ENSOFT

EARTHQUAKE ANALYSIS FEATURES OF BUILD-MASTER 2005

We have recently released New version of **BUILD-MASTER** i.e. **Version 2005**. Many new features are added in the software. The most important revision is that now Earthquake loads are calculated as per **IS 1893 : 2002** code and Wind loads are calculated as per **IS 875 : 1987** code of practice.

In this new version program generates 11 load cases and up to 205 load combinations automatically during the Analysis of Space Frame with Horizontal Loads.

Analysis output includes **factored values** of forces and moments (after multiplying partial safety factors for various combinations), if frame analysis is performed for **Limit State of Collapse**. Alternatively these values are un-factored if **Limit State of Serviceability** option is selected for the analysis. Factored values are used for designing the RCC components and un-factored values are used for checking the deflections and calculating the sizes of footings.

Program calculates the **Center of Gravity** (i.e. center of mass) and **Center of Rotation** (i.e. center of stiffness) at each floor level and considers the design eccentricity while applying the Earthquake forces. Since wind forces act on the face of building, program calculates the **Center of Width** (i.e. center of sides) of each floor while applying the wind loads.

CALCULATING SEISMIC FORCES:

Torsion:

The seismic force is caused by inertia of the building mass; hence the resultant of seismic forces on each floor acts at the center of mass (i.e. Center of Gravity) **C.G.** of that floor. If the building is not symmetrical about the two principal axes then, the center of mass does not coincide with the center of stiffness. In this case the lateral force at center of mass causes a torsion i.e. it tries to rotate the floor about the center of stiffness (i.e. center of rotation) **C.R.** The lateral force at the **C.G.** can be thought of as lateral force at the **C.R.** plus a twisting moment about vertical Y-axis as illustrated in Fig. 1 below. **EPX** is the earthquake force parallel to X-axis and **EPZ** parallel to Z-axis. Ex is the actual eccentricity between C.G. and C.R. parallel to X axis and Ey parallel to Y-axis. **TPX** is the torsion moment due to EPX and **TPZ** due to EPZ.

Since the calculation of the location of center of mass and center of stiffness, and therefore of eccentricity, is only approximate, the code requires that minimum eccentricity of at least **5%** of the base dimension perpendicular to the direction of applied force as shown in Fig. 2 below shall be considered to account for the "**accidental eccentricity**".

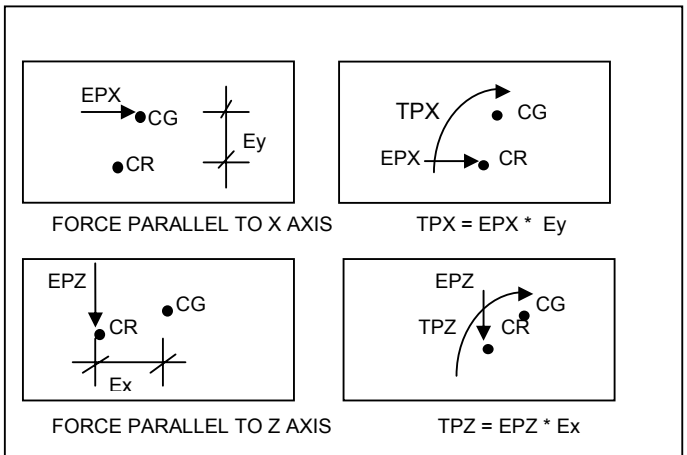


FIG.1 SEISMIC FORCE ACTS AT CENTRE OF MASS. IT IS SAME AS A FORCE + A TWISTING MOMENT AT CENTRE OF STIFFNESS

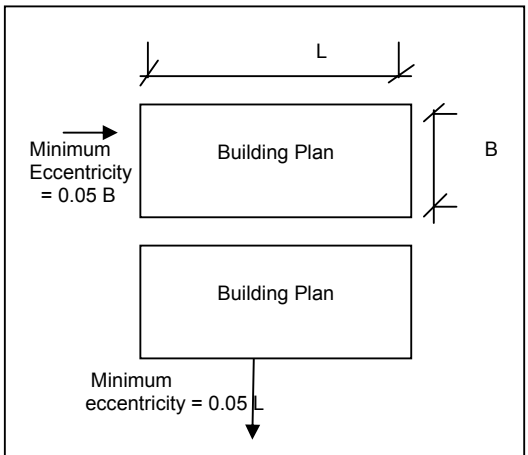


FIG. 2 MINIMUM ECCENTRICITY PROVISION OF THE CODE

Design Eccentricity (Ed) :

