# LEARNING OF ETABS SOFTWARE

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A step-by-step procedure for modeling and analysis of frame structure using ETABS is explained through a simple example. Subsequently an example of seismic analysis of regular frame structure and irregular frame structure are solved manually and through ETABS.

## Example

A plan of five storey reinforced concrete (RC) frame structure is considered for modeling and analysis using ETABS.

Beam sizes	300×450 mm	Storey Height	3.2 m.
Columns sizes	300×450 mm	Live Load	$3 \text{ kN/m}^2$
Slab thickness	120 mm	Floor Finish Load	$1 \text{ kN/m}^2$
Concrete grade	M25	Steel Fe415	



Fig. 1 Plan view of building

Elevation of Building

Earthquake parameters considered are:

Zone: VImportance Factor 1Medium soil,Response Reduction Factor: 5

Site Specific Time history and response spectrum: Passport Office Site

# Step by step procedure to learn ETABS

- 1) Modeling using ETABS.
- 2) Comparison of total DL and LL.
- 3) Time period and Mode participation factor of building in X and Y direction.
- 4) Seismic force calculation as per IS: 1893(Part 1) 2002.
  - a) Static method
  - b) Dynamic method
- 5) Site specific response spectra
- 6) Site specific time history
- 7) Design under gravity and seismic load
- 8) Performance based design using pushover analysis

# **Step 1: Modeling using ETABS**

- 1) Open the ETABS Program
- 2) Check the units of the model in the drop-down box in the lower right-hand corner of the ETABS window, click the drop-down box to set units to **kN-m**

	-	NP	-
		Kip-ft	
		KN-mm	
		KN-m	E
		Kgf-mm	
		Kgf-m	
		N-mm	
3) Click the <b>File</b> mer	nu > New model command	N-m	-
		KN-m	•
	New Model Initialization		
	Do you want to initialize your new model with definitions and preferences from an existing .edb file? (Press F1 Key for help	p.)	
	Choose.edb Default.edb No		

Note: we select No because this first model you will built

4) The next form of **Building Plan Grid System and Story Data Definition** will be displayed after you select **NO** button.

ilding Plan Grid System and Story Data Definition	
Grid Dimensions (Plan)	Story Dimensions
Uniform Grid Spacing	Simple Story Data
Number Lines in X Direction 5	Number of Stories 5
Number Lines in Y Direction 4	Typical Story Height 3.2
Spacing in X Direction 5	Bottom Story Height 3.2
Spacing in Y Direction 4	C Custom Story Data Edit Story Data
C Custom Grid Spacing	Units
Grid Labels Edit Grid	KN-m 💌
Add Structural Objects	-
Steel Deck Staggered Flat Slab Flat S Truss Perime	ilab with Waffle Slab Two Wayor <b>Grid Only</b> ter Beams Ribbed Slab
ОК	Cancel

Set the grid line and spacing between two grid lines. Set the story height data using Edit Story Data command

6	Label						
6	Label I	Height	Elevation	Master Story	Similar To	Splice Point	Splice Height
I X K 2	STORY5	3.2	16.	Yes		No	0.
5 9	STORY4	3.2	12.8	No	STORY5	No	0.
4 9	STORY3	3.2	9.6	No	STORY5	No	0.
3 9	STORY2	3.2	6.4	No	STORY5	No	0.
2 9	STORY1	3.2	3.2	No	STORY5	No	0.
	BASE						
- Reset Se	lected Rows-			Units	o Unito	KN	
Height	3.2 Story No		Reset	Chang	e onics		
Simlar T		IE 💌	Reset				
Splice P	Point	<b>–</b>	Reset				
Splice H	leight 0		Reset	[	OK	Cancel	

5) Define the design code using **Options > Preferences > Concrete Frame Design** command

Options	
Preferences •	Dimensions/Tolerances
<u>⊆</u> olors	Output Decimals
<u>W</u> indows	Steel Frame Design
Set Calculator Memory	Concrete Frame Design
✓ Show <u>T</u> ips at Startup	Composite <u>B</u> eam Design… Shear Wall Design…
<ul> <li>Show Bounding Plane</li> </ul>	Poinforcomont Par Sizon
✓ Moment Diagrams on Tension Side	Live Load <u>R</u> eduction
✓ Sou <u>n</u> d	
📓 Lock Model	
Auto Save Model	
Show <u>A</u> erial View Window	
<ul> <li>Show Eloating Property Window</li> </ul>	
Show Cross <u>h</u> airs	
✓ Enhanced Graphics	
<u>R</u> eset Toolbars	

This will Display the **Concrete Frame Design Preference** form as shown in the figure.

Desian Code	Indian IS 456-2000		
Number of Interaction Curves	24		
Number of Interaction Points	11		
Consider Minimum Eccentricity	Yes		
Gamma (Steel)	1.15		
Gamma (Concrete)	1.5		
Pattern Live Load Factor	0.75		
Utilization Factor Limit	0.95		-
		ОК	
		Lancel	

## 6) Click the **Define menu > Material Properties**

Define		
Material Properties	Define Materials	
<ul> <li>☑ Erame Sections</li> <li>☑ Wall/Slab/Deck Sections</li> <li>№ Link Properties</li> <li>Frame Nonlinear Hinge Properties</li> </ul>	Materials CONC OTHER STEEL	Click to: Add New Material Modify/Show Material Delete Material OK Cancel

Add New Material or Modify/Show Material used to define material properties

Material Property Data			
		Display Color	
Material Name	M25	Color	
Type of Material		Type of Design	
Isotropic     Orthotropic		Design	Concrete 💌
Analysis Property Data		Design Property Data (Indian IS 45	6-2000)
Mass per unit Volume	2.4007	Conc Cube Comp Strength, fck	25000.
Weight per unit Volume	23.5616	Bending Reinf. Yield Stress, fy	415000.
Modulus of Elasticity	25000000.	Shear Reinf, Yield Stress, fys	415000.
Poisson's Ratio	0.2	Lightweight Concrete	
Coeff of Thermal Expansion	9.900E-06	Shear Strength Reduc. Facto	r
Shear Modulus	10416666.7		
	ОК	Cancel	

7) Define section columns and beams using **Define > Frame section** 

Define Material Properties ✓ Frame Sections Wall/Slab/Deck Sections K Link Properties Frame Nonlinear Hinge Properties	Define Frame Properties Properties Type in property to find: B300X450 C300X450 C300X450	Click to: Import I/Wide Flange  Add I/Wide Flange Modify/Show Property Delete Property
		OK

Define beam sizes and click Reinforcement command to provided concrete cover

Section Name	B300×450		Design Type O Column	<ul> <li>Beam</li> </ul>
Properties Section Properties Dimensions Depth (t3) Width (t2)	Property Modifiers Set Modifiers	Material M25 STEEL 3 4 Display Color	Concrete Cover to Reb Top Bottom Reinforcement Override Left Top 0. Bottom 0.	ar Center

Define column sizes and click **Reinforcement command** to provided concrete cover and used two options **Reinforcement checked or designed** 

Rectangular Section			Reinforcement Data	
Section Name	C300×450	Material	Configuration of Reinforcement	C Beam
Section Properties Se	t Modifiers	M25  M25 STEEL	Lateral Reinforcement	C Spiral
Depth (t3) 0. Width (t2) 0.	45		Rectangular Reinforcement Cover to Rebar Center Number of Bars in 3-dir	0.045
Samut			Number of Bars in 2-dir Bar Size Corner Bar Size	3 16d <b>•</b> 16d <b>•</b>
Reinforcement		Display Color	Check/Design	cked
ОК	Cancel		Reinforcement to be Des	Cancel

## 8) Define wall/slab/deck

Define			
📧 Material Properties	Define Wall/Slab/Deck Sections		
T Frame Sections			
Sections	S120		
k E Li <u>n</u> k Properties			
Frame Nonlinear <u>H</u> inge Properties	Modify/Show Section		
	Delete Section		
	ок		
	Lancel		

To define a slab as membrane element and one way slab define using **special one way load distribution** 

Wall/Slab Section
Section Name S120
Material M25
Thickness
Membrane 0.12
Bending 0.12
Туре
C Shell 📀 Membrane C Plate
Thick Plate
Load Distribution
Use Special One-Way Load Distribution
Set Modifiers Display Color
OK Cancel

## 9) Generate the model

Draw beam using Create Line Command and draw column using Create Column command

। Select Object		Draw Lines (Plan, Elev, 3D)	
🚡 Reshape Object	<u>\</u>	Create Lines in <u>R</u> egion or at C	Ilicks (Plan, Elev, 3D)
( ) Draw Point Objects	I	Create Columns in Region or a	at <u>⊂</u> licks (Plan)
Draw Line Objects		Create <u>S</u> econdary Beams in R	egion or at Clicks (Plan)
Draw <u>A</u> rea Objects	• <b>ж</b>	CreateBracesinRegion	
🛱 Draw Developed Elevation Definition		Properties of Object	×
Draw Section <u>C</u> ut		Tupo of Line	Eramo
** Draw Di <u>m</u> ension Line		Property	Frame
🗙 Draw Reference P <u>o</u> int		Moment Beleases	Continuous
Sn <u>a</u> p to	•	Plan Offset Normal	0.

