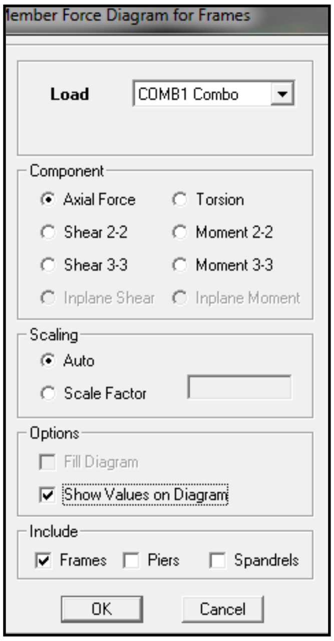


Fig 11: Actual Mass Source window in ETABS (Ref.6)

E. Seismic weight calculation of building

As per III, C

W1=W2=W3=W4=W5=W6=W7= 3512.5875 kN.

Lumped mass at roof floor.

In the calculation of seismic weight, for the terrace floor 50% of the weight is considered for walls and columns.

W8 = 432 + (230.4 / 2) + 1822.5 + (648 / 2)

= 2693.7 kN.

Total weight (W) = (3512.587 x 7) + 2693.7

= 27281.8125 kN.

Now the seismic weight obtain in ETABS software is as shown below.

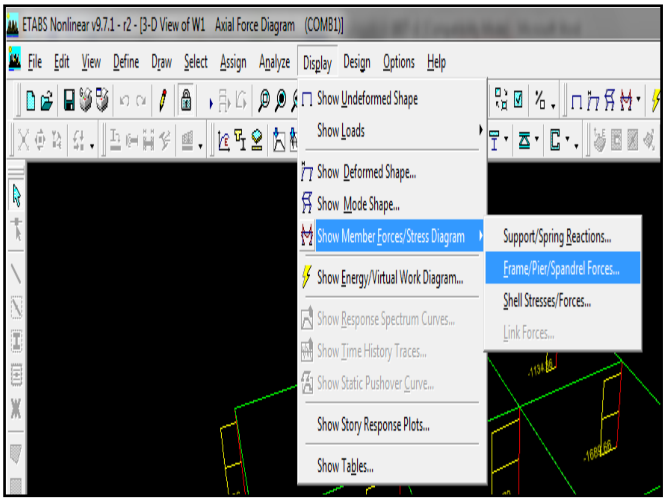


Fig 12: Procedure to display axial loads in columns (ETABS model) (Ref.6)

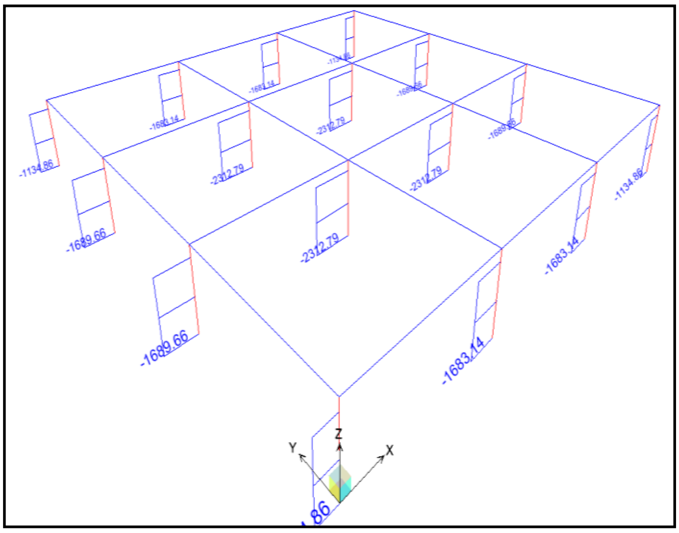
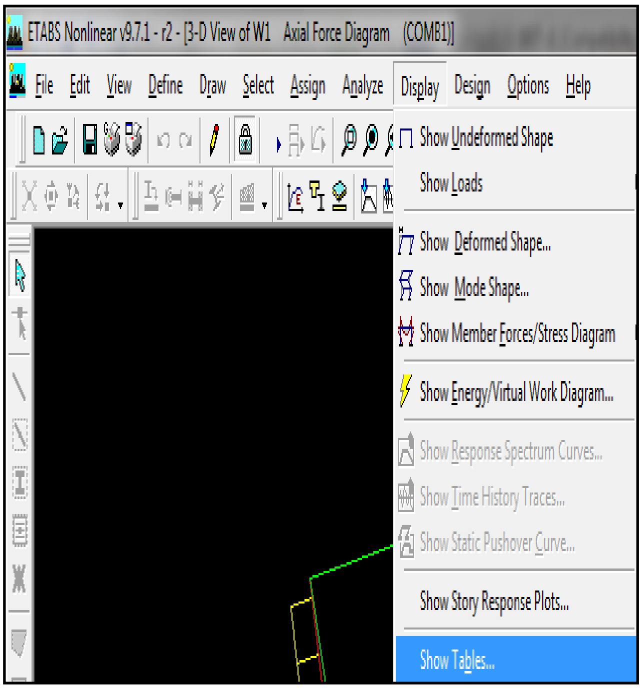


