

FEAKalc3D

Response Spectrum Analysis Verification Report

Comparison with ETABS for one concrete building benchmark

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Verified by Rabee Kafina CEng MStructE MIEAust CPEng NER

1. Introduction

This report compares the linear elastic response-spectrum results of FEAkalc3D and ETABS for Model 1, an irregular concrete building. The SpecX case uses the same reference spectrum, six Ritz modes, CQC modal combination, SRSS directional combination and 5% diaphragm eccentricity. The comparison extends the completed modal-analysis verification to spectrum response recovery and reporting.

FEAkalc is in agreement with ETABS across the principal response measures examined. Base shear differs by -0.61% in X and $+1.72\%$ in Y, all six reported periods agree within 0.83% , and the base moments agree within $\sim 4\%$. The storey shear and floor response plots support this strong overall agreement, with their respective reporting definitions kept clear.

2. Verification findings

Quantity	ETABS	FEAkalc	Difference
Base shear X	2440.5 kN	2425.5 kN	-0.61%
Base shear Y	1354.1 kN	1377.4 kN	$+1.72\%$
Overturning moment My	38044.4 kN m	37903 kN m	-0.37%
Torsional moment Mz	36712.6 kN m	38315 kN m	$+4.36\%$
Fundamental period	2.134 s	2.1231 s	-0.51%
Mass retained X	90.50%	90.437%	-0.063 pp
Mass retained Y	92.34%	92.365%	$+0.025$ pp

Differences are $100 \times (\text{FEAkalc} / \text{ETABS} - 1)$, calculated from the displayed figures. Mass-capture differences are percentage points (pp). The comparison is descriptive; no numerical acceptance threshold has been imposed.

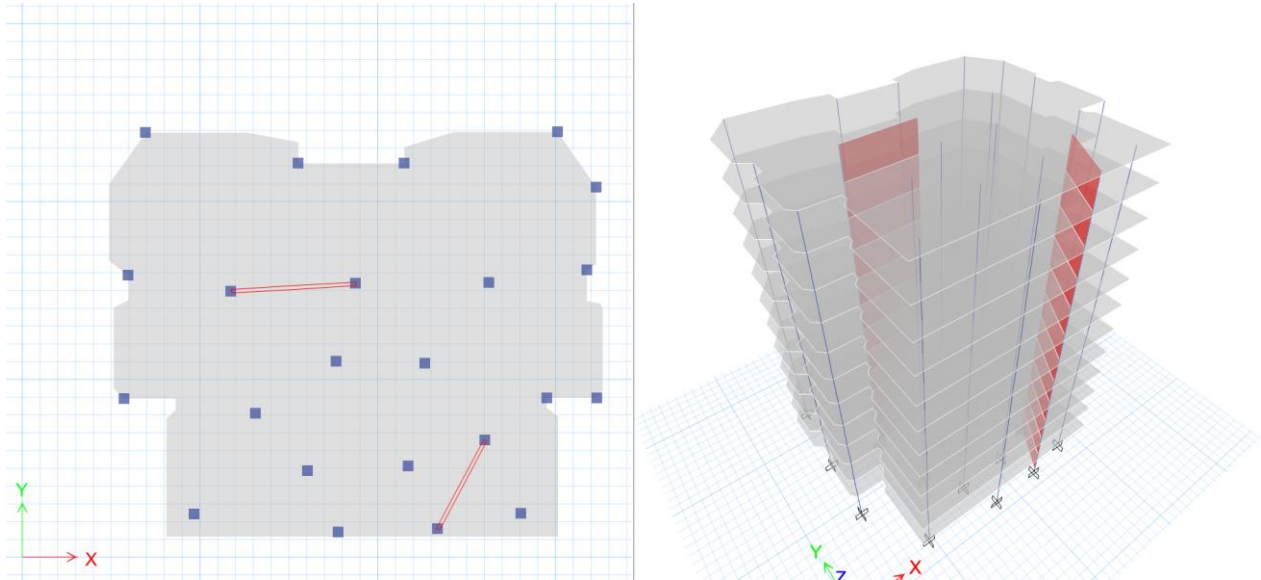
2.1. Verification scope

One building model is included, supported by the completed modal verification. This case checks how the retained modal response is recovered into global spectrum forces and floor response. Confidence comes from consistent agreement across periods, mass participation, base actions and deformation profiles, rather than from a single matching result.

3. Model geometry and structural arrangement

Model 1 has an irregular concrete floor plate supported by columns and two wall alignments. Twelve slab elevations extend from 0 to 33 m at 3 m intervals, above the support base at -3 m. The saved FEAkalc model contains 276 frame objects, 12 slab polygons and 24 wall panels. Diaphragm D1 is defined as semi-rigid.