Slab is created using 3 options in which  $1^{st}$  draw any shape area,  $2^{nd}$  draw rectangular area and  $3^{rd}$  create area in between grid line



Above creating option used to generate the model as shown in below figure



10) Define various loads (Dead load, live load, Earthquake load)



<u>Dead Load</u>: self weight multiplier is used 1 to calculate dead load as default. <u>Live load or any other define load</u>

 $1^{st}$  select the member where assign this load than click the assign button.

Assign			
Joint/Point	⊩	岁 Uniform	
Erame/Line	⊧	I	
<u>S</u> hell/Area	۲	Wind Pressure Coefficient	
Joint/Point Loads	⊧	Uniform Surface Loads	
Frame/Line Loads	Þ		
Shell/ <u>A</u> rea Loads	►	Load Case Name	KN-m V
∽ Group <u>N</u> ames		Uniform Load UVE	
⊆lear Display of Assigns		Load 3 EQX EQY	Existing Loads
Copy Assigns	_	Direction Gravity C Del	ete Existing Loads
Paste Assigns	⊩		
		OK Can	cel

## Assign point load and uniform distributed load

Select assigning point or member element than click the assign button

<u>A</u> ssign					
Joint/Point	→ 55	Force			
Frame/Line	▶ m≣	📲 Ground <u>D</u> isplacement			
Shell/Area	► ₽5	Temperature			
Electrica	_				
Joint/ <u>P</u> oint Loads	▶.	Point Forces			
Frame/Line Loads	•	Load Case Name	DEAD		
Shell/ <u>A</u> rea Loads	- F		, Options		
∽ Group <u>N</u> ames		Force Global X	C Add to Existing Loads		
	_	Force Global Y	O Delete Existing Loads		
		Force Global Z 0	)		
Copy Assigns		Moment Global XX  0			
Paste Assigns	- I-				
		Moment Global ZZ JU			
<u>A</u> ssign					
Joint/Point	🕨 📥 🖻	joint			
<u>F</u> rame/Line	• 💆 🖸	jstributed			
Sbell/Area		emperature			
2/10///1/03	_ <u> </u>	)pen Structure Wind Parameters			
Joint/ <u>P</u> oint Loads	•	Frame Distributed Loads			
Frame/Line Loads	•		Units		
Shell/ <u>A</u> rea Loads	•	Load Case Name	DEAD V KN-m		
4 Croup Names	- 1	Load Type and Direction	Options		
- Group Manies	_	Forces C Momen	ts		
⊆lear Display of Assigns	-	Direction Gravity	C Delete Existing Loads		
Copy Assigns		Trapezoidal Loads	2 3 4		
Copy Assigns		Distance 0.	0.25 0.75 1.		
Paste Assigns	P	Load 0.	0. 0.		
		<ul> <li>Relative Distance from</li> </ul>	om End-I C Absolute Distance from End-I		
		Uniform Load			

#### 11) Assign support condition

Drop-down box in the lower right-hand corner of the ETABS window, Select only bottom single storey level to assign fixed support using assign > Joint/Point>Restrain (Support) command

Cone Story All Stories Similar Stories One Story

<u>A</u> ssign		
<u>J</u> oint/Point	🔀 Diaphragms	
Erame/Line	Panel Zone	Restraints in Global Directions
Shell/Area	다 Restraints (Supports)	✓ Translation × ✓ Rotation about ×
Joint/ <u>P</u> oint Loads	I Point Springs	✓ Translation Y ✓ Botation about Y
Frame/Line Loads	🗆 🖁 Li <u>n</u> k Properties	
Shell/ <u>A</u> rea Loads	🛛 🎖 🛛 Additional Point <u>M</u> ass	
℃ Group <u>N</u> ames		Fast Restraints
⊆lear Display of Assigns		
Copy Assigns		OK Cancel
Paste Assigns	- F	

12) In building, slab is considered as a single rigid member during earthquake analysis. For that, all slabs are selected first and apply diaphragm action for rigid or semi rigid condition.



13) Mass source is defined from Define > mass source command. As per IS: 1893-2002, 25% live load (of 3 kN/m<sup>2</sup>) is considered on

all floor of building



 $kN/m^2$ ) is considered on except at roof level.

## 14) Run analysis from Analysis > Run Analysis command



# Step 2: Comparison of total DL and LL

**Dead Load** 

Weight of slab =  $5 \times 12 \times 20 \times 0.12 \times 24 = 345$  kN Weight of beam =  $5 \times 0.3 \times 0.45 \times (12 \times 5 + 20 \times 4) \times 24 = 2268$  kN Weight of column =  $5 \times 0.3 \times 0.45 \times (3.2 - .45) \times 24 = 891$  kN Total weight = 6615 kN

Live Load

Live load =  $4 \times 12 \times 20 \times 3 + 1 \times 12 \times 20 \times 1.5 = 3240$  kN

# Floor Finish Load

 $FF = 5 \times 12 \times 20 \times 1 = 1200 \text{ kN}$ 

In ETABS, dead load and other loads are shown from table as shown in figure.



# Step 3: Time period and Mode participation factor of building in X and Y direction.

- Static time period base on the IS 1893 is  $0.075 \text{H}^{0.75} = 0.6 \text{ sec}$
- Dynamic time period as per ETABS analysis is 0.885 sec in X direction and 0.698 sec in Y direction

Time period is shown in ETABS from **Display > Show Mode Shape** 



Mass participation factor is shown from **Display > Show Table > Model Information > Building Model Information > Model Participating Ratio.** 

Modal P	articipating Ma	ss Ratios							
Edit Vie	ew								
					Modal Pa	articipating Mass I	Ratios		-
	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX
	1	0.884954	85.0817	0.0000	0.0000	85.0817	0.0000	0.0000	0.0000
	2	0.697994	0.0000	83.5026	0.0000	85.0817	83.5026	0.0000	99.4182
	3	0.649635	0.0000	0.0000	0.0000	85.0817	83.5026	0.0000	0.0000
	4	0.291666	9.7869	0.0000	0.0000	94.8686	83.5026	0.0000	0.0000
	5	0.224333	0.0000	10.4317	0.0000	94.8686	93.9343	0.0000	0.3093
	6	0.210519	0.0000	0.0000	0.0000	94.8686	93,9343	0.0000	0.0000
	7	0.173069	3.3883	0.0000	0.0000	98.2568	93,9343	0.0000	0.0000
	8	0.127575	0.0000	3.8521	0.0000	98.2568	97.7863	0.0000	0.2607
	9	0.125375	1.3785	0.0000	0.0000	99.6353	97.7863	0.0000	0.0000
	10	0.121394	0.0000	0.0000	0.0000	99.6353	97.7863	0.0000	0.0000
	11	0.103887	0.3647	0.0000	0.0000	100.0000	97.7863	0.0000	0.0000
	12	0.088617	0.0000	1.7181	0.0000	100.0000	99.5044	0.0000	0.0000

Bending moment and shear force diagram is shown from **Display > Show Member Forces > Frame/Pier/Spandrel Forces command** 



Bending Moment Diagram for Dead Load

Shear Force Diagram for Dead Load

Select any beam or column member and press right click to shown below figure



# Step 4: Seismic force calculation as per IS: 1893(Part 1) - 2002.

## (a) Static Method

Define static load from **Define > Static load command** 

Define	-				
📧 Material Properties	Define Static Load	Case Names			
<sup>12</sup> I Frame Sections	Loads				Click To:
Sall/Slab/Deck Sections	Load	Туре	Self Weight Multiplier	Auto Lateral Load	Add New Load
K Link Properties	EQX	QUAKE	• 0	IS1893 2002 💌	Modify Load
Frame Nonlinear <u>H</u> inge Properties	LIVE	LIVE DEAD	0		Modify Lateral Load
Diaphragms	EQX EQY	QUAKE QUAKE	0	IS1893 2002 IS1893 2002	Delete Load
<u>G</u> roups					ОК
Section <u>C</u> uts		1	1	1	Cancel
🔁 Response Spectrum Functions					
🙀 Time History Functions					
EL Static Load Cases					

Press modify lateral load to shown below figure and assign various value as per IS 1893.