Fig 13: Axial load in each column of first floor(W1) (ETABS model) (Ref.6)

Now the algebraic sum of all the axial forces gives seismic weight of the complete building. The same values can be obtained in the table form and facility of exporting these values in excel is available in ETABS that algebraic sum and other any mathematical calculations can be simplified in excel. The procedure of exporting these values in ETABS is explained as below in four steps.

Step 1



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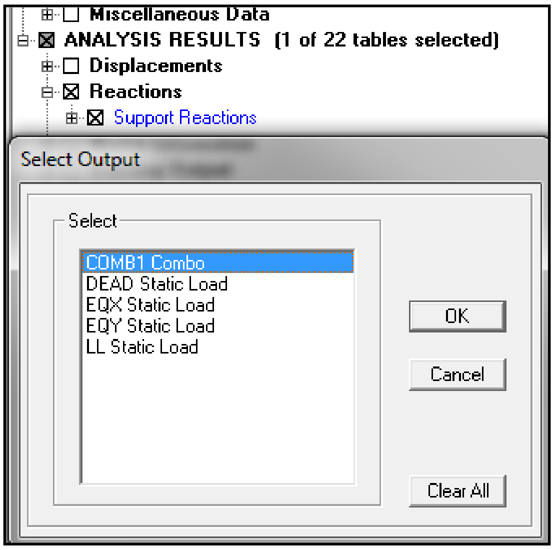
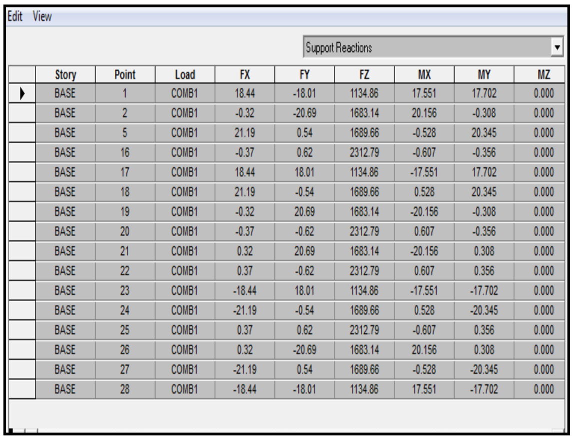
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 9, March 2015