Code specifies Two Cases of Design eccentricity to be used instead of the actual eccentricity while calculating the torsion moment, namely,

Case **1. Ed = 1.5 * Ea + 0.05 b** and **Case 2. Ed = Ea – 0.05 b**

Where Ea is actual eccentricity, b is the fl. plan dimension perpendicular to the direction of force. Program calculates the Torsion Moment due to design eccentricity for both these cases.

Non Orthogonal Buildings:

Code specifies that when the lateral load resisting elements (beams & columns) are not oriented along the orthogonal horizontal directions (as in the sample building plan shown on the next page), the structure shall be designed for the effect due to full design earthquake load in one horizontal direction plus 30% of the design load in the other direction.

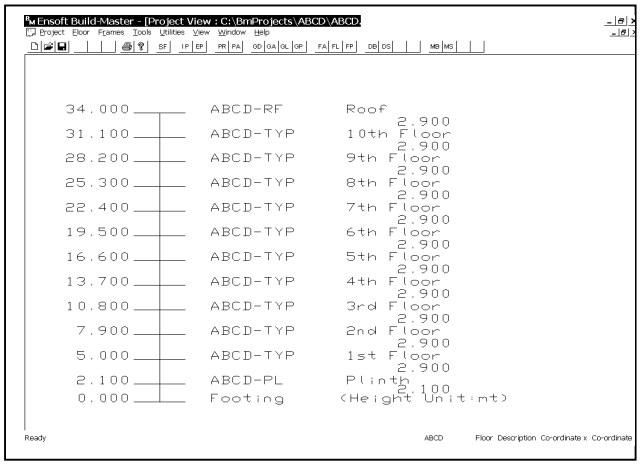
Program takes into account all the above provisions of IS 1893-2002 code while considering the effect of earthquake loads. It gives a option for the user Whether To **Consider Earthquake Eccentricity Effect**? And also asks whether to **Consider the Non-Orthogonal Building Effect?** Generates the appropriate Loading Cases for the analysis.

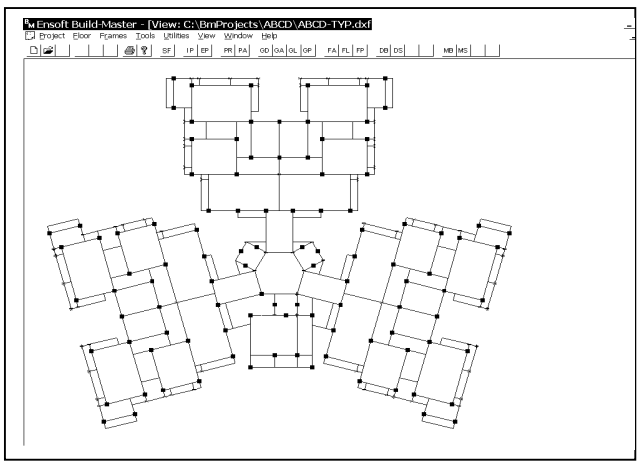
SPACE FRAME ANALYSIS WITH HORIZONTAL LOADS:

Steps for Space Frame Analysis with horizontal earthquake and wind loads :

1. Basic parameters for calculating Earthquake and wind loads as per code provisions are defined.
2. Seismic weight of each floor is calculated using Floor grid analysis results of that level.
3. Base Shear is calculated as per new formulae of IS 1893 – 2002 code.
4. Base shear is distributed along the building height and forces at each floor level are calculated.
5. Center of Gravity, Center of Rotation and Design eccentricity is worked out at each level.
6. Torsion moment due to eccentricity is calculated for two cases as per code.
7. Floor width and center of width is calculated at each level depending on floor dimensions.
8. Wind pressure and wind loads are calculated at each floor level.
9. Various load combinations are generated for Dead Loads, Imposed, Earthquake and Wind loads.
10. Frame analysis is carried out for the 3D model.