ETABS



FEAkalc

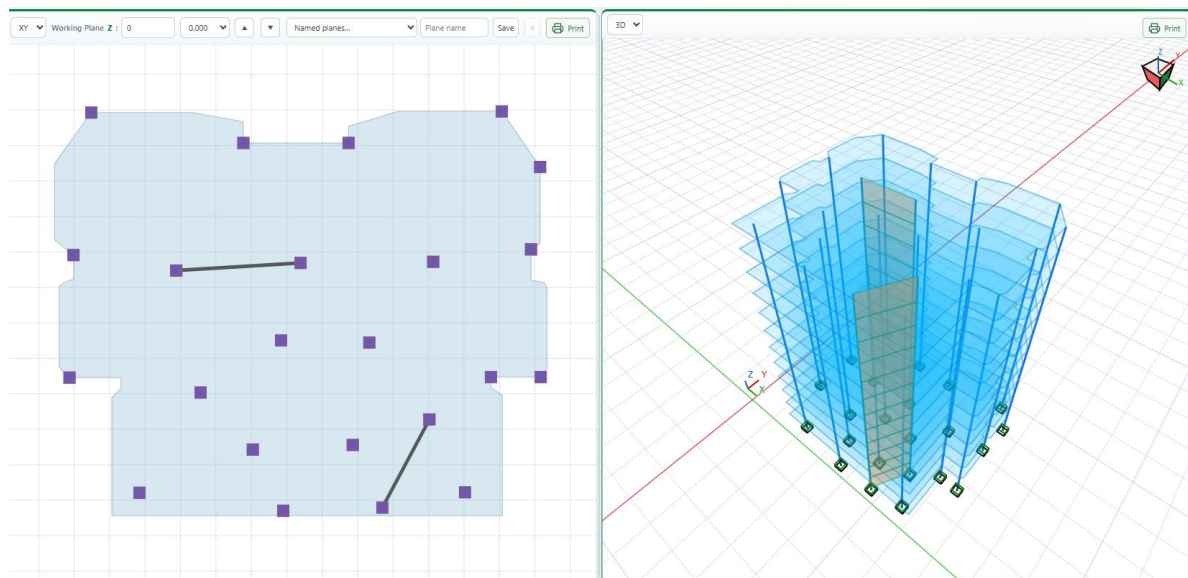


Figure 1. Plan and three-dimensional views of Model 1. The irregular floor outline, column positions and wall alignments are represented in both applications.

The saved FEAkalc mesh setup specifies 1.0 m Smooth Quad slabs and rectangular wall meshing.

Mesh topology and software display scales are independent; this comparison does not assume identical node or element layouts.

4. Response spectrum function

The reference function is AS 1170.4—2007, using site subsoil class C, probability factor $k_p = 1.3$, hazard factor $Z = 0.09$, structural performance factor $S_p = 0.77$ and ductility factor $\mu = 2$. Function damping is 5%. FEAKalc retains the 23-point reference table as dimensionless S_a/g ordinates; the C_e label in its interface accompanies the saved Class C reference.