Step 2



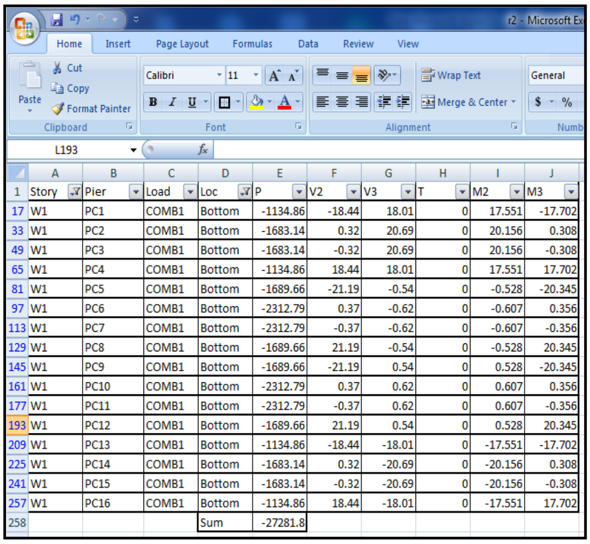
Step 3



Support Reactions

Story	Point	Load	FX	FY	FZ	MX	MY	MZ
BASE	1	COMB1	18.44	-18.01	1134.86	17.551	17.702	0.000
BASE	2	COMB1	-0.32	-20.69	1683.14	20.156	-0.308	0.000
BASE	5	COMB1	21.19	0.54	1689.66	-0.528	20.345	0.000
BASE	16	COMB1	-0.37	0.62	2312.79	-0.607	-0.356	0.000
BASE	17	COMB1	18.44	18.01	1134.86	-17.551	17.702	0.000
BASE	18	COMB1	21.19	-0.54	1689.66	0.528	20.345	0.000
BASE	19	COMB1	-0.32	20.69	1683.14	-20.156	-0.308	0.000
BASE	20	COMB1	-0.37	-0.62	2312.79	0.607	-0.356	0.000
BASE	21	COMB1	0.32	20.69	1683.14	-20.156	0.308	0.000
BASE	22	COMB1	0.37	-0.62	2312.79	0.607	0.356	0.000
BASE	23	COMB1	-18.44	18.01	1134.86	-17.551	-17.702	0.000
BASE	24	COMB1	-21.19	-0.54	1689.66	0.528	-20.345	0.000
BASE	25	COMB1	0.37	0.62	2312.79	-0.607	0.356	0.000
BASE	26	COMB1	0.32	-20.69	1683.14	20.156	0.308	0.000
BASE	27	COMB1	-21.19	0.54	1689.66	-0.528	-20.345	0.000
BASE	28	COMB1	-18.44	-18.01	1134.86	17.551	-17.702	0.000

Step 4



	Story	Pier	Load	Loc	P	V2	V3	T	M2	M3
17	W1	PC1	COMB1	Bottom	-1134.86	-18.44	18.01	0	17.551	-17.702
33	W1	PC2	COMB1	Bottom	-1683.14	0.32	20.69	0	20.156	0.308
49	W1	PC3	COMB1	Bottom	-1683.14	-0.32	20.69	0	20.156	-0.308
65	W1	PC4	COMB1	Bottom	-1134.86	18.44	18.01	0	17.551	17.702
81	W1	PC5	COMB1	Bottom	-1689.66	-21.19	-0.54	0	-0.528	-20.345
97	W1	PC6	COMB1	Bottom	-2312.79	0.37	-0.62	0	-0.607	0.356
113	W1	PC7	COMB1	Bottom	-2312.79	-0.37	-0.62	0	-0.607	-0.356
129	W1	PC8	COMB1	Bottom	-1689.66	21.19	-0.54	0	-0.528	20.345
145	W1	PC9	COMB1	Bottom	-1689.66	-21.19	0.54	0	0.528	-20.345
161	W1	PC10	COMB1	Bottom	-2312.79	0.37	0.62	0	0.607	0.356
177	W1	PC11	COMB1	Bottom	-2312.79	-0.37	0.62	0	0.607	-0.356
193	W1	PC12	COMB1	Bottom	-1689.66	21.19	0.54	0	0.528	20.345
209	W1	PC13	COMB1	Bottom	-1134.86	-18.44	-18.01	0	-17.551	-17.702
225	W1	PC14	COMB1	Bottom	-1683.14	0.32	-20.69	0	-20.156	0.308
241	W1	PC15	COMB1	Bottom	-1683.14	-0.32	-20.69	0	-20.156	-0.308
257	W1	PC16	COMB1	Bottom	-1134.86	18.44	-18.01	0	-17.551	17.702
258				Sum	-27281.8					

Fig 14: Procedure to export axial force of column in excel

Seismic weight obtained from ETABS = 27281.8 kN.

IV. ANALYSIS FOR BASE SHEAR

A. Design Seismic Base Shear

As per IS 1893:2002, Page No. 24, The total design lateral force or design seismic base Shear (VB) along any principal direction shall be determined by the following expression:

$$V_B = A_h \times w$$

Where, ……(Ref.5)

Ah = Design horizontal acceleration spectrum Value as per Clause 6.4.2, using the fundamental natural period T, as per Clause 7.6 in the considered direction of vibration, and

w = Seismic weight of the building as per Clause 7.4.2.

As per IS 1893:2002, Clause 6.4.2, Page No. 14,

$$A_h = \frac{Z}{2} x \frac{I}{R} x \frac{S_a}{g}$$

Where, ……(Ref.5)

Z =0.16, As per IS 1893:2002, Table No.2 and ANNEX E, Zone Factor for IIIrd zone.