Direction and Eccentricity		Seismic Coefficients	
X Dir     X Dir     X Dir + Eccen Y     Y Dir     X Dir + Eccen Y     Y Dir     X Dir - Eccen Y     Y Dir     Ecc. Ratio (All Diaph.)     Override Diaph. Eccen.	r + Eccen X r - Eccen X Override	Seismic Zone Factor, Z	0.16 <b>•</b>       <b>•</b>  1.
Time Period         C Approximate       Ct (m)         Image: Program Calc         C User Defined       T =			
Story Range Top Story St Bottom Story B/	TORY5 - ASE -	ОК	]
Factors		Cancel	

## (b) Dynamic Analysis Method

The design response spectra of IS 1893-2002 given as input in the **Define menu > Response Spectrum Functions.** Response spectra load cases are define in **Response Spectrum cases** 

Define	
🚈 Material Properties	Define Response Spectrum Functions
<sup>177</sup> I Frame Sections	- Response Spectra - Chasse Expetien Type to Add
Wall/Slab/Deck Sections	Choose Function Type to Add
SE Link Properties	UBC97 Spectrum
K & Link Properties	
Frame Nonlinear <u>H</u> inge Properties	- NZS4203 Spectrum - Chinese2002 Spectrum
Diaphragms	Italian3274 Spectrum IS1893:2002 Spectrum ≡
Groups	- IBC2006 Spectrum
Groups	Delete Spectrum
Response Spectrum Functions	OK Cancel
🐜 Time History Functions	
₽ Static Load Cases	
Response Spectrum Cases	Define Response Spectra
WH Time History Cases	Spectra Click to:
Static Noplinear (Pushover Cases	IS1893 Add New Spectrum
Add Sequential Construction Case	
Add Degdendal Construction Case	- Modity/Show Spectrum
맕Load Combinations	Delete Spectrum
Add Default Design Combos	
Convert Combos to Nonlinear Cases	ОК
Special Seismic Loa <u>d</u> Effects	Cancel
•? Mass Source	

The damping value is specified which is used to generate the response spectrum curve. 5% damping factor and 9.81 (g) scale factor is assigned as shown in Figure

Response Spectrum Case Data	
Caratum Cara Nama (191992)	Function Name IIS1893
Spectrum Lase Name	Parameters Define Function
Structural and Function Damping	Seismic Zone Factor, Z 0.16 Period Acceleration
Damping 0.05	Soil Type II   Add Add Add
Modal Combination	0.1 0.5 0.0 0.2 0.2 0.4 0.4 0.4 0.4 0.4 0.4 0.4 0.4 0.4
● CQC O SRSS O ABS O GMC	0.8 0.2/2 Delete
8	1.2 0.1813
11	Convert to User Defined 1.6 0.136 1.8 ▼ 0.1209 ▼
Directional Combination	Ensite Cost
C ABS Dithogonal SE	
C Modified SBSS (Chinese)	
Input Response Spectra	
Direction Function Scale Factor	
U1 IS1893 💌 0.981	
U2 IS1893 💌 0.981	
UZ 🔽	Display Graph ( 0.332 , 0.4 )
Excitation angle 0.	Cancel

# **Step 5: Site Specific Response Spectra**

Site specific response spectrum is define from **Define > Response Spectrum Function > Spectrum from File.** 

<u>Material Properties</u>	Define Response Spectrum Functions
T Frame Sections	Response Spectra Choose Function Type to Add
Wall/Slab/Deck Sections	UBC97 Spectrum
k S Link Properties	C User Spectrum
Frame Nonlinear <u>H</u> inge Properties	UBC94 Spectrum UBC97 Spectrum
Diaphragms	BOCA96 Spectrum NBCC95 Spectrum
Groups,	▼ IBC2003 Spectrum NEHRP97 Spectrum
Section Cuts	Delete Spectrum
Besperce Spectrum Europtions	OK Cancel
Rections	esponse Spectrum Function Definition
E Static Load Cases	Function Name Function Damping Ratio
Response Spectrum Cases	PASSPORT 0.05
MM Time History Cases,	Define Function
Static Nonlinear/ <u>P</u> ushover Cases	Period     Acceleration       1.000E-03     0.1599       Add
	1.000E-03 A 0.1599 0.01 0.1598 Modify
Here Load Combinations	0.02 0.1939 0.04 0.1873 Delete
Response Spectrum Function Definition	0.08 0.2494 0.1 0.2707
	0.12 0.14 • 0.3118 •
Function Name PASSPORT	Function Graph
Function File	
File Name Browse	
Header Lines to Skip	
	Response Spectrum Case Data
Convert to User Defined View File	
Function Graph	
	Spectrum Lase Name
The domning value is specified which is	Structural and Function Damping
The damping value is specified which is	Damping 0.05
used to generate the response spectrum	Modal Combination
curve. 5% damping factor and 9.81 (g	
scale factor is assigned as shown in	1 1 1 12
Figure	
Nefine Resnonse Spectra	Directional Combination
	© SRSS
Spectra Click to:	C ABS Orthogonal SF
	C Modified SRSS (Chinese)
PASSPORT Add New Spectrum	Input Response Spectra
Modify/Show Spectrum	Direction Function Scale Factor
	UI PASSPORT V 0.981
Delete Spectrum	
	U2 PASSPORT U.981
OK	UZ 🔽
	Excitation angle
	Excitation angle 0.

# **Step 6: Site Specific Time History**

Site specific time history is define from **Define > Time History Function** 



Run the analysis and various curves is shown from **Display > Show Story Response Plot** 





# Step 7: Design under Gravity and Seismic Load

Design is carried out using different combination. ETABS have facility to generate combination as per IS 456-2000.

	Define Load Combinations
Define         Image: Material Properties         Image: Frame Sections         Image: Wall/Slab/Deck Sections         Image: Wall/Sla	Combinations       Click to:         DCON3       Add New Combo         DCON5       Modify/Show Combo         DCON6       Delete Combo         DCON10       DCON11         DCON12       OK         Cancel       Cancel
Section Quts         Response Spectrum Functions         Time History Functions         P         Static Load Cases	Load Combination Data
<ul> <li><u>Response Spectrum Cases</u></li> <li><u>₩</u> <u>Time History Cases</u></li> <li>Static Nonlinear/<u>P</u>ushover Cases</li> <li>Add Seguential Construction Case</li> </ul>	Load Combination Type ADD Define Combination
Load Combinations         Add Default Design Combos         Convert Combos to Nonlinear Cases         Special Seismic Load Effects         ? Mass Source	Case Name Scale Factor       DEAD Static Load     0.9       EQX Static Load     -1.5       FF Static Load     0.9
	ОК

Select assigning combination for Design from **Design > Concrete Frame Design > Select Design Combination** 

Design	
<u>S</u> teel Frame Design	•
Concrete Frame Design	•
🝸 Composite Beam Design	Select Design Combo
Steel Joist Design	View/Revise <u>O</u> verwrites,
Overwrite Frame Design <u>P</u> rocedure,	Start Design/Check of Structure
	Display Design Info
	C <u>h</u> ange Design Section Re <u>s</u> et Design Section to Last Analysis
	Verify Analysis vs Design Section
	Reset All Concrete Over <u>w</u> rites
	Delete Concrete Design Results

hoose Combos List of Combos DCON2 DCON2 DCON3 DCON4 DCON5 DCON5 DCON5 DCON6 DCON7 DCON8 DCON9	> Design Combos DCON1 DCON10 DCON11 DCON12 DCON13 DCON13 DCON14 DCON15 DCON16 DCON17 DCON18
---	--

Design is carried out from **Design > Concrete Frame Design > Start Concrete Design** 

Design	
I Steel Frame Design	<ul> <li>Select Design <u>C</u>ombo</li> </ul>
Concrete Frame Design	View/Revise Overwrites,
👕 Composite Beam Design	Start Design/Check of Structure
🛣 Steel Joist Design	Takawakiwa Canawaka Ewana Danian
🕻 Shear Wall Design	Interactive Concrete Frame Design
Overwrite Frame Design Procedure	Display Design Info
5 _	Change Design Section,
	Reget Design Section to Last Analysis
	Verify Analysis vs Design Section
	Reset All Concrete Over <u>w</u> rites
	Delete Concrete Design Res <u>u</u> lts

Various results in form of percentage of steel, area of steel in column beam is shown from **Design > Concrete Frame Design > Display Design Information** 

olay Design Results		
Design Output	Rebar Percentage	•
O Design Input	Longitudinal Reinforcing Rebar Percentage Shear Reinforcing Column P-M-M Interaction Ratios	
40	Beam/Column Capacity Ratios Column/Beam Capacity Ratios General Reinforcement Details	