Frame Analysis Report for a Sample Building is listed below:





FRAME ANALYSIS REPORT (ENSOFT BUILD-MASTER Version 2005)

PROJECT NAME : ABCD NUMBER OF LEVELS : 12 **S E I S M I C W E I G H T**

LEVEL NO.	FLOOR CODE	HEIGHT (mt)	Ht.ABOVE FOOTING	FLOOR DESCRIPTION	TOTAL DL (T)	TOTAL IL (T)	IL % Percentage	REDUCED IL (T)
1	ABCD-PL	2.100	2.100	Plinth	431.240	0.490	25.000	0.122
2	ABCD-TYP	2.900	5.000	1st Floor	890.740	103.130	25.000	25.782
3	ABCD-TYP	2.900	7.900	2nd Floor	890.740	103.130	25.000	25.782
4	ABCD-TYP	2.900	10.800	3rd Floor	890.740	103.130	25.000	25.782
5	ABCD-TYP	2.900	13.700	4th Floor	890.740	103.130	25.000	25.782
6	ABCD-TYP	2.900	16.600	5th Floor	890.740	103.130	25.000	25.782
7	ABCD-TYP	2.900	19.500	6th Floor	890.740	103.130	25.000	25.782
8	ABCD-TYP	2.900	22.400	7th Floor	890.740	103.130	25.000	25.782
9	ABCD-TYP	2.900	25.300	8th Floor	890.740	103.130	25.000	25.782
10	ABCD-TYP	2.900	28.200	9th Floor	890.740	103.130	25.000	25.782
11	ABCD-TYP	2.900	31.100	10th Floor	890.740	103.130	25.000	25.782
12	ABCD-RF	2.900	34.000	Roof	574.310	103.130	0.000	0.000

EARTHQUAKE DATA

Zone Factor Z = 0.160
Damping Factor F = 1.000
Importance Factor I = 1.000
Building Height h = 34.000 mt
Time Period = 0.09 * h / sqrt(d)
Seismic Zone : 3 Intensity : Moderate
Damping Per : 5.000 %
Response Reduction Factor R = 5.000
Frame Type = 1.RC With Infill
Soil Type = 1.Hard Soil

Building Dimensions
Base Dimensions in X BDimX : 37.644 mt
Base Dimensions in Y BDimY : 30.686 mt

WIND DATA

Class Of Structure : 1 All General Bldgs.(50 yr.)
Basic Wind Speed : 44.000 mt/sec
Building Class : B. Max Dim bet. 20 & 50 mt
Terrain Category : 3. Closely spaced Less/Low obstructions

Risk Coefficient K1 : 1.000
Terrain size Factor K2: 0.880 up to 10 mt
Topography Factor K3: 1.000
Force Coeff. Cfx: 1.000
Force Coeff. Cfy: 1.000
Design Wind Speed : 38.720 mt/sec
Bldg Height Bldg Ht h : 34.000 mt
Plinth Height : 0.500 mt
Parapet Height : 1.000 mt

BASE SHEAR CALCULATIONS

PARAMETER		X Direction	Y Direction	
Building Height	h	34.000	34.000	mt
Base Dimension at Plinth Level.	d	37.644	30.686	mt
Time Period in Sec.	T	0.499	0.552	sec
Avg. Response Acceleration Coeff.	Sa/g	2.005	1.810	
Design Horizontal Seismic Coeff.	Ah	0.032	0.029	
Seismic Weight of Building	W	10170.897	10170.897	T
Design Seismic Base Shear	Vb	326.291	294.597	T