I= 1, As per IS 1893:2002, Table No.6, Importance factor, It is depends on the functional use of the structure.

R= 3, As per IS 1893:2002, Table No.7, Response reduction factor.

Sa/g = Average response acceleration coefficient.

The value of average response acceleration coefficient is determined from the graph given on page no.16 of IS 1893:2002.

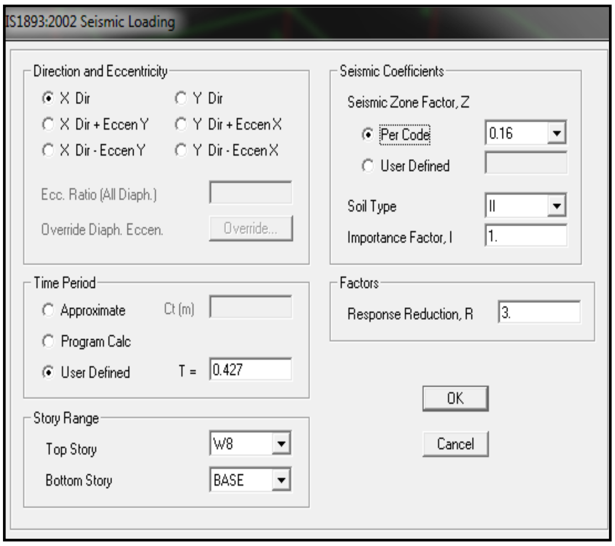


Fig 15: Graph Sa/g Vs. Time period. (Ref.5)

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International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 9, March 2015

For determination of average response acceleration coefficient, it is required to calculate time period.
As per IS 1893:2002, Page No.7, time period T is given by

$$T_a = \frac{0.09H}{\sqrt{d}}$$

Where, …..(Ref.5)
H= Height of the building in meter. = 24 m
Note: As per IS 1893:2002 for the terrace floor, half of the total load is considered for walls and columns. So while modeling in ETABS, top story height is modeled 1.5m while height of other stories is 3m. So in ETABS model H = 22.5m
d=Base dimension of the building in meter = 22.4 m
T_a = 0.455 sec.

T_a = 0.427 sec.(In case of ETABS)

From the graph as shown in Fig. 12.

Sa/g = 2.5.

Now Design horizontal acceleration spectrum Value can be calculated.

$$A_h = \frac{0.16}{2} x \frac{1}{3} x\ 2.5 = 0.0667$$

Now base shear

$V_B = A_h$ x w = 0.0667 x 27281.8125

VB = 1819.696 kN.

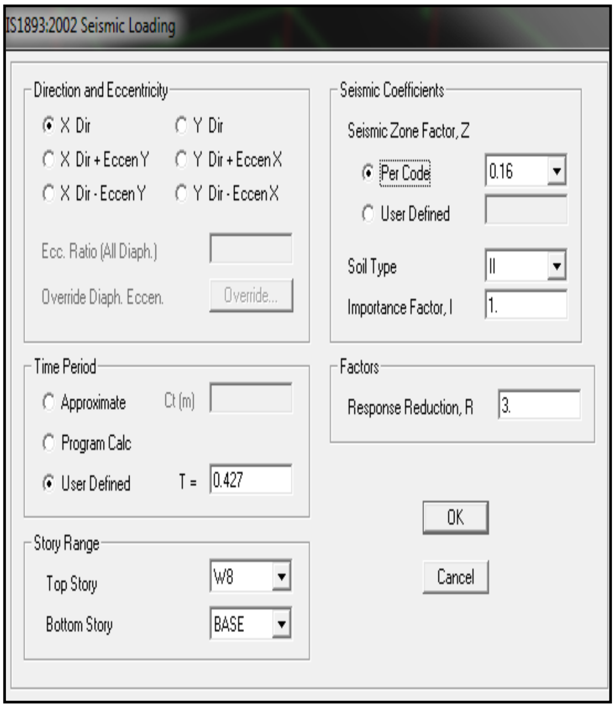
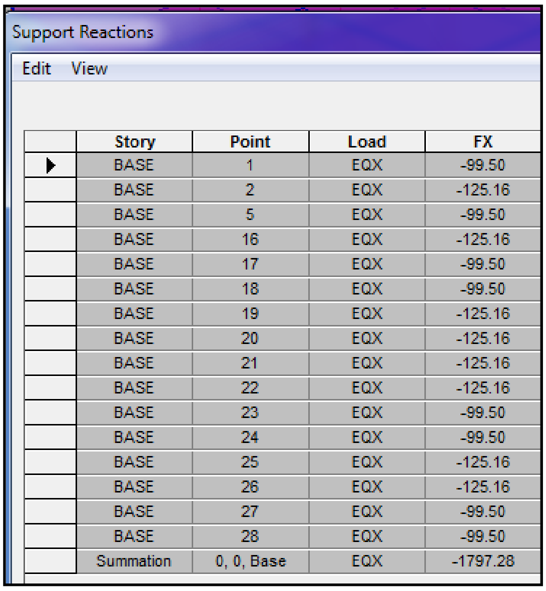