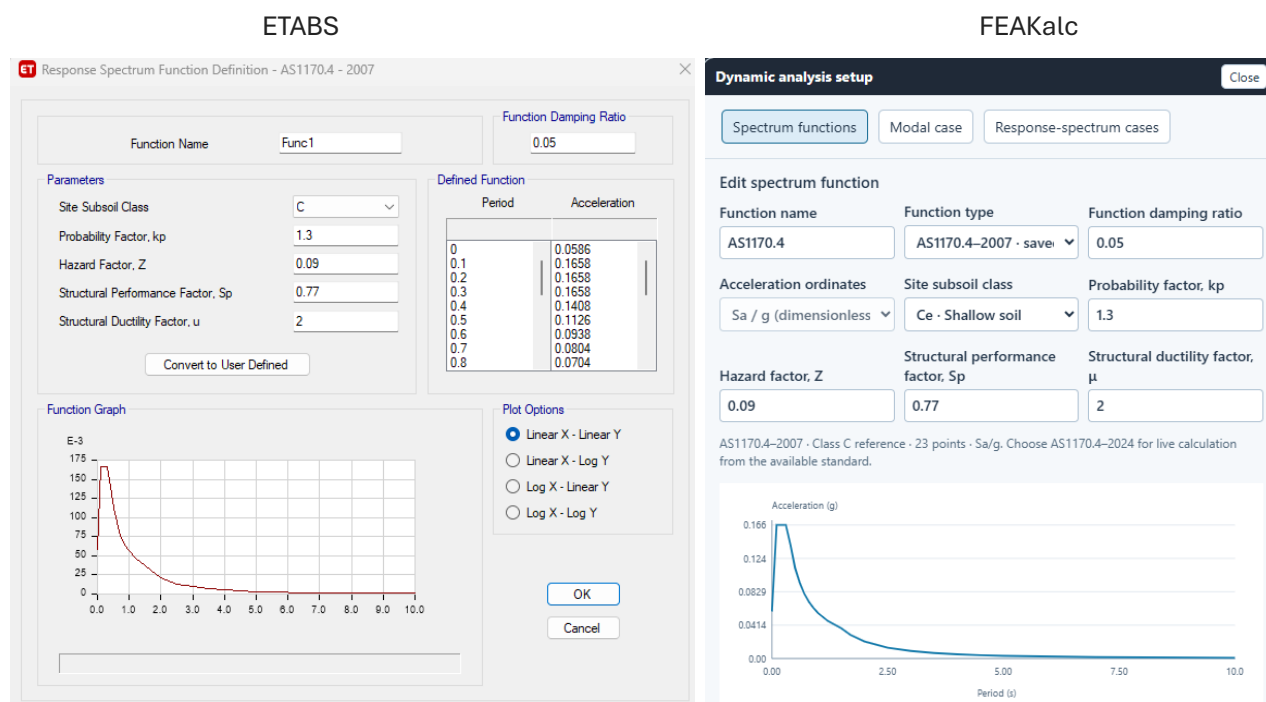


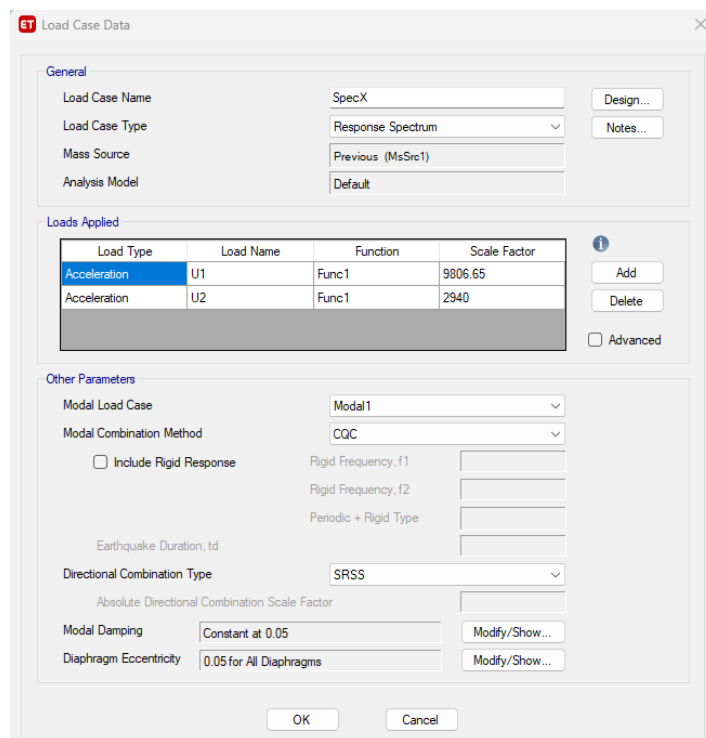
Figure 2. Spectrum-function definitions. ETABS is left and FEAKalc right. The comparison uses the retained AS 1170.4—2007 reference curve.

Parameter	ETABS	FEAKalc
Site reference	C	Class C saved reference
k_p / Z	1.3 / 0.09	1.3 / 0.09
S_p / μ	0.77 / 2	0.77 / 2
Function damping	0.05	0.05
S_a/g at $T = 0$ s	0.0586 displayed	0.058559 saved
S_a/g at $T = 0.1$ s	0.1658 displayed	0.165766 saved

Acceleration ordinates are converted to the solver acceleration units once through the case scale factor. The reference curve is an input to this software comparison; the report does not rederive or certify the spectrum parameters for a particular site.

5. Spectrum case and combination conventions

ETABS



Load Case Data

General

Load Case Name: SpecX
 Load Case Type: Response Spectrum
 Mass Source: Previous (MSrc1)
 Analysis Model: Default

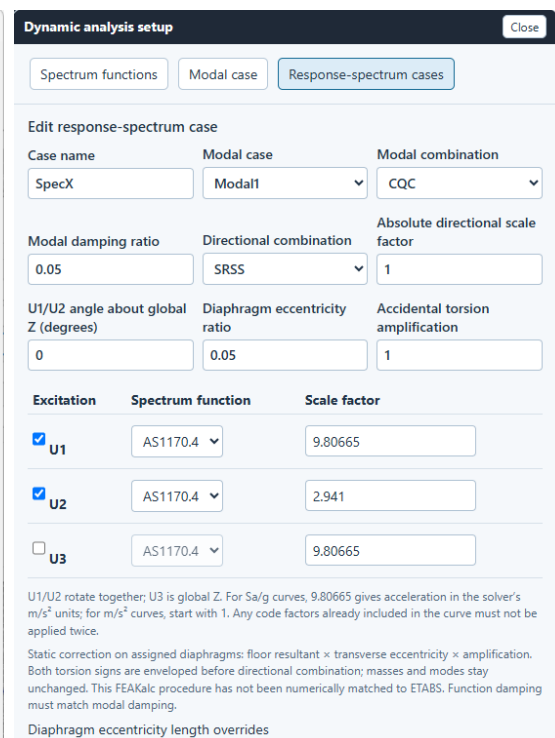
Loads Applied

Load Type	Load Name	Function	Scale Factor
Acceleration	U1	Func1	9806.65
Acceleration	U2	Func1	2940

Other Parameters

Modal Load Case: Modal1
 Modal Combination Method: CQC
☐ Include Rigid Response
 Rigid Frequency, f1:
 Rigid Frequency, f2:
 Periodic + Rigid Type:
 Earthquake Duration, td:
 Directional Combination Type: SRSS
 Absolute Directional Combination Scale Factor:
 Modal Damping: Constant at 0.05
 Diaphragm Eccentricity: 0.05 for All Diaphragms

FEAKalc



Dynamic analysis setup

Response-spectrum cases

Edit response-spectrum case

Case name: SpecX
 Modal case: Modal1
 Modal combination: CQC

Modal damping ratio: 0.05
 Directional combination: SRSS
 Absolute directional scale factor: 1

U1/U2 angle about global Z (degrees): 0
 Diaphragm eccentricity ratio: 0.05
 Accidental torsion amplification: 1

Excitation	Spectrum function	Scale factor
☒ U1	AS1170.4	9.80665
☒ U2	AS1170.4	2.941
☐ U3	AS1170.4	9.80665

U1/U2 rotate together; U3 is global Z. For Sa/g curves, 9.80665 gives acceleration in the solver's m/s² units; for m/s² curves, start with 1. Any code factors already included in the curve must not be applied twice.

