

SR1 • RESPONSE-SPECTRUM-FRAME

Response-spectrum analysis of a two-dimensional rigid frame

Full response-spectrum pipeline verified on the canonical two-dimensional rigid-frame benchmark

PASS

error +0.219% · tol 1%

§2 TECHNICAL FEATURES TESTED

Response-spectrum analysis (RSA)

Modal + spectrum + SRSS / CQC

ElasticTimoshenkoBeam frame element

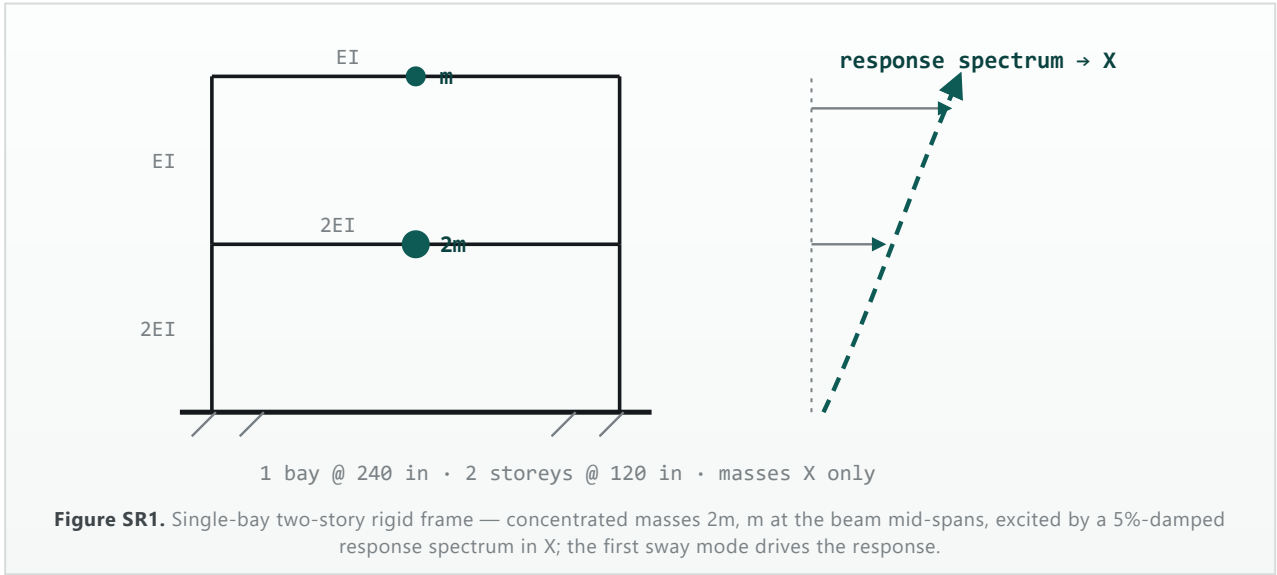
Per-mode inertia-force solve + force recovery

Periods · displacements · bending moments

Bending-only · concentrated mass · 5% damping

§3 PROBLEM DESCRIPTION

The **response-spectrum analysis of a two-dimensional rigid frame** is the classical textbook RSA benchmark, adopted as **CSI SAP2000 Verification Example 1-020** with the independent solution from **Chopra, *Dynamics of Structures* (1995), Example 13.11**. A **single-bay, two-story** fixed-base plane frame carries concentrated floor masses ($2m$, m) and is excited by a **5%-damped response spectrum** in the horizontal direction. It exercises the entire STRIX RSA path: the modal solve, a per-mode **inertia-force static analysis** with element force recovery, spectral scaling, and the **SRSS and CQC** modal combinations. Following the reference, only **bending deformations** are retained (axial and shear made rigid via the section stiffness modifiers) and the mass acts in X only; the concentrated masses enter through the production Loads-to-Masses path. The reference is reproduced directly at its own 8-element discretisation.