EARTHQUAKE FORCES APPLIED AT C.R. WITH ECCENTRICITY AT EACH FLOOR

LEVEL NO.	FLOOR CODE	CENTRE OF GRAVITY CGX	CGY	CENTRE OF ROTATION CRX	CRY	ACTUAL ECCENTRICITY Esix	Esiy	5% FLOOR WIDTH 0.05bx	0.05by	FLOOR NODE NEAR C.R. NODE NO.	CordX	CordY	SPACE NODE
1	ABCD-PL	0.074	-4.361	0.079	-5.410	0.005	-1.049	1.882	1.534	181	1.066	-3.657	287
2	ABCD-TYP	0.008	-4.351	0.079	-5.410	0.071	-1.059	1.882	1.534	181	1.066	-3.657	629
3	ABCD-TYP	0.008	-4.351	0.079	-5.410	0.071	-1.059	1.882	1.534	181	1.066	-3.657	971
4	ABCD-TYP	0.008	-4.351	0.079	-5.410	0.071	-1.059	1.882	1.534	181	1.066	-3.657	1313
5	ABCD-TYP	0.008	-4.351	0.079	-5.410	0.071	-1.059	1.882	1.534	181	1.066	-3.657	1655
6	ABCD-TYP	0.008	-4.351	0.079	-5.410	0.071	-1.059	1.882	1.534	181	1.066	-3.657	1997
7	ABCD-TYP	0.008	-4.351	0.079	-5.410	0.071	-1.059	1.882	1.534	181	1.066	-3.657	2339
8	ABCD-TYP	0.008	-4.351	0.079	-5.410	0.071	-1.059	1.882	1.534	181	1.066	-3.657	2681
9	ABCD-TYP	0.008	-4.351	0.079	-5.410	0.071	-1.059	1.882	1.534	181	1.066	-3.657	3023
10	ABCD-TYP	0.008	-4.351	0.079	-5.410	0.071	-1.059	1.882	1.534	181	1.066	-3.657	3365
11	ABCD-TYP	0.008	-4.351	0.079	-5.410	0.071	-1.059	1.882	1.534	181	1.066	-3.657	3707
12	ABCD-RF	0.036	-4.309	0.079	-5.410	0.043	-1.101	1.882	1.534	181	1.066	-3.657	4049

TOTAL EARTHQUAKE LOAD APPLIED AT EACH FLOOR

LEVEL NO.	FLOOR CODE	SPACE FRAME NODE NO.	FORCES IN X DIRECTION(T) EPX	TPX1	TPX2	FORCES IN Z DIRECTION(T) EPZ	TPZ1	TPZ2
1	ABCD-PL	287	0.145	-0.006	-0.375	0.131	0.248	-0.246
2	ABCD-TYP	629	1.744	-0.095	-4.523	1.574	3.131	-2.850
3	ABCD-TYP	971	4.353	-0.237	-11.289	3.930	7.818	-7.117
4	ABCD-TYP	1313	8.135	-0.443	-21.098	7.345	14.611	-13.301
5	ABCD-TYP	1655	13.091	-0.713	-33.951	11.819	23.511	-21.402
6	ABCD-TYP	1997	19.219	-1.047	-49.844	17.352	34.517	-31.422
7	ABCD-TYP	2339	26.521	-1.445	-68.782	23.945	47.632	-43.361
8	ABCD-TYP	2681	34.996	-1.907	-90.762	31.596	62.852	-57.215
9	ABCD-TYP	3023	44.644	-2.433	-115.784	40.307	80.180	-72.990
10	ABCD-TYP	3365	55.465	-3.022	-143.848	50.077	99.615	-90.682
11	ABCD-TYP	3707	67.459	-3.676	-174.954	60.906	121.156	-110.291
12	ABCD-RF	4049	50.522	-5.905	-133.130	45.614	88.809	-83.885