Select any beam member and left click to shown below figure

Story Beam	STORY1 B16		Section Name	B300×450		
сомво	STATION	тор	BOTTOM	SHEAR		
ID	LOC	STEEL	STEEL	STEEL		
DCON18	2.500	0.000	0.000	0.000		
DCON18	2.970	0.000	0.000	0.000		
DCON18	3.440	0.000	0.000	0.000		
DCON18	3.910	0.000	0.000	0.000		
DCON18	4.380	0.000	0.000	0.000		
DCON18	4.850	0.000	0.000	0.000		•
	Overwrites	Summary	Flex. Details Sh	ear Details En	velope	

Concrete [	esign l	nformat	ion Indian I	S 456-2000							
ile											
T	C 1.57	0.000	DEAN OF		FCION T.				(5)		
	3 450	-2000	BEHIT SE	CITON D	ESIGN IY	pe: Ducti	te Frame	UNILS: KM-M	(Frexur)	ar vera	(15)
Level		STOR	71	L=5.	000				r		
Element	1 1	B16		D=0.	450	B=0.30	0	bf=0.300		+++++	
Section	ID :	B300	X450	ds=0	. 000	dct=0.	040	dcb=0.040			
Combo ID		DCON	18	E=25	000000.00	fc=250	90.000	Lt.Wt. Fac.=1	.000		
Station	Loc :	4.85	9	fy=4	15000.000	i fys=41!	5000.000			2	
Gamma(Co	ncret	e): 1	500								
Gamma(St	eel)	1 i	.150								
FLEXURAL	REIN	FORCE	MENT FOR	MOMENT	, M3		Denulau				
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Flexure detailing of beam element is shown in Figure

Shear detailing of beam element is shown in Figure

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DCON19 DCON19 DCON19 DCON20	0.000 1.375 2.750 0.000	0.001 0.001 0.001 0.001	0.000 0.000 0.000 0.000	0.000 0.000 0.000 0.000		•
DCON20 DCON20	1.375 2.750	0.001 0.001	0.000 0.000	0.000 0.000		
0,	verwrites	Interaction Sum	mary Flex Details	Shear Details B/	/C Details Envelope	

Pu-Mu interaction curve, Flexural detailing, shear detailing and beam/column detailing is shown in figure.

	Р	M3	M2	-P
1	-1422.3735	0.	0.	
2	-1357.8333	23.7262	0.	
3	-1189.6562	40.415	0.	
4	-1015.1306	52.2717	0.	
5	-834.7131	59.2889	0.	M2 /
6	-650.2563	61.2191	0.	
7	-509.5157	57.4622	0.	-M3 <del>&lt; -∳∕ →</del> M3
8	-363.5744	50.2178	0.	
9	-218.4327	37.8615	0.	
10	-40.0388	18.5262	0.	
11	97.4348	0.	0.	
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16				25 🚽 Elevation PM3 PM2
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Station Loc : 2.750		RLL	F=0.90	3									1	•	
Gamma(Concrete): 1.	500								_		E	8 < •	-	•	
Gamma(Steel) : 1.	150					_						•	•	•	
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Minor Shear(V3)	0.000	23	.918	257.	451	6	8.846	<b>9</b>	. 000	68	.846				
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Major Shear(V2)	19.955	118	.238	24.	674										
Minor Shear(V3)	14.477	118	.238	23.	918										
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# Step 8: Performance based design using pushover analysis

Design is carried out as per IS 456-2000 than select all beam to assign hinge properties from Assign > Frame/Line > Frame Nonlinear Hinges command



Moment and shear (M & V) hinges are considered for beam element and axial with biaxial moment (P-M-M) hinges are considered for column element as shown in Figure

Assign Frame Hinges (Pushover)	Assign Frame Hinges (Pushover)
Frame Hinge Data         Hinge Property       Relative Distance         Default-M3       0.         Default-M3       1.         Default-M2       0.         Default-V2       1.         Default-V2       1.         Default-V2       1.         Default-V2       1.	Frame Hinge Data       Hinge Property       Relative Distance       Relative
OK Cancel	OK Cancel
Prame Hinge Property Data for B10-STORY1-H1 - M3           Edit           Point         Moment/SF           Rotation/SF           D-         -0.2           0-         -0.2           C-         -1.1           0.         0.           B-         -1           C         1.1           D         0.2           E         0.2           N         Minge is Rigid Plastic	Prame Hinge Property Data for C2-STORY4-H2 - PMM           Edit           Point         Moment/SF           0.2         -0.025           0         -0.2           0.1         -0.015           B-         -1           A         0.           B         1.           D         0.2           C         1.1           D         0.2           Scaling for Moment and Rotation           Very Yield Moment SF           Use Yield Rotation SE
Positive     Negative       Use Yield Moment     Moment SF       64.3616	Acceptance Criteria (Plastic Rotation/SF)     Positive     Negative       Immediate Occupancy     2.500E-03
Acceptance Criteria (Plastic Rotation/SF) Positive Negative Immediate Occupancy 5:000E-03 Life Safety 0:01 Collapse Prevention 0:02	Axial Load - Displacement Relationship     C Proportional to Moment - Rotation     C Elastic - Perfectly Plastic     Cancel

Defining static nonlinear load cases from **Define > Static Nonlinear/Pushover command**. For push over analysis first apply the gravity loading as PUSHDOWN shown in Figure and subsequently use lateral displacement or lateral force as PUSH 2 in sequence to derive capacity curve and demand curve as shown in Figure. Start from previous pushover case as PUSHDOWN for gravity loads is considered for lateral loading as PUSH 2.

Static Nonlinear	Case Name	PUS	HDOWN		
Options					
Contract Load to Level Defined by Pat	tern	Minimum Save	d Steps	1	
C Push to Disp. Magnitude		Maximum Null 9	Steps	50	
🔽 Use Conjugate Displ. for I	Control	Maximum Tota	Steps	200	)
Monitor 🔽 🔽 1	STORY5 -	Maximum Iteral	ions/Step	10	
Start from Previous Case	-	Iteration Tolera	nce	1.0	00E-04
🔽 Save Positive Increments Or	ily	Event Tolerand	æ	0.0	1
Member Unloading Method		Geometric Nonlin	earity Effects		
Unload Entire Structure	-	P-Delta			-
oad Pattern		Active Structure			
Load Scale Factor		_	Active Gro	oup	
FF • 1		Stage	ALL	-	Add
DEAD 1 LIVE 25	Add	1	ALL	-	Modify
FF 1	Modify				luce and
	Delete				msen
I					Delete
		📃 🗔 Loads Appli	uto Added Ele	ements	Ωnlu

Pushdown a gravity load cases

tic Nonlinear Case Data	
Static Nonlinear Case Name	PUSH2
Options	
C Load to Level Defined by Pattern	Minimum Saved Steps 10
Push to Disp. Magnitude 0.64	Maximum Null Steps 50
🔽 Use Conjugate Displ. for Control	Maximum Total Steps 200
Monitor	Maximum Iterations/Step 10
Start from Previous Case	Iteration Tolerance 1.000E-04
Save Positive Increments Only	Event Tolerance 0.01
Member Unloading Method	Geometric Nonlinearity Effects
Unload Entire Structure	P-Delta
Load Pattern	Active Structure
Load Scale Factor	Active Group
	Modify
Modify	Insert
Delete	Delete
	Loads Apply to Added Elements Only
ОК	Cancel

Push2 lateral load cases

Run the Pushover analysis from Analysis > Run Static Nonlinear Analysis command.



Review the pushover analysis results from **Display > Show Static Pushover Curve command**.



PUSH	OVER CURVE										
Step	Displacement	Base Force	А-В	B-10	IO-LS	LS-CP	CP-C	C-D	D-E	>E 1	TOTAL
0	0.0000	0.0000	818	2	0	0	0	0	0	0	820
1	0.0200	489.9547	750	70	0	0	0	0	0	0	820
2	0.0381	778.1516	732	88	0	0	0	0	0	0	820
3	0.0427	818.5428	714	106	0	0	0	0	0	0	820
4	0.0478	845.0795	688	94	38	0	0	0	0	0	820
5	0.0831	936.7535	686	88	46	0	0	0	0	0	820
6	0.0862	939.7776	672	32	50	66	0	0	0	0	820
7	0.1518	965.8489	660	42	18	100	0	0	0	0	820
8	0.1896	974.9493	654	46	4	112	0	4	0	0	820
9	0.2188	979.0764	654	46	4	112	0	0	4	0	820
10	0.2188	919.7686	654	46	4	112	0	0	4	0	820
11	0.2208	935.4454	654	46	4	108	0	4	4	0	820
12	0.2234	944.1318	654	46	4	98	0	2	16	0	820
13	0.1778	-173.1125	820	0	0	0	0	0	0	0	820



## Capacity spectrum, demand spectrum and performance point are shown in Figure

Step	Teff	ßeff	Sd(C)	Sa(C)	Sd(D)	Sa(D)	ALPHA	PF*Ø
0	0.937	0.050	0.000	0.000	0.051	0.235	1.000	1.000
1	0.937	0.050	0.015	0.071	0.051	0.235	0.821	1.299
2	1.034	0.098	0.030	0.112	0.047	0.177	0.821	1.280
3	1.070	0.117	0.034	0.118	0.046	0.162	0.821	1.274
4	1.116	0.141	0.038	0.122	0.045	0.146	0.820	1.268
5	1.406	0.232	0.067	0.136	0.048	0.097	0.816	1.247
6	1.432	0.237	0.069	0.136	0.048	0.094	0.818	1.246
7	1.928	0.292	0.124	0.134	0.059	0.064	0.853	1.229
8	2.150	0.309	0.154	0.134	0.066	0.057	0.858	1.230
9	2.307	0.318	0.178	0.135	0.071	0.053	0.860	1.230
10	2.385	0.331	0.178	0.126	0.073	0.052	0.862	1.228
11	2.377	0.333	0.180	0.128	0.073	0.052	0.863	1.228
12	2.382	0.334	0.182	0.129	0.073	0.052	0.864	1.227

Show the deform shape from **Display > Show Deform shape** 

At various stages hinge formation is shown with change the value in **step** box. Step 4 is shown in this Figure.