Static correction on assigned diaphragms: floor resultant × transverse eccentricity × amplification. Both torsion signs are enveloped before directional combination; masses and modes stay unchanged. This FEAKalc procedure has not been numerically matched to ETABS. Function damping must match modal damping.

Diaphragm eccentricity length overrides

Figure 3. SpecX case definitions. Both use Modal1, CQC, SRSS, 5% modal damping and 5% diaphragm eccentricity; FEAKalc torsion amplification is 1.0.

Setting	ETABS	FEAKalc
U1 acceleration scale	9806.65 mm/s ²	9.80665 m/s ²
U2 acceleration scale	2940 mm/s ²	2.941 m/s ²
Modal damping	5%	5%
Horizontal rotation	0 degrees	0 degrees
Vertical excitation	Not applied	Not applied

The U2 inputs differ by 0.001 m/s², or 0.034% of the ETABS value. This small input difference is retained in the comparison rather than concealed by normalisation. Function damping and case modal damping are both 5%; the case damping controls modal correlation [R1].

FEAKalc applies signed static accidental-torsion corrections for each excitation direction and envelopes both torsional signs before combining directions.

The ETABS comparison assigns the semi-rigid D1 diaphragm to the slab area objects as well as the original joints, so that generated floor mesh nodes are included in the diaphragm loading. Consistent assignments are as important as matching the numerical case settings.

6. Modal basis used for spectrum analysis

Both spectrum cases use six Ritz modes with horizontal starting excitations. The figures below document the actual retained basis for this response-spectrum comparison, rather than importing the twelve-vector results from the earlier modal report.

ETABS

	Case	Mode	Period sec	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	s
▶	Modal1	1	2.134	0.0302	0.4525	2.793E-06	0.0302	0.4525	2.793E-06	0.1045	0.0058	0.2848	
	Modal1	2	1.074	0.2023	0.1244	3.981E-05	0.2325	0.577	4.261E-05	0.0439	0.0677	0.3467	
	Modal1	3	0.922	0.4482	0.1377	1.456E-06	0.6808	0.7147	4.406E-05	0.0683	0.1485	0.0818	
	Modal1	4	0.647	0.0009	0.0741	8.843E-06	0.6817	0.7887	0.0001	0.179	0.0213	0.0357	
	Modal1	5	0.251	0.0413	0.0953	0.0001	0.7229	0.884	0.0001	0.1271	0.0486	0.0166	
	Modal1	6	0.204	0.182	0.0394	1.355E-05	0.905	0.9234	0.0001	0.0491	0.2212	0.0001	

FEAKalc

U1 · retained mass 90.44%								
Mode	T (s)	Γ	Sa (m/s ²)	Sd (m)	Effective mass (kg)	Mass (%)	Cumulative (%)	Modal base shear (kN)
1	2.1231	357.39	0.18861	0.021536	1.2773e+5	2.9150	2.9150	24.091
2	1.0704	-964.20	0.51976	0.015086	9.2968e+5	21.217	24.132	483.22
3	0.91439	1387.8	0.60470	0.012807	1.9259e+6	43.952	68.084	1164.6
4	0.64314	-52.516	0.86358	0.0090480	2758.0	0.062941	68.147	2.3817
5	0.24942	440.80	1.6256	0.0025616	1.9431e+5	4.4344	72.581	315.87
6	0.20301	-884.55	1.6256	0.0016970	7.8243e+5	17.856	90.437	1271.9
U2 · retained mass 92.36%								
Mode	T (s)	Γ	Sa (m/s ²)	Sd (m)	Effective mass (kg)	Mass (%)	Cumulative (%)	Modal base shear (kN)
1	2.1231	-1409.3	0.056563	0.0064585	1.9860e+6	45.324	45.324	112.34
2	1.0704	729.05	0.15588	0.0045242	5.3151e+5	12.130	57.454	82.850
3	0.91439	780.86	0.18135	0.0038408	6.0974e+5	13.915	71.370	110.58
4	0.64314	573.81	0.25899	0.0027135	3.2926e+5	7.5143	78.884	85.275
5	0.24942	-639.33	0.48752	0.00076824	4.0874e+5	9.3282	88.212	199.27
6	0.20301	-426.58	0.48752	0.00050892	1.8197e+5	4.1529	92.365	88.714

Figure 4. Six-mode periods and horizontal mass participation. ETABS ratios are fractions; the FEAKalc case tables display cumulative percentages for each excitation.