Fig 16: Window of ETABS showing IS 1893:2000 inputs Time Period, Zone factor, Soil factor, response reduction factor. (Ref.6)



Story	Point	Load	FX
BASE	1	EQX	-99.50
BASE	2	EQX	-125.16
BASE	5	EQX	-99.50
BASE	16	EQX	-125.16
BASE	17	EQX	-99.50
BASE	18	EQX	-99.50
BASE	19	EQX	-125.16
BASE	20	EQX	-125.16
BASE	21	EQX	-125.16
BASE	22	EQX	-125.16
BASE	23	EQX	-99.50
BASE	24	EQX	-99.50
BASE	25	EQX	-125.16
BASE	26	EQX	-125.16
BASE	27	EQX	-99.50
BASE	28	EQX	-99.50
Summation	0, 0, Base	EQX	-1797.28

Fig 17: Window of ETABS base shear value V_b (1797.28 kN) in ETABS. (Ref.6)

B. Vertical Distribution of Base Shear to Different Floor Levels:

The design base shear V_B shall be distributed long the height of the building as per following equation

$$Q_i = V_B\, x \frac{W_i\ h_i^{\ 2}}{\sum_{j=1}^{n} W_i\ h_i^{\ 2}}$$

….(Ref.5)

Where,

Q_i = Design lateral force at floor ***i***,

W_i = Seismic weight of floor i,

h_i = Height of floor ***i*** measured from base, and

n = Number of storeys in the building is the number of levels at which the masses are located.

Floor	Height (Meter)	Wi hi^2	Q	Base Shear
W1	3	31613.29	9.624	1819.69
W2	6	126453.15	38.5	1810.07
W3	9	284519.59	86.62	1771.57
W4	12	505812.6	153.98	1684.95
W5	15	790332.19	240.6	1530.97
W6	18	1138078.3	346.46	1290.37
W7	21	1549051	471.57	943.91
W8	24	1551571.2	472.34	472.34
$\sum W_i\ h_i^{\ 2}$		5977431.9		

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International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 9, March 2015

C. Vertical Distribution of Base Shear to Different Floor Levels from ETABS

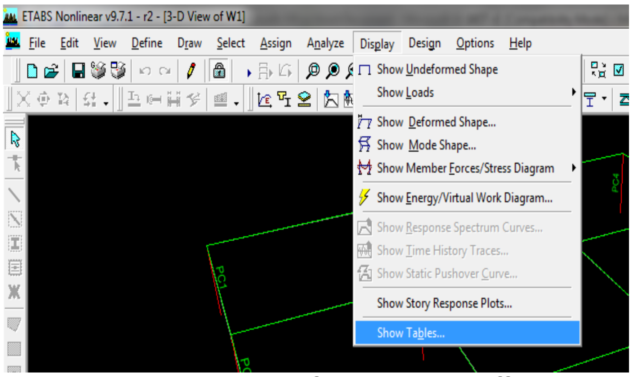


Fig 18: Vertical Distribution of Base Shear to Different Floor Levels.