WIND LOADS APPLIED AT CENTRE OF WIDTH

LEVEL NO.	FLOOR CODE	FLOOR DIMENSIONS COORDINATES MinX	MaxX	MinY	MaxY	CENTRE OF WIDTH CWX	CWY	FLOOR NODE NEARCW NODE No.	CordX	CordY	SPACE NODE
1	ABCD-PL	-18.822	18.822	-19.079	11.607	0.000	-3.736	180	-1.066	-3.657	286
2	ABCD-TYP	-18.822	18.822	-19.079	11.607	0.000	-3.736	180	-1.066	-3.657	628
3	ABCD-TYP	-18.822	18.822	-19.079	11.607	0.000	-3.736	180	-1.066	-3.657	970
4	ABCD-TYP	-18.822	18.822	-19.079	11.607	0.000	-3.736	180	-1.066	-3.657	1312
5	ABCD-TYP	-18.822	18.822	-19.079	11.607	0.000	-3.736	180	-1.066	-3.657	1654
6	ABCD-TYP	-18.822	18.822	-19.079	11.607	0.000	-3.736	180	-1.066	-3.657	1996
7	ABCD-TYP	-18.822	18.822	-19.079	11.607	0.000	-3.736	180	-1.066	-3.657	2338
8	ABCD-TYP	-18.822	18.822	-19.079	11.607	0.000	-3.736	180	-1.066	-3.657	2680
9	ABCD-TYP	-18.822	18.822	-19.079	11.607	0.000	-3.736	180	-1.066	-3.657	3022
10	ABCD-TYP	-18.822	18.822	-19.079	11.607	0.000	-3.736	180	-1.066	-3.657	3364
11	ABCD-TYP	-18.822	18.822	-19.079	11.607	0.000	-3.736	180	-1.066	-3.657	3706
12	ABCD-RF	-18.822	18.822	-19.079	11.607	0.000	-3.736	180	-1.066	-3.657	4048

TOTAL WIND LOAD APPLIED AT EACH FLOOR

LEVEL NO.	FLOOR CODE	HEIGHT	COEFF K2	WIND SPEED Vz (mt/sec)	WIND PRESSURE Pz(T/mt2)	FORCES IN X DIRECTION FL. WIDTH	LOAD SPACE NODE	FORCES IN Z DIRECTION FL. WIDTH	LOAD SPACE NODE
1	ABCD-PL	2.100	0.880	38.720	0.090	30.686	5.370 286	37.644	6.588 286
2	ABCD-TYP	5.000	0.880	38.720	0.090	30.686	8.009 628	37.644	9.825 628
3	ABCD-TYP	7.900	0.880	38.720	0.090	30.686	8.009 970	37.644	9.825 970
4	ABCD-TYP	10.800	0.940	41.360	0.103	30.686	9.144 1312	37.644	11.218 1312
5	ABCD-TYP	13.700	0.940	41.360	0.103	30.686	9.144 1654	37.644	11.218 1654
6	ABCD-TYP	16.600	0.980	43.120	0.112	30.686	9.942 1996	37.644	12.197 1996
7	ABCD-TYP	19.500	0.980	43.120	0.112	30.686	9.942 2338	37.644	12.197 2338
8	ABCD-TYP	22.400	1.030	45.320	0.123	30.686	10.955 2680	37.644	13.439 2680
9	ABCD-TYP	25.300	1.030	45.320	0.123	30.686	10.955 3022	37.644	13.439 3022
10	ABCD-TYP	28.200	1.030	45.320	0.123	30.686	10.955 3364	37.644	13.439 3364
11	ABCD-TYP	31.100	1.090	47.960	0.138	30.686	12.274 3706	37.644	15.058 3706
12	ABCD-RF	34.000	1.090	47.960	0.138	30.686	10.372 4048	37.644	12.724 4048

DESCRIPTION OF LOAD CASES

1	DL	Dead Load
2	IL	Imposed Load
3	RIL	Reduced Imposed Load
4	EPX	Earthquake Parallel to +ve X Direction
5	TPX1	Torsion Case 1 for EQ +ve X Direction
6	TPX2	Torsion Case 2 for EQ +ve X Direction
7	EPZ	Earthquake Parallel to +ve Z Direction
8	TPZ1	Torsion Case 1 for EQ +ve Z Direction
9	TPZ2	Torsion Case 2 for EQ +ve Z Direction
10	WPX	Wind Parallel to +ve X Direction
11	WPZ	Wind Parallel to +ve Z Direction

LOAD COMBINATIONS FOR DL, IL & WIND LOADS

1.5 DL + 1.5 IL **(1 COMBINATION OF DL + IL)**

1.5 DL ± 1.5 WPX
1.5 DL ± 1.5 WPZ

0.9 DL ± 1.5 WPX
0.9 DL ± 1.5 WPZ

1.2 DL + 1.2 IL ± 1.2 WPX
1.2 DL + 1.2 IL ± 1.2 WPZ **(12 COMBINATIONS OF WIND)**

(Horizontal forces in -ve Axis direction are of same magnitude of +ve Axis but with –ve sign.)