§4 GEOMETRY, PROPERTIES & LOADING

GEOMETRY		MEMBER & MASS		LOADING & DYNAMICS	
Bays	1	E	3000 ksi	Excitation	Response spectrum
Storeys	2	I (base)	1000 in ⁴	Damping	5 %
Bay width	240 in	Deformation	Bending only	Combination	SRSS · CQC
Storey height	120 in	Mass	2m, m (X only)	Active DOF	Ux, Uz, Ry

§5 REFERENCE SOLUTION

Period — mode 1: $(K - \omega^2 M) \cdot \phi = 0$, $T = 2\pi/\omega = 1.562$ s

Displacement Ux — joint 3 (roof): $u = \sqrt{(\sum (\Gamma_m \cdot S_{a_m} / \omega_m^2 \cdot \phi_m)^2)} = 18.81$ in

Moment — story-1 column base (jt 1): $M = \sqrt{(\sum M_m^2)} = 12624$ kip·in

CSI SAP2000 Software Verification, Example 1-020 (Response-Spectrum Analysis of a Two-Dimensional Rigid Frame); independent solution = Chopra, "Dynamics of Structures" (1995), Ex. 13.11, p.521. A single-bay, two-story fixed-base plane frame under a 5%-damped response spectrum, bending deformations only (shear/axial ignored), mass excited in X only. Reference values (Chopra) are the two periods, the SRSS lateral displacements, and the SRSS column/beam bending moments.

§6 RESULTS COMPARISON

RESPONSE QUANTITY	PROBE	STRIX	REFERENCE	DIFF	VERDICT
Period — mode 1 (s)	SRSS · s	1.56213	1.562	+0.0080%	PASS
Period — mode 2 (s)	SRSS · s	0.58681	0.5868	+0.0020%	PASS
Displacement Ux — joint 2 (floor 1) (in)	SRSS · in	7.579	7.566	+0.165%	PASS
Displacement Ux — joint 3 (roof) (in)	SRSS · in	18.844	18.81	+0.183%	PASS
Moment — story-1 column base (jt 1) (kip·in)	SRSS · kip·in	12640	12624	+0.126%	PASS
Moment — story-2 column base (jt 2) (kip·in)	SRSS · kip·in	6025	6024	+0.016%	PASS
Moment — floor-1 beam at column (jt 2) (kip·in)	SRSS · kip·in	9813	9792	+0.219%	PASS
Moment — roof beam at column (jt 3) (kip·in)	SRSS · kip·in	5224	5220	+0.079%	PASS

§7 MODAL COMBINATION

METHOD	ROOF UX (IN)	DIFF
SRSS	18.844	+0.183%
CQC	18.83	+0.108%

The reference (Chopra) uses the **SRSS** modal combination; §6 compares STRIX's SRSS response to it. This table runs STRIX's independent **CQC** combination (Der Kiureghian) on the same per-mode responses and reports the governing roof displacement under each method. The two modes are **well separated** ($T_1/T_2 \approx 2.66$), so CQC and SRSS agree closely and both land **within tolerance** of the same independent reference — verifying both combination paths, not only the one the reference happens to use.

§8 CONCLUSION

PASS

STRIX reproduces the **periods, SRSS displacements and column/beam bending moments** of the canonical **CSI 1-020 / Chopra 13.11** frame to **better than a quarter of a percent** — as closely as SAP2000 does. This verifies the complete STRIX **response-spectrum pipeline**: the modal solve, the per-mode inertia-force analysis with element force recovery, the spectral scaling, and **both** the SRSS and CQC modal combinations — the core of STRIX's seismic-analysis capability.

§9 REFERENCES & ANALYSIS FILES

1. CSI SAP2000 Software Verification, Example 1-020 — Response-Spectrum Analysis of a Two-Dimensional Rigid Frame.
2. A. K. Chopra, *Dynamics of Structures*, Ex. 13.11, p.521 (Prentice Hall, 1995) — independent solution.
3. E. L. Wilson, A. Der Kiureghian & E. P. Bayo, *EESD* **9**(2), 1981 — CQC modal-combination rule. STRIX harness: `buildRsaPy` → `opensees.pyd` → `rsa_modal.bin`.

EVIDENCE ARCHIVE `verif-evidence-eng1.0.6-win-x64.zip` · SR1/ `sha256` (pending publish)