Mode	ETABS period s	FEAKalc period s	Difference
1	2.134	2.12310	-0.51%
2	1.074	1.07040	-0.34%
3	0.922	0.91439	-0.83%
4	0.647	0.64314	-0.60%
5	0.251	0.24942	-0.63%
6	0.204	0.20301	-0.49%

Final cumulative mass capture is 90.50% X and 92.34% Y in ETABS, against 90.437% X and 92.365% Y in FEAKalc. These differ by -0.063 and +0.025 percentage points. The six-period comparison has a maximum absolute difference of 0.83%; the underlying modal formulation was assessed separately in the completed modal-analysis verification.

7. Base reactions and reference point

Both base-resultant reports use the reference point (X, Y, Z) = (0, 0, -3) m. This common elevation is essential when comparing overturning moments. The table uses the SpecX row and the displayed FEAkalc resultants.

ETABS

	Output Case	Case Type	Step Type	FX kN	FY kN	FZ kN	MX kN-m	MY kN-m	MZ kN-m	X m	Y m	Z m
►	Dead	LinStatic		0	0	43274.8	537749	-828063	0	0	0	-3
	Live	LinStatic		0	0	0	0	0	0	0	0	-3
	SpecX	LinRespSpec	Max	2440.5	1354.1	16.9	19265.4	38044.4	36712.6	0	0	-3

FEAkalc

SpecX · CQC / SRSS

Show results in active pane

Base resultants: Fx: 2425.5 · Fy: 1377.4 · Fz: 17.976 · Mx: 19514 · My: 37903 · Mz: 38315

Base reaction reference point (X, Y, Z): (0.0000, 0.0000, -3.0000) m.

Static accidental torsion

Figure 5. SpecX base resultants about (0, 0, -3) m. Values are statistically combined response magnitudes, rather than simultaneous signed actions.

Component	ETABS	FEAkalc	Difference
Fx kN	2440.5	2425.5	-0.61%
Fy kN	1354.1	1377.4	+1.72%
Fz kN	16.9	17.976	+6.37%
Mx kN m	19265.4	19514	+1.29%
My kN m	38044.4	37903	-0.37%
Mz kN m	36712.6	38315	+4.36%

Horizontal shear differences are below 1.8%, while the two overturning moments differ by -0.37% and +1.29%. The vertical resultant differs by +6.37%, but is small relative to the horizontal resultants. Vertical ground excitation is not applied; a vertical response can nevertheless arise from the coupled three-dimensional modes.

The ETABS torsional resultant is 36,712.6 kN m, compared with 38,315 kN m in FEAkalc: a difference of +4.36%. With diaphragm assignments aligned, this is close agreement for the combined 5% accidental-eccentricity case. The comparison illustrates why matching the physical scope of the loading is essential before judging a numerical difference.

Signed reactions are summed within each mode before CQC and directional combination. Independently combined support peaks must not be added to reproduce a base resultant [R2]. Likewise, a peak moment cannot be shifted to another reference by simply multiplying a separately combined peak force by the height offset.

8. Storey shear comparison

The ETABS plot reports whole-building global X and Y storey shears, including the base. Its maximum displayed X shear is 2440.504503 kN at the base, consistent with the Base Reactions table. ETABS uses a stepped storey representation with values on either side of the floor levels.