Depending on whether Building is Orthogonal or Not and Earthquake Eccentricity is considered or Not Program generates following **Load Combinations** with Earthquake Loads:

ORTHOGONAL BUILDING WITHOUT ECCENTRICITY

1.5 DL ± 1.5 EPX
1.5 DL ± 1.5 EPZ
0.9 DL ± 1.5 EPX
0.9 DL ± 1.5 EPZ
1.2 DL + 1.2 RIL ± 1.2 EPX
1.2 DL + 1.2 RIL ± 1.2 EPZ

Earthquake combinations = 12
Total Load Combinations = 25

NON ORTHOGONAL BUILDING WITHOUT ECCENTRICITY

1.5 DL ± 1.5 EPX ± 0.45 EPZ
1.5 DL ± 1.5 EPZ ± 0.45 EPX
0.9 DL ± 1.5 EPX ± 0.45 EPZ
0.9 DL ± 1.5 EPZ ± 0.45 EPX
1.2 DL + 1.2 RIL ± 1.2 EPX ± 0.36 EPZ
1.2 DL + 1.2 RIL ± 1.2 EPZ ± 0.36 EPX

Earthquake combinations = 24
Total Load Combinations = 37

ORTHOGONAL BUILDING WITH ECCENTRICITY

1.5 DL ± 1.5 EPX ± 1.5 TPX1
1.5 DL ± 1.5 EPX ± 1.5 TPX2
1.5 DL ± 1.5 EPZ ± 1.5 TPZ1
1.5 DL ± 1.5 EPZ ± 1.5 TPZ2

0.9 DL ± 1.5 EPX ± 1.5 TPX1
0.9 DL ± 1.5 EPX ± 1.5 TPX2
0.9 DL ± 1.5 EPZ ± 1.5 TPZ1
0.9 DL ± 1.5 EPZ ± 1.5 TPZ2
1.2 DL + 1.2 RIL ± 1.2 EPX ± 1.2 TPX1
1.2 DL + 1.2 RIL ± 1.2 EPX ± 1.2 TPX2
1.2 DL + 1.2 RIL ± 1.2 EPZ ± 1.2 TPZ1
1.2 DL + 1.2 RIL ± 1.2 EPZ ± 1.2 TPZ2

Earthquake Combinations = 48
Total Load Combinations = 61

NON-ORTHOGONAL BUILDING WITH ECCENTRICITY

1.5 DL ± 1.5 EPX ± 1.5 TPX1 ± 0.45 EPZ ± 0.45 TPZ1
1.5 DL ± 1.5 EPX ± 1.5 TPX2 ± 0.45 EPZ ± 0.45 TPZ2
1.5 DL ± 1.5 EPZ ± 1.5 TPZ1 ± 0.45 EPX ± 0.45 TPX1
1.5 DL ± 1.5 EPZ ± 1.5 TPZ2 ± 0.45 EPX ± 0.45 TPX2

0.9 DL ± 1.5 EPX ± 1.5 TPX1 ± 0.45 EPZ ± 0.45 TPZ1
0.9 DL ± 1.5 EPX ± 1.5 TPX2 ± 0.45 EPZ ± 0.45 TPZ2
0.9 DL ± 1.5 EPZ ± 1.5 TPZ1 ± 0.45 EPX ± 0.45 TPX1
0.9 DL ± 1.5 EPZ ± 1.5 TPZ2 ± 0.45 EPX ± 0.45 TPX2
1.2 DL + 1.2 RIL ± 1.2 EPX ± 1.2 TPX1 ± 0.36 EPZ ± 0.36 TPZ1
1.2 DL + 1.2 RIL ± 1.2 EPX ± 1.2 TPX2 ± 0.36 EPZ ± 0.36 TPZ2
1.2 DL + 1.2 RIL ± 1.2 EPZ ± 1.2 TPZ1 ± 0.36 EPX ± 0.36 TPX1
1.2 DL + 1.2 RIL ± 1.2 EPZ ± 1.2 TPZ2 ± 0.36 EPX ± 0.36 TPX2

Earthquake Combinations = 192
Total Load Combinations = 205