Load PUS	H2 Static Nonlii 💌
Step	4
Scaling	
O Auto	
Scale Factor	10.
🔽 Cubic Curve	
ΟΚ	Cancel







## **Illustrative Example**

For the illustration purpose the data is taken from SP 22 for analysis of a 15 storey RC building as shown in fig. 1(a). The live load on all the floors is  $200 \text{ kg/m}^2$  and soil below the building is hard. The site lies in zone V. All the beams are of size  $40 \times 50$  cm and slabs are 15 cm thick. The sizes of columns are  $60 \times 60$  cm in all the storeys and wall alround is 12 cm thick.

Analysis of the building

- (a) Calculation of dead load, live load and storey stiffness: Dead loads and live loads at each floor are computed and lumped. Stiffness in a storey is lumped assuming all the columns to be acting in parallel with each column contributing stiffness corresponding to  $K_c = 12EI/L^3$ , where I is the moment of inertia about bending axis, L is the column height, and E the elastic modulus of the column material. The total stiffness of storey is thus  $\Sigma K_c$ . The lumped mass at all floor level is 52.43 (t-s<sup>2</sup>/m) and at roof level is 40 (t-s<sup>2</sup>/m). The values of I,  $K_c$  and  $\Sigma K_c$  for all the floors / storeys are  $1.08 \times 10^8$  cm<sup>4</sup>, 9024 t/m and 180480 t/m, respectively. The value of modulus of elasticity of column material considered is 1880000 t/m<sup>2</sup>.
- (b) For undamped free vibration analysis the building is modeled as spring mass model. As the building is regular one degree of freedom can be considered at each floor level. Total degrees of freedom are 15. So mass and stiffness matrix are having size 15 × 15 given as in Table 1.

Stiffness matrix [k]	Mass matrix [m]
360960 - 180480 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	$52.43\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0$
$-180480\ 360960\ -180480\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0$	$0\ 52.43\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0$
0 -180480 360960 -180480 0 0 0 0 0 0 0 0 0 0 0 0	$0\ 0\ 52.43\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0$
0 0 -180480 360960 -180480 0 0 0 0 0 0 0 0 0 0 0	$0\ 0\ 0\ 52.43\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0$
0 0 0 -180480 360960 -180480 0 0 0 0 0 0 0 0 0 0	$0\ 0\ 0\ 0\ 52.43\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0$
0 0 0 0 -180480 360960 -180480 0 0 0 0 0 0 0 0	$0\ 0\ 0\ 0\ 0\ 52.43\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0$
0 0 0 0 0 -180480 360960 -180480 0 0 0 0 0 0 0	$0\ 0\ 0\ 0\ 0\ 0\ 52.43\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0$
0 0 0 0 0 -180480 360960 -180480 0 0 0 0 0 0	000000052.430000000
0 0 0 0 0 0 -180480 360960 -180480 0 0 0 0 0	$0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 52.43\ 0\ 0\ 0\ 0\ 0\ 0$
0 0 0 0 0 0 0 -180480 360960 -180480 0 0 0 0	$0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 52.43\ 0\ 0\ 0\ 0\ 0$
0 0 0 0 0 0 0 0 0 -180480 360960 -180480 0 0 0	000000000052.430000
0 0 0 0 0 0 0 0 0 0 -180480 360960 -180480 0 0	00000000000052.43000
0 0 0 0 0 0 0 0 0 0 0 -180480 360960 -180480 0	000000000000052.4300
0 0 0 0 0 0 0 0 0 0 0 0 -180480 360960 -180480	$0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 52.43\ 0$
0 0 0 0 0 0 0 0 0 0 0 0 0 0 -180480 180480	$0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0$

Table 1: Stiffness and mass matrix

The first three natural frequencies and the corresponding mode shape are determined using solution procedure of Eigen value problem i.e.  $Det([k] - \omega^2 [m]) = \{0\}$ . Time periods and mode shape factors are given in table 2.

(c) The next step is to obtain seismic forces at each floor level in each individual mode as per IS 1893. These calculations are shown in Table 3.

Mode No.	1	2	3
Period in seconds	1.042	0.348	0.210
Mode shape coeffic	cient at vari	ious floor le	evels
$\phi_1^{(r)}$	0.037	0.108	0.175
$\phi_2^{(r)}$	0.073	0.206	0.305
$\phi_3^{(r)}$	0.108	0.285	0.356
$\phi_4^{(r)}$	0.143	0.336	0.315
$\phi_5^{(r)}$	0.175	0.356	0.192
$\phi_6^{(r)}$	0.206	0.342	0.019
$\phi_7^{(r)}$	0.235	0.296	-0.158
$\phi_8^{(r)}$	0.261	0.222	-0.296
φ <sub>9</sub> <sup>(r)</sup>	0.285	0.127	-0.355
$\phi_{10}^{(r)}$	0.305	0.019	-0.324
$\phi_{11}^{(r)}$	0.323	-0.089	-0.208
$\phi_{12}^{(r)}$	0.336	-0.190	-0.039
$\phi_{13}^{(r)}$	0.347	-0.273	0.140
$\phi_{14}^{(r)}$	0.353	-0.330	0.283
φ <sub>15</sub> <sup>(r)</sup>	0.356	-0.355	0.353

Table 2. Periods and modes shape coefficients at various levels for first three modes

As per clause 7.8.4.4 of IS 1893, if the building does not have closely spaced modes, the peak response quantity due to all modes considered shall be obtained as per SRSS method. In this example as shown below, the frequencies in each mode differ by more than 10%, so building is not having closely spaced modes and so, SRSS method can be used.

Mode	Time period	Natural frequency $2\pi / T$
1	1.042	6.03
2	0.348	18.06
3	0.210	29.92

The comparison of storey shear using SRSS method and CQC method is shown in table 3. As per clause 7.8.2 of IS 1893 the design base shear ( $V_B$ ) shall be compared with base shear ( $V_B$ ) calculated using a fundamental period Ta . When  $V_B$  is less than  $V_B$ , all the response quantities (e.g. member forces, displacements, storey forces, storey shear and base reactions ) shall be multiplied by  $V_B/V_B$ . For this example  $T_a = 0.075 h^{0.75}$  for RC frame building  $T_a = 0.075 (45)^{0.75} = 1.3031 \text{ sec}$ For hard soil Sa/g =  $1.00/T_a = 1/1.3031 = 0.7674$   $\overline{V}_B = A_h W$   $W = 514.34 \times 14 + 392.4 = 7593.16 t$   $A_h = (Z I S_a) / (2 R g)$  Z = 0.36 (for zone V) I = 1.0 R = 5.0 (considering SMRF)  $A_h = (0.36 \times 1 \times 0.7674) / (2 \times 5.0) = 0.0276$ Base shear  $\overline{V}_B = 0.0276 \times 7593.16 = 209.77 t$ Base shear from dynamic analysis  $V_B = 229.9 t$ So,  $V_B > \overline{V}_B$ , response quantities need not required to be modified. The storey shear distribution along the height is shown in fig. 1 (c).