ETABS

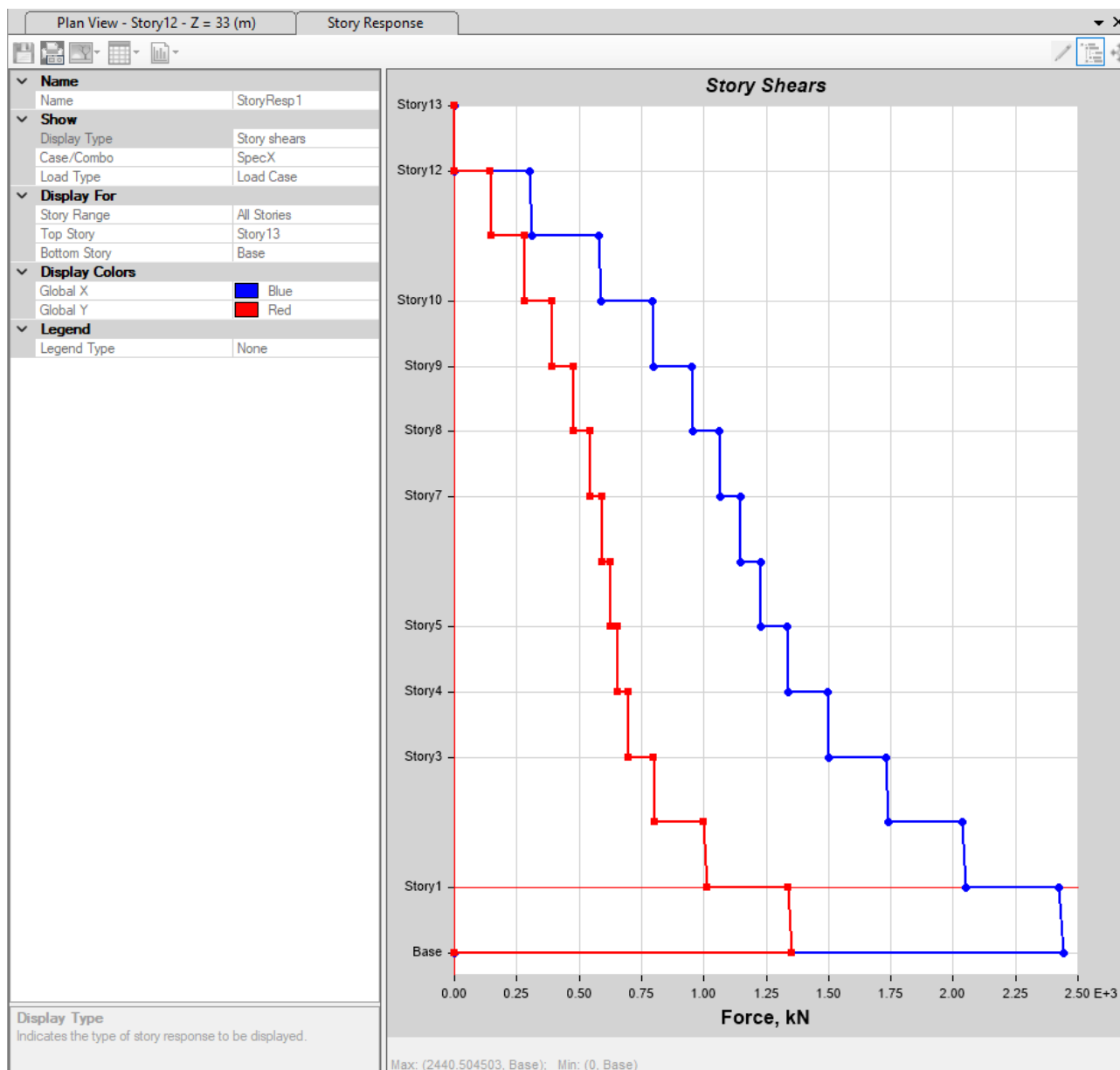


Figure 6. ETABS SpecX storey shears. Blue is global X and red global Y. The horizontal axis is force in kN with an E+3 scale factor.

8.1. FEAKalc storey shear recovery

FEAKalc reports whole-building cuts at assigned diaphragm elevations and the modal base: 13 cuts from –3 to 33 m. The curve shows recovered shear at those elevations, with straight segments joining points; it does not duplicate ETABS' stepped top-and-bottom presentation.

FEAKalc

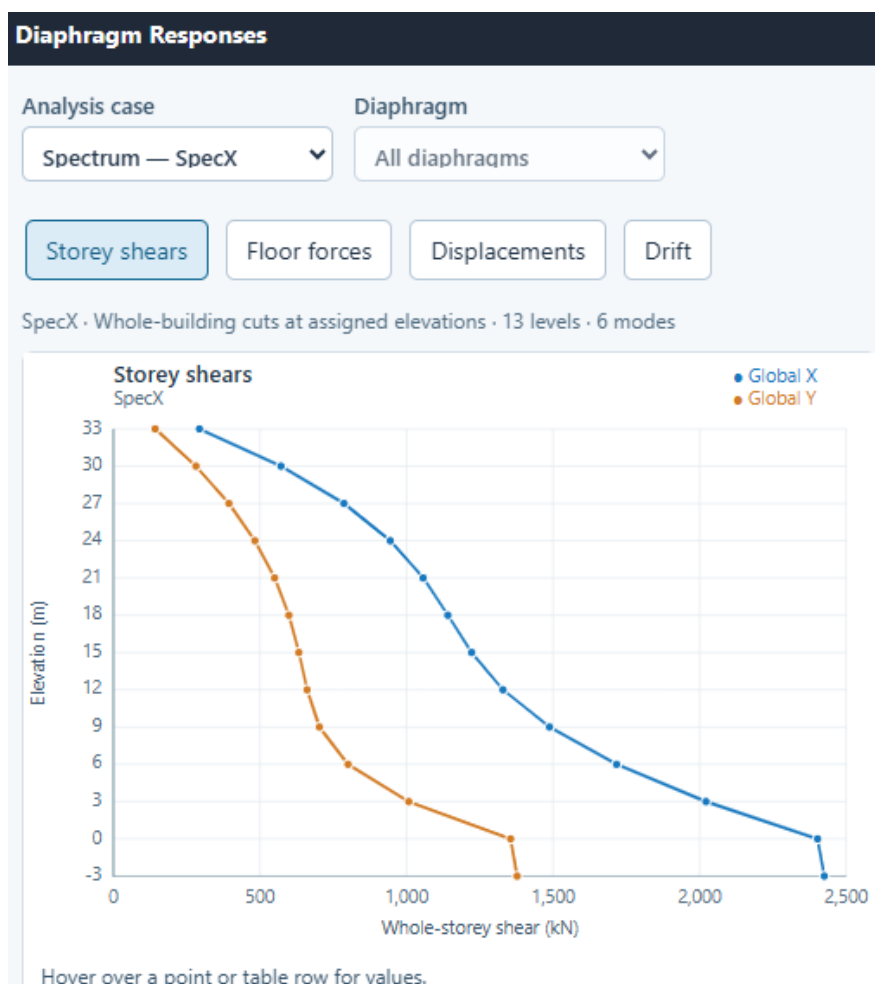


Figure 7. FEAKalc SpecX storey shears after recovery correction. Blue is global X and orange global Y. The –3 m base reaches approximately 2425.5 kN in X and 1377.4 kN in Y, consistent with Figure 5.