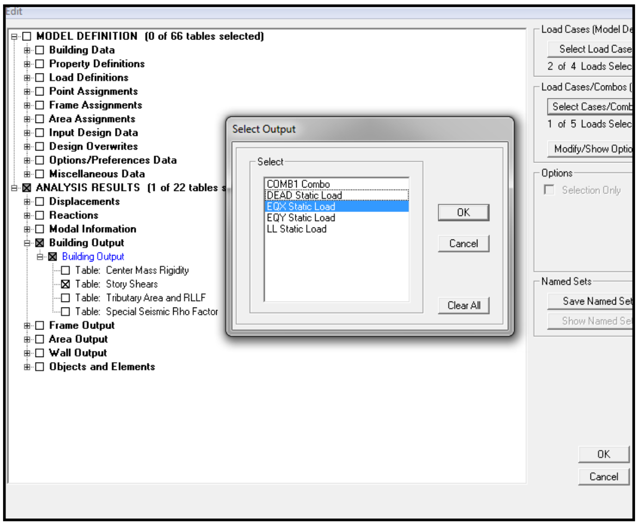
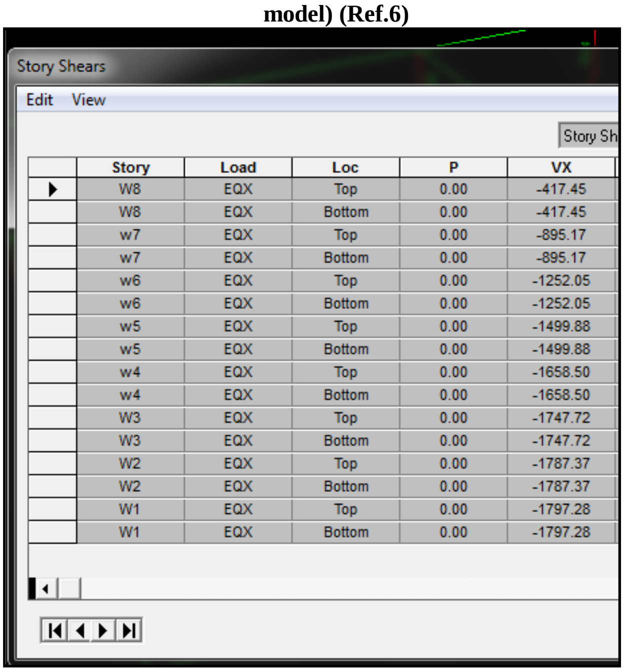


Fig 19: Procedure to display base shear of each story (ETABS model) (Ref.6)


Story Shears

Edit View

Story	Load	Loc	P	VX
W8	EQX	Top	0.00	-417.45
W8	EQX	Bottom	0.00	-417.45
w7	EQX	Top	0.00	-895.17
w7	EQX	Bottom	0.00	-895.17
w6	EQX	Top	0.00	-1252.05
w6	EQX	Bottom	0.00	-1252.05
w5	EQX	Top	0.00	-1499.88
w5	EQX	Bottom	0.00	-1499.88
w4	EQX	Top	0.00	-1658.50
w4	EQX	Bottom	0.00	-1658.50
W3	EQX	Top	0.00	-1747.72
W3	EQX	Bottom	0.00	-1747.72
W2	EQX	Top	0.00	-1787.37
W2	EQX	Bottom	0.00	-1787.37
W1	EQX	Top	0.00	-1797.28
W1	EQX	Bottom	0.00	-1797.28

Fig 20: Vertical Distribution of Base Shear to Different Floor Levels (Out put from ETABS) (Ref.6)

V. CONCLUSION

From the data revealed by the manual as well as software analysis for the structures with seismic coefficient method using various loading combinations tried following conclusions are drawn:

1. Seismic analysis was done by using ETABS software and successfully verified manually as per IS 1893-2002.
2. There is a gradual increase in the value of lateral forces from bottom floor to top floor in both manual as well as software analysis
3. Calculation of seismic weight by both manual analysis as well as software analysis gives exactly same result.
4. There is slight variation in the values of base shear in manual analysis as well as software analysis
5. Base shear values obtained by manual analysis are slightly higher than software analysis.
6. Results as compared and approximately same mathematical values are obtained for 8-story building.
7. Complete guideline for the use of ETABS 7.1 for seismic coefficient analysis is made available by this paper.
8. To conclude a complete design involving several parameters so as to result the earthquake has been done and a 3D prospective is shown for easy understanding and use.

VI. FUTURE ENHANCEMENT

1. Any structural engineer can use this paper as a guide line for seismic analysis of any multistoried building.
2. The results obtained by this method can be compared with results of Response Spectrum Method and Time History Method.

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