Floor	Weight	Mod	e coeffici	ents		$W_i \phi_{ik}$			$W_i \phi_{ik}^2$	
No.	$W_{i}(t)$	$\phi_{i1}$	<b>\$</b> _{i2}	\$\$\phi_{i3}\$	$W_i \phi_{i1}$	$W_i\phi_{i2}$	$W_i\phi_{i3}$	$W_i \phi_{i1}^2$	$W_i \phi_{i2}{}^2$	$W_i \phi_{i3}^2$
1	514.34	0.037	0.108	0.175	19.030	55.548	90.009	0.704	5.999	15.751
2	514.34	0.073	0.206	0.305	37.546	105.953	156.873	2.740	21.826	47.846
3	514.34	0.108	0.285	0.356	55.548	146.586	183.104	5.999	41.777	65.185
4	514.34	0.143	0.336	0.315	73.550	172.817	162.016	10.517	58.066	51.035
5	514.34	0.175	0.356	0.192	90.009	183.104	98.752	15.751	65.185	18.960
6	514.34	0.206	0.342	0.019	105.953	175.903	9.772	21.826	60.159	0.185
7	514.34	0.235	0.296	-0.158	120.869	152.244	-81.265	28.404	45.064	12.839
8	514.34	0.261	0.222	-0.296	134.242	114.183	-152.244	35.037	25.348	45.064
9	514.34	0.285	0.127	-0.355	146.586	65.320	-182.590	41.777	8.295	64.819
10	514.34	0.305	0.019	-0.324	156.873	9.772	-166.645	47.846	0.185	53.993
11	514.34	0.323	-0.089	-0.208	166.131	-45.776	-106.982	53.660	4.074	22.252
12	514.34	0.336	-0.190	-0.039	172.817	-97.724	-20.059	58.066	18.567	0.782
13	514.34	0.347	-0.273	0.140	178.475	-140.414	72.007	61.930	38.333	10.081
14	514.34	0.353	-0.330	0.283	181.561	-169.731	145.557	64.091	56.011	41.192
15	392.40	0.356	-0.355	0.353	139.694	-139.301	138.517	49.731	49.452	48.896
Total					1778.890	588.486	346.824	498.085	498.346	498.886

**Table 3: Calculation of Seismic forces** 

# Table 3: Calculation of Seismic forces (Continued)

	Mode 1	Mode 2	Mode 3
Mode participation factor $P_k = \Sigma W_i \phi_{ik} / \Sigma Wi(ik2)$	3.571456	1.180878	0.695197
Modal mass $Mk = ((Wi(ik)2/(Wi(ik2)$	6353.23	694.91	241.37
% of total mass = $Mk / (Mk)$	83.67 %	9.15 %	3.18 %
Time Period (Tk)	1.042 Sec	0.348 Sec	0.210 Sec
Sa/g	0.9596	2.5	2.5
	Z = 0.36 (zo	ne V), $I = 1.0$	,
	R = 5.0, Har	d soil	
Design horizontal spectrum value $Ak = (Z I Sa) / (2 R g)$	0.0345456	0.09	0.09
Base Reaction	219.44	62.54	21.72

Table 3: Calculation of Seismic forces (Continue)	e 3: Calci	lation of S	Seismic	forces (	Continued	I)
---	------------	-------------	---------	----------	-----------	----

Floor	Q <sub>ik</sub> =	$= A_k \phi_{ik} P_k$	Wi	$V_{ik} = \Sigma Q_i$	k		Combinat	ion of store	ey shear
NO.	Q <sub>i1</sub>	Q <sub>i2</sub>	Q <sub>i3</sub>	V <sub>i1</sub>	V <sub>i2</sub>	V <sub>i3</sub>	SAV	SRSS	CQC
1	2.348	5.903	5.631	219.497	62.543	21.699	303.741	229.263	229.911
2	4.6328	11.260	9.815	217.149	56.640	16.068	289.857	224.989	225.523
3	6.854	15.579	11.456	212.516	45.379	6.253	264.148	217.397	217.745
4	9.075	18.366	10.137	205.662	29.800	-5.203	240.665	207.875	208.027
5	11.106	19.460	6.178	196.586	11.433	-15.340	223.360	197.515	197.521
6	13.073	18.694	0.611	185.480	-8.026	-21.519	215.026	186.897	186.828
7	14.914	16.180	-5.084	172.406	-26.721	-22.130	221.258	175.863	175.763
8	16.564	12.135	-9.525	157.492	-42.901	-17.045	217.440	164.119	163.973
9	18.087	6.942	-11.424	140.928	-55.037	-7.520	203.486	151.481	151.230
10	19.356	1.038	-10.426	122.841	-61.979	3.903	188.724	137.646	137.233
11	20.498	-4.865	-6.693	103.484	-63.017	14.330	180.833	122.007	121.423
12	21.323	-10.386	-1.255	82.985	-58.152	21.024	162.162	103.491	102.803
13	22.022	-14.923	4.505	61.661	-47.766	22.279	131.707	81.118	80.450
14	22.402	-18.038	9.107	39.639	-32.843	17.773	90.257	54.460	53.949
15	17.236	-14.804	8.666	17.236	-14.804	8.666	40.708	24.318	24.075



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## Above mention 15 storey example solved in ETABS is describe follow:

(1) Generate model: Material properties are assign as per Indian Code. Beam, column and slab are define as per given above dimension. 3D model of 15 story building is shown in Fig. 2.





Fig. 2 3D model of 15 storey building

(2) Static analysis load case: Loading parameters are defined as per Indian Code as shown in Fig. 3 and 4. Consider dead load and live load as a gravity load in vertical downward direction and earthquake load as lateral load in horizontal direction. Earthquake load is defined as per IS 1893-2002.

.oads		Self Weight	Auto	Click To:
Load	Туре	Multiplier	Lateral Load	
EQX	QUAKE	• 0	IS1893 2002 💌	Modify Load
DEAD	DEAD	1		
EOX	QUAKE	0	IS1893 2002	Modify Lateral Load
EQY	QUAKE	0	IS1893 2002	Delete Load
				OK

Fig. 3 Define static load case

IS1893:2002 Seismic Loading	
Direction and Eccentricity         Image: Construct of the second secon	Seismic Coefficients Seismic Zone Factor, Z Per Code 0.36 User Defined Soil Type I Importance Factor, I 1.
Time Period       O Approximate     Ct (m)       Image: Comparent Calc       O User Defined     T =	
Story Range         Top Story       STORY15 •         Bottom Story       BASE •         Factors       Response Reduction Factor, R 5.	OK Cancel

Fig. 4 Define a seismic loading as per IS: 1893-2002

(3) Dynamic analysis: IS 1893 response spectrum curve for zone V is shown in Fig. 5. The damping value of 5% is specified to generate the response spectrum curve. The scale factor of 9.81 (i.e. g) is assigned as shown in Fig. 6.



Fig. 5 IS 1893 response Spectra Graphs



(4) The design acceleration time history for passport office site is given as input in Define menu > Time History Function. The time history load cases are defined from the Time History Cases option as shown in the Fig. 7. The acceleration time history of Passport office site as defined in ETABS is shown in Fig. 8.



Fig. 7 Time History Options





Time history case data is defined for simplicity of analysis. Number of output time steps is 300. Linear analysis case and two direction acceleration load case are considered. The scale factor 9.81 i.e. gravitational acceleration (m/sec<sup>2</sup>) and 5% damping are defined as shown in Fig. 9.



Fig. 9 Time History Case Data

(5) Mass source is defined in modeling as shown in Fig. 10. As per IS: 1893-2002, 25% live load (of 200 kg/m<sup>2</sup>) is considered on all floor of building except at roof level. (6) In building, slab is considered as a single rigid member during earthquake analysis. ETABS has a facility to create rigid diaphragm action for slab. For that, all slabs are selected first and apply diaphragm action for rigid or semi rigid condition.











Fig. 12 Time Period of different mode

Table 4 percentage	of	total	seismic	mass
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Mode	Period	UX	UY	UZ
1	1.109689	83.6450	0.0000	0.0000
2	0.371229	9.1628	0.0000	0.0000
3	0.224349	3.2049	0.0000	0.0000

Table 5 Base reaction for all modes

Mode	Dir	F1	F2	F3
1	U1	2109.86	0.00	0.00
2	U1	635.94	0.00	0.00
3	U1	222.43	0.00	0.00
All	All	2221.54	0.00	0.00

## Compare manual static and dynamic results with ETABS static and dynamic results

	М	Manual analysis			ABS Anal	ysis
Mode No.	1	2	3	1	2	3
Period in seconds	1.042	0.348	0.210	1.109	0.371	0.224
Mode shape coefficient	cient at var	ious floor le	evels			
$\phi_1^{(r)}$	0.037	0.108	0.175	0.036	0.109	0.175
$\phi_2^{(r)}$	0.073	0.206	0.305	0.073	0.206	0.304
$\phi_3^{(r)}$	0.108	0.285	0.356	0.109	0.283	0.356
$\phi_4^{(r)}$	0.143	0.336	0.315	0.143	0.336	0.315
$\phi_5^{(r)}$	0.175	0.356	0.192	0.175	0.356	0.195
$\phi_6^{(r)}$	0.206	0.342	0.019	0.206	0.342	0.023
$\phi_7^{(r)}$	0.235	0.296	-0.158	0.234	0.297	-0.154
$\phi_8^{(r)}$	0.261	0.222	-0.296	0.261	0.224	-0.290
φ <sub>9</sub> <sup>(r)</sup>	0.285	0.127	-0.355	0.283	0.129	-0.354
$\phi_{10}^{(r)}$	0.305	0.019	-0.324	0.304	0.023	-0.327
$\phi_{11}^{(r)}$	0.323	-0.089	-0.208	0.322	-0.086	-0.213
$\phi_{12}^{(r)}$	0.336	-0.190	-0.039	0.336	-0.186	-0.045
(13 (r)	0.347	-0.273	0.140	0.345	-0.270	0.134
(14 (r)	0.353	-0.330	0.283	0.351	-0.327	0.277
(15 (r)	0.356	-0.355	0.353	0.356	-0.354	0.351