Storey cuts sum each mode's signed recovered nodal member forces $K\phi$ over the nodes at and above the elevation before statistical combination. At the support base the signed modal support resultant is used. This keeps the storey-force recovery consistent with the member forces and Base Reactions.

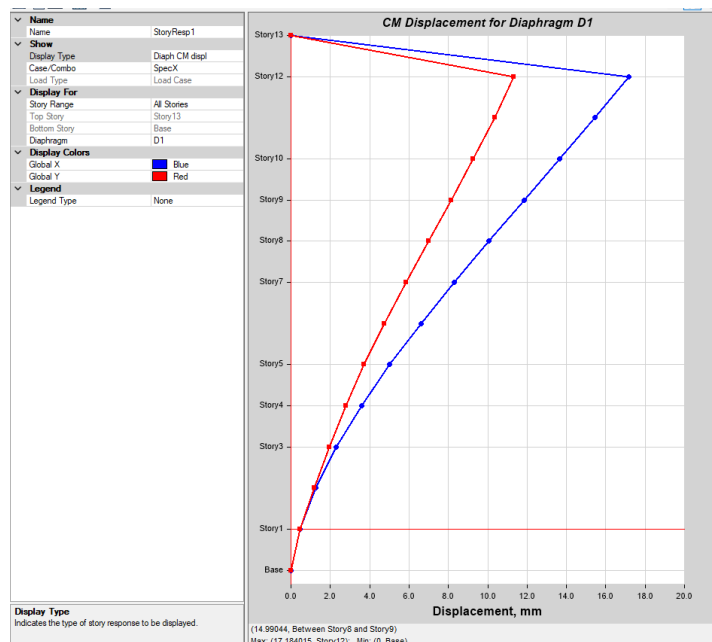
The previous plot summed modal inertia $\omega^2 M\phi$. A truncated Ritz basis need not satisfy $K\phi = \omega^2 M\phi$ at every full-system degree of freedom, so the inertia sum could differ from the recovered support resultant even with the base elevation present. The published figure uses the corrected recovery, without scaling the plot to fit a combined peak.

The two profiles show close agreement in the overall shear distribution and its reduction with elevation. The FEAKalc base cut is also consistent with its independently reported Base Reactions result. Together these checks support the force recovery throughout the building; the figures are a graphical profile comparison, rather than a numerical error table at every elevation.

9. Diaphragm displacement comparison

The ETABS plot is labelled “CM Displacement for Diaphragm D1”. FEAKalc reports an area-weighted mean diaphragm translation, using nodal tributary areas. These are different spatial response measures for a semi-rigid floor and should not be presented as point-for-point equivalents.

ETABS



FEAKalc

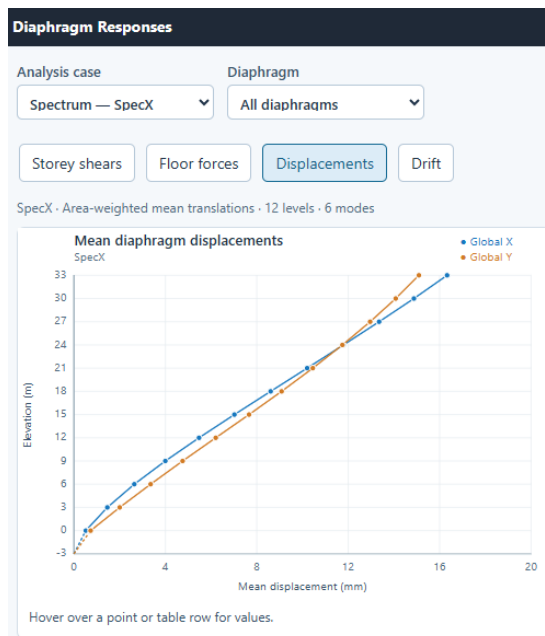


Figure 8. SpecX diaphragm translations. ETABS is left (mm); FEAKalc is right (mm). ETABS colours are blue X and red Y; FEAKalc colours are blue X and orange Y.

Both plots show the same overall increase in translation with height, supporting close agreement in the building’s lateral deformation pattern. ETABS displays a maximum X translation of 17.184015 mm at Story12; the FEAKalc top-floor mean X translation is approximately 16 mm by the plotted scale. Centre-of-mass and area-mean translations remain distinct measures on a semi-rigid floor, so their difference is not assigned a point-for-point error percentage.

ETABS includes a Story13 point with zero response above the highest displaced diaphragm point. The physical FEAKalc slab elevations end at 33 m. The extra ETABS story label is not interpreted as an additional matched floor or as evidence of a roof-displacement drop in Model 1.

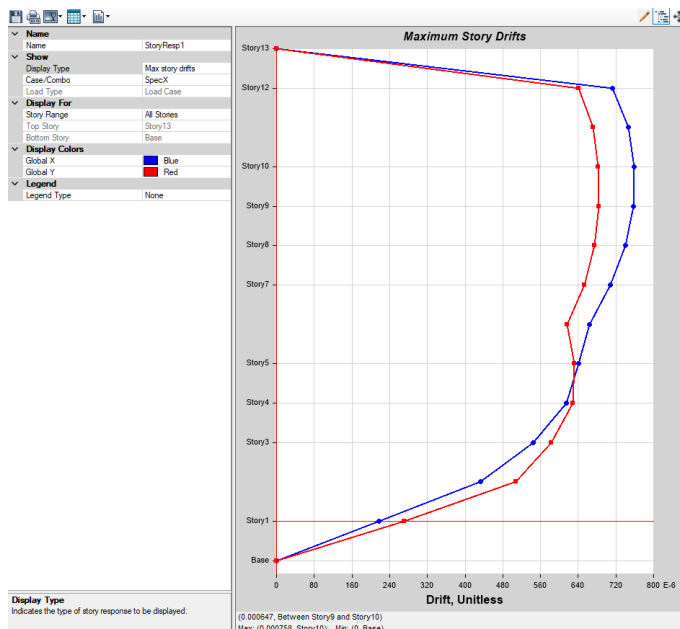
9.1. Mean floor translation

For each signed modal field, FEAKalc forms $\bar{u} = \frac{\sum_{n=1}^N A_n u_n}{\sum_{n=1}^N A_n}$ over the assigned floor nodes, then applies the saved modal and directional combinations and signed torsional correction. A centre-of-mass translation, an area mean and a maximum nodal translation can differ on an irregular semi-rigid diaphragm.

10. Storey drift comparison

The ETABS figure reports “Maximum Story Drifts”, while the FEAkalc figure reports “Mean diaphragm drift”. The two plots therefore document different response measures. ETABS uses a unitless ratio and FEAkalc displays a percentage.

ETABS



FEAkalc



Figure 9. SpecX drift profiles. ETABS maximum drift is left; FEAkalc relative mean diaphragm drift is right. An ETABS axis value of 800×10^{-6} corresponds to 0.08%.

The displayed drift magnitudes remain below 0.08% in both plots. ETABS reports a maximum X drift of 0.000758, or 0.0758%, at Story10; the FEAkalc maximum mean X drift is approximately 0.055% by the plotted scale. The mean and maximum measures provide complementary views of the elastic floor response, rather than interchangeable numerical values.

10.1. Relative modal response before combination

FEAkalc subtracts the lower floor’s signed area-mean translation from the upper floor’s signed mean within each mode. It combines these relative responses, incorporates the signed static-torsion relative correction, then divides by the actual storey height. The first level references the base-support displacement.

Subtracting separately combined peak floor displacements would not give the same relative response, because spectrum peaks are statistical and generally nonconcurrent [R3]. The plotted ratios are elastic analysis responses; no additional design drift amplification is applied in this comparison.

The screenshots establish the overall height-dependent trends, but do not establish numerical equivalence of maximum drift or local edge displacement. A comparison of the same diaphragm location and the same drift definition would be needed for that claim.

11. Conclusions and reproducibility

This single-model benchmark shows that FEAkalc3D is very close to ETABS across the principal aspects of the response-spectrum comparison: modal periods, cumulative horizontal mass participation, horizontal base shears, overturning moments, base torsion and the overall storey response profiles. The six periods agree within 0.83%, horizontal base shears within 1.72%, and base moments within 4.36%.

The agreement is supported by consistent input settings, aligned diaphragm assignments and a common base-moment reference. These details matter: a comparison is most useful when the same physical model and response quantity are being measured. The displacement and drift figures reinforce the overall agreement while retaining the distinction between ETABS centre-of-mass or maximum responses and FEAkalc area-mean responses.

Together with the completed modal validation, this benchmark provides strong evidence that FEAkalc reproduces the global linear elastic response-spectrum behaviour of the stated model. The conclusions apply to the saved SpecX spectrum, six-mode basis and support assumptions. Local member forces, diaphragm stresses and maximum edge drifts remain separate response quantities requiring their own matched comparisons.

11.1. Reproduction record

Item	Record
Model files	Model1.FEAkalc3D; Model1.EDB; Model1.\$et
Evidence	16 figures in Model1/Figures, Figures 1 to 9 in this report
Spectrum basis	AS 1170.4—2007 saved Class C reference; 5% damping
Analysis case	SpecX; Modal1; six Ritz modes; CQC / SRSS; eccentricity 0.05
Reference point	Base resultants about (0, 0, -3) m
Numerical source	Displayed values in the published figures; no substitution from separate harness runs

12. Technical references

[R1] Computers and Structures Inc. Response Spectrum. ETABS Help. Modal combination, damping, directional combination and diaphragm eccentricity. Accessed 28 October 2026.

https://docs.csiamerica.com/help-files/etabs/Menus/Define/Load_Cases/Response_Spectrum.htm

[R2] Computers and Structures Inc. Base reactions for response-spectrum analysis. CSI Knowledge Base. Modal summation before statistical combination. Accessed 28 October 2026.

<https://web.wiki.csiamerica.com/wiki/spaces/kb/pages/2003704/Base%2Breactions%2Bfor%2Bresponse-spectrum%2Banalysis>

[R3] Computers and Structures Inc. CSI Analysis Reference Manual. Response-Spectrum Analysis chapter. Statistical peak responses and modal superposition. Accessed 28 October 2026.

[R4] <https://docs.csiamerica.com/manuals/etabs/Analysis%20Reference.pdf>