Table 6. Periods and modes shape coefficients at various levels for first three modes

Table 7. Compare the time period, mass participation and base reaction

Mode	Time per	riod (sec)	Percentag Seismi	ge of Total c Mass	Base reaction (kN)		
	Manual	ETABS	Manual	ETABS	Manual	ETABS	
1	1.042	1.109	83.67	83.64	2194.40	2109.86	
2	0.348	0.348 0.371 9.15 9		9.16	625.43	635.94	
3	0.210	0.224	3.18	3.20	217.21	222.43	

		Static A	nalysis			Dynamic	Passport o Time Histor	ffice Site y Analysis		
Story No.	Story She	ear (kN)	Story Force (kN)		Story Shear (kN)		Story Force (kN)		Story Shear (kN)	Story Force (kN)
	Manual	ETABS	Manual	ETABS	Manual	ETABS	Manual	ETABS	ETABS	ETABS
15	303.55	325.46	303.55	325.46	243.10	252.87	243.10	252.87	114.15	114.15
14	650.00	673.89	346.46	348.43	544.60	545.14	301.50	292.27	250.58	136.43
13	948.73	974.33	298.73	300.44	811.10	801.74	266.50	256.60	378.82	128.24
12	1203.27	1230.33	254.54	256.00	1034.90	1015.87	223.80	214.13	495.44	116.62
11	1417.16	1445.43	213.88	215.10	1220.00	1191.48	185.10	175.61	598.18	102.74
10	1593.92	1623.21	176.76	177.78	1376.40	1338.91	156.40	147.43	686.07	87.89
9	1737.10	1767.20	143.18	143.99	1514.80	1468.49	138.40	129.58	759.32	73.25
8	1850.23	1880.98	113.13	113.78	1641.10	1586.46	126.30	117.97	819.05	59.73
7	1936.84	1968.09	86.61	87.11	1758.60	1695.82	117.50	109.36	866.9	47.85
6	2000.48	2032.09	63.64	64.00	1868.90	1799.56	110.30	103.74	904.69	37.79
5	2044.67	2076.53	44.19	44.44	1975.10	1901.64	106.20	102.08	934.11	29.42
4	2072.95	2104.97	28.28	28.44	2078.70	2003.54	103.60	101.90	956.48	22.37
3	2088.86	2120.97	15.91	16.00	2173.90	2099.83	95.20	96.29	972.71	16.23
2	2095.93	2128.09	7.07	7.12	2249.80	2177.58	75.90	77.75	983.34	10.63
1	2097.70	2129.86	1.77	1.77	2292.60	2221.55	42.80	43.97	993.82	10.48
0	2097.70	2130.00	0.00	0.00	2292.60	2221.60	0.00	0.00	993.82	0

Table 8 comparison of Static Dynamic and Time history analysis



## TORSION ANALYSIS OF BUILDING

**EXAMPLE:** A four storeyed building (with load 300 kg/m<sup>2</sup>) has plan as shown in Fig. 1 and is to be designed in seismic zone III. Work out the seismic shears in the various storeys of the proposed building. The foundation is on hard soil and importance factor is 1.0 (Data from SP- 22 : 1982)

As building is having height 12 m and is in zone III, earthquake forces can be calculated by seismic coefficient method using design spectrum.

## (a) Lumped mass Calculation

Total weight of beams in a storey =  $27 \times 7.5 \times 0.4 \times 0.5 \times 2.4 = 97.2$  t Total weight of columns in a storey =  $18 \times 3 \times 0.4 \times 0.6 \times 2.4 = 31.10$  t Total weight of slab in a storey =  $(22.5 \times 15 + 15 \times 15) \times 0.15 \times 2.4 = 202.5$  t Total weight of walls =  $(22.5 + 15 + 7.5 + 30 + 15 + 15 - 6 \times 0.6 - 8 \times 0.4) \times 0.2 \times 3 \times 2.0$ = 117.8 tLive load in each floor =  $(22.5 \times 15 + 15 \times 15) \times 0.3 \times 0.25 = 42.18$  t Lumped weight at floor 1, 2 and 3 = Dead load + Live load= (97.2 + 31.10 + 202.5 + 117.8) + 42.18 = 490.8 tLumped weight at roof floor = Dead load (97.2 + 31.10/2 + 202.5 + 117.8/2) = 374.17 tTotal weight of building W =  $490.8 \times 3 + 374.17 = 1846.57$  t (b) Base shear calculation: Base shear  $V_B = A_h W$  $A_{h} = (Z I S_{a}) / (2 R g)$ Z = 0.16 (Zone III) I = 1.0R = 5 (considering SMRF)  $T = 0.075 \times h^{0.75}$  $= 0.075 \times 12^{0.75} = 0.4836$  sec  $S_a/g = 1/0.4836 = 2.07$  $A_h = (0.16 \times 1.0 \times 2.07) / (2 \times 5) = 0.033$  $V_B = 0.033 \times 1846.57 = 60.94 t$ 

## (c) Shear force in various storeys

Calculation of storey shear distribution along height is shown in Table 1.

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#### (d) Calculation of eccentricity

Assuming mass is uniformly distributed over the area

Horizontal distance of center of mass

 $X_m = (15 \times 22.5 \times 7.5 + 15 \times 15 \times 22.5) / (15 \times 22.5 + 15 \times 15) = 13.5 m$ 

Vertical distance of center of mass

 $Y_m = (15 \times 22.5 \times 11.25 + 15 \times 15 \times 7.5) / (15 \times 22.5 + 15 \times 15) = 9.75 \text{ m}$ 

As columns are of equal size their stiffness are also same. So horizontal distance of center of rigidity,

 $X_r = (4 \times 7.5 + 4 \times 15 + 3 \times 22.5 + 3 \times 30) / 18 = 13.75 m$ 

Vertical distance of center of rigidity,

 $Y_r = (5 \times 7.5 + 5 \times 15 + 3 \times 22.5) / 18 = 10 \text{ m}$ 

Static eccentricity in X direction =  $e_{si} = X_r - X_m = 13.75 - 13.5 = 0.25m$ 

Design eccentricity in X direction =  $1.5 \times 0.25 + 0.05 \times 30 = 1.875$  m

$$Or = 0.25 - 1.5 = -1.25 \text{ m}$$

Static eccentricity in Y direction =  $e_{si} = Y_r - Y_m = 10.00 - 9.75 = 0.25m$ 

Design eccentricity in Y direction =  $1.5 \times 0.25 + 0.05 \times 22.5 = 1.5$  m

Or = 0.25 - 1.125 = -0.875 m

The center of mass and center of rigidity and design eccentricity are shown in Fig. 2.

Total rotational stiffness Ip =  $\Sigma(K_x y^2 + K_y x^2)$ 

 $K_x$  = Stiffness of one column in X direction = 12 EI / L<sup>3</sup>

 $= 12 \times 1880000 \times (0.6 \times 0.4^{3}/12)/3^{3} = 2673.78 \text{ t/m}$ 

 $K_v =$ Stiffness of one column in Y direction = 12 EI / L<sup>3</sup>

$$= 12 \times 1880000 \times (0.4 \times 0.6^3/12)/3^3 = 6016.00 \text{ t/m}$$

$$K_x y^2 = 2673.78 \times (5(10^2) + 5(2.5^2) + 5(5^2) + 3(12.5^2)) = 3008002.5$$

$$K_y x^2 = 6016.0 \times (4(13.75^2) + 4(6.25^2) + 4(1.25^2) + 3(8.75^2) + 3(16.25^2))$$

 $I_p = 3008002.5 + 11674799.0 = 14682802.5$ 

## (e) Torsional due to seismic force in X direction

Torsional moment T at various floors is considering seismic force in X direction only is shown in Table 3.

Torsional shear at each column line is worked out as follows using following equation:

 $V_x = (T/I_p) \times y \times K_{xx}$ 

 $K_{xx} = 5 \times K_x$  (for column line 1, 2, 3)

 $= 3 \times K_x$  (for column line 4)

 $K_{yy} = 4 \times K_y$  (for column line A, B, C)

 $= 3 \times K_y$  (for column line D, E)

Additional shear due to torsional moments in columns at various floor levels are shown in Table 4.

## (f) Torsional due to seismic force in Y direction

Torsional moment T at various floors is considering seismic force in Y direction only is shown in Table 5.

Torsional shear at each column line is worked out as follows using following equation:

 $V_y = (T/I_p) \times x \times K_{yy}$ 

Additional shear due to torsional moments in columns at various floor levels are shown in Table 6.

As per the codal provisions only positive values or additive shear should be considered. This shear is to be added in to shear force resisted by columns due to seismic force in respective directions. Y



Fig. 1 Example



Fig. 2 Position of Center of Mass, Center of Rigidity and Design Eccentricities



Fig. 3 Plan and 3D view of modeled building in ETABS

Floor	W <sub>i</sub> t	h <sub>i</sub> m	$W_i h_i^2$	Q <sub>i</sub> t	V <sub>i</sub> t
1	490.8	3	4417.20	2.32	60.94
2	490.8	6	17668.80	9.30	58.61
3	490.8	9	39754.80	20.93	49.30
4	374.17	12	53880.48	28.37	28.37
			1157212.80		

Table:1 Storey shear at various floors (manual)

Floor	Weight of each	height	Storey shear
1	487.55	3.00	59.90
2	487.55	6.00	57.66
3	487.55	9.00	48.70
4	388.13	12.00	28.54

## Table: 2 Storey shear (tone) from ETABS

Story	Snears											
Edit	dit View											
	Story	Load	Loc	Р								
►	STORY4	DL025LL	Тор	3570.30								
	STORY4	DL025LL	Bottom	3881.34								
	STORY3	DL025LL	Тор	8445.77								
	STORY3	DL025LL	Bottom	8756.81								
	STORY2	DL025LL	Тор	13321.23								
	STORY2	DL025LL	Bottom	13632.27								
	STORY1	DL025LL	Тор	18196.70								
	STORY1	DL025LL	Bottom 🖊	18507.74								

18507.74 - 13632.27 =4875.5 kN (seismic weight of first storey)



Fig. 4 Storey shear (kN) in ETABS for earthquake in X direction

С	Center Mass Rigidity												
E	dit	View											
	Center Mass Rigidity 🗸 🗸										*		
[		Story	Diaphra <u>c</u>	MassX	MassY	XCM	YCM	CumMassX	CumMassY	XCCM	YCCM	XCR	YCR
	•	STORY4	D1	373.3691	373.3691	13.606	9.854	373.3691	373.3691	13.606	9.854	13.376	9.760
		STORY3	D1	490.6002	490.6002	13.640	9.889	863.9693	863.9693	13.626	9.874	13.410	9.776
		STORY2	D1	490.6002	490.6002	13.640	9.889	1354.5696	1354.5696	13.631	9.879	13.457	9.802
		STORY1	D1	490.6002	490.6002	13.640	9.889	1845.1698	1845.1698	13.633	9.882	13.560	9.868

Fig. 5 Centre of mass and centre of rigidity at each storey in ETABS

Torsional moment in	$e_{di} = 1.5 m$	$e_{di} = -0.875 \text{ m}$
Storey 1 T <sub>1</sub>	$60.94 \times 1.5 = 91.41$	-53.32
Storey 2 T <sub>2</sub>	58.61×1.5 = 87.92	-51.28
Storey 3 T <sub>3</sub>	49.30× 1.5 = 73.96	-43.14
Storey 4 T <sub>4</sub>	$28.37 \times 1.5 = 42.56$	-24.82

Table: 3 Torsional moment due to seismic force in X direction

Table: 4 Additional shear due to seismic force in X direction

Column	First storey			Total	Second storey		Total	Third storey			Total	Fourth Storey			Total	
line	(shear in one column)			shear	(shear in one column)		shear	(shear in one column)			shear	(shear in one column)		mn)	shear	
	Direct	Torsional Shear V <sub>a</sub>	Total	from ETABS	Direct	Torsional Shear V <sub>r</sub>	Total	from ETABS	Direct	Torsional Shear V <sub>a</sub>	Total	from ETABS	Direct	Torsional Shear V.	Total	from ETABS
1 y = 10	3.39	+0.83	4.22	16.79	2.26	0.80	4.06	16.30	2.74	+0.67	3.41	13.63	1.58	+0.39	1.97	7.86
m		(-0.49)	2.90		5.20	(-0.47)	2.79		2.74	(-0.39)	2.35			(-0.23)	1.35	
2 y = 2.5	3.39	+0.21	3.60	16.80	2.20	0.20	3.46	16.45	2.74	+0.17	2.91	13.70	1.58	+0.10	1.68	7.92
m		(-0.12)	3.27		3.26	(-0.12)	3.14		2.74	(-0.10)	2.64			(-0.06)	1.52	
2 5	3.39	-0.42	2.97	16.80	2.26	-0.40	2.86	16.55	2.74	-0.34	2.40	13.75	1.58	-0.19	1.39	7.96
5 y = 5 m		(+0.24)	3.63		5.20	(+0.23)	3.49		2.74	(+0.20)	2.94			(+0.11)	1.69	
4 y =	2 20	-0.62	2.77	9.48	2.26	-0.60	2.66	8.28	2.74	-0.51	2.23	7.36	1 59	-0.29	1.29	4.10
12.5 m	5.59	(+0.36)	3.75		5.20	(+0.35)	3.61		2.74	(+0.29)	3.03		1.38	(+0.17)	1.75	
			62.18	50.97			59.81	57 50			50.28	10 12			29.00	27.05
			60.17	39.87			57.86	37.38			48.73	40.43			27.98	27.85



Fig. 7 Shear force (kN) in column line 3 and line 4 due to earthquake force in X direction

Torsional moment in	$e_{di} = 1.875 \text{ m}$	$e_{di} = -1.25 \text{ m}$
Storey 1 T <sub>1</sub>	60.94 × 1.875 = 114.26	-76.18
Storey 2 T <sub>2</sub>	58.61 × 1.875 = 109.90	-73.27
Storey 3 T <sub>3</sub>	$49.30 \times 1.875 = 92.45$	-61.64
Storey 4 T <sub>4</sub>	$28.37 \times 1.875 = 53.20$	-35.47

Table: 5 Torsional moment due to seismic force in Y direction

Table: 6 Additional shears due to seismic force in Y direction

Column line	First storey (shear in one column)			Total shear	Second storey (shear in one column)			Total shear	Third storey (shear in one column)			Total shear	Fourth Storey (shear in one column)		, imn)	Total shear
	Direct	Torsional Shear V <sub>y</sub>	Total	from ETABS	Direct	Torsional Shear V <sub>y</sub>	Total	from ETABS	Direct	Torsional Shear V <sub>y</sub>	Total	from ETABS	Direct	Torsional Shear V <sub>y</sub>	Total	from ETABS
A		+2.57	5.96	13.44		+2.48	5.74	12.88		+2.08	4.82	10.87		+1.20	2.78	6.25
A x = 13.75 m	3.39	(-1.72)	1.67		3.26	(-1.65)	1.61		2.74	(-1.39)	1.35		1.58	(-0.80)	0.78	
B x =	2 20	+1.17	4.56	13.485	2.26	+1.13	4.39	13.16	2.74	+0.95	3.69	11.00	1 50	+0.54	2.12	6.38
6.25 m	5.59	(-0.78)	2.61		5.20	(-0.75)	2.51		2.74	(-0.63)	2.11		1.38	(-0.36)	1.22	
C x =	3.39	-0.23	3.16	13.514	2.26	-0.22	3.04	13.40	2.74	-0.19	2.55	11.11	1.58	-0.11	1.47	6.50
1.25 m		(+0.16)	3.55		5.20	(+0.15)	3.41		2.74	(+0.13)	2.87			(+0.07)	1.65	
D x =	2 20	-1.23	2.16	9.707	2.26	-1.18	2.08	8.99	2.74	-0.99	1.75	7.69	1 50	-0.57	1.01	4.33
8.75 m	5.59	(+0.82)	4.21		5.20	(+0.79)	4.05		2.74	(+0.66)	3.40		1.38	(+0.38)	1.96	
E x =	0.00	-2.28	1.11	9.721	2.24	-2.20	1.06	9.15	0.74	-1.85	0.89	7.77	1 50	-1.06	0.52	4.40
16.25 m	3.39	(+1.52)	4.91		3.26	(+1.46)	4.72		2.74	(+1.23)	3.97		1.58	(+0.71)	2.29	
			64.48	50.87			62.03	57 50			52.15	19 12			30.00	27.85
			58.63	37.07		56.36		57.58			47.42	40.45			27.28	21.83



Fig. 9 Shear force (kN) in column line D and E due to earthquake force in Y direction