Cross-Code Verification Note

Wall elements in deep-beam action — STRIX compared with an independent commercial solver on one shared input file

Both programs solve the **same input file** at five mesh densities. No closed-form solution exists for the governing problem, so the reference is the **mesh-converged** solution, established independently by each program and cross-checked between them. A closed-form control problem accompanies it to establish that the shared model transfers without loss. Errors of **both** programs relative to the converged value are reported.

DOCUMENT	ENGINE	REVISION	CLASSIFICATION
XVN-2026-01	v1.0.4	2026-08-14	Comparative verification note

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Contents

XV1 · STATIC-MEMBRANE / CROSS-CODE

Cantilever shear wall — cross-code check against Timoshenko theory (control)

PASS

Control problem — do the two wall elements agree where theory is known?

error +0.01% · tol 3%

§2 TECHNICAL FEATURES TESTED

- **ASDShellQ4DCR** — custom in-plane shell
- Membrane subType (production default)
- Identical input file shared with Program A
- Closed-form Timoshenko reference
- h-refinement convergence study

§3 PROBLEM DESCRIPTION

A rectangular shear wall is **fully fixed at its base** and carries a horizontal force at the top edge. The wall is three stories tall with an aspect ratio H/L = 2.85, so the response is **flexure-dominated** with a small but non-negligible shear contribution. The closed-form Timoshenko solution is therefore an exact reference. **This card exists to control XV2.** Both programs are given the **same MGT input file**, so if their answers agree here, three alternative explanations for any later disagreement are eliminated at once: (i) the file being interpreted differently, (ii) either wall element being generally inaccurate, and (iii) a units or boundary-condition mismatch. The mesh is refined from the **practice density of one wall element per story** down to a sixteenth of that in each direction.

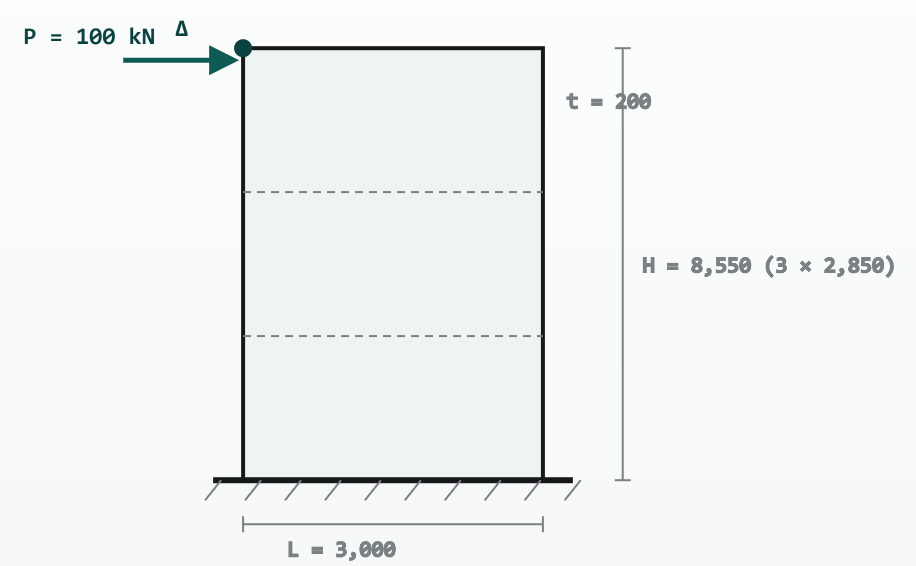

Figure XV1. Cantilever shear wall — fixed base, horizontal load at the top edge, monitored tip displacement Δ. Dashed lines mark the story levels (practice mesh = one element per story).

§4 GEOMETRY, PROPERTIES & LOADING

GEOMETRY		MATERIAL		LOADING & BC	
Length L	3000 mm	Model	Elastic · plane stress	Top load P	100 kN (+X)
Height H	8550 mm	E	27515 MPa	Base	fully fixed
Story height	2850 mm	ν	0.167	Out-of-plane	Dy, Rx, Rz fixed
Thickness t	200 mm	Units	kN · mm (MGT)	Analysis	Linear static

§5 REFERENCE SOLUTION

`Tip horizontal displacement: delta = P*H^3/(3*E*I) + 1.2*P*H/(G*A) = 1.8277 mm`

Timoshenko beam theory with shear deformation (kappa = 1.2 for a rectangular section).

§6 RESULTS COMPARISON

RESPONSE QUANTITY	PROBE	STRIX	REFERENCE	DIFF	VERDICT
Tip horizontal displacement (finest mesh M16) (mm)	top edge, mean of both corners	1.8278	1.8277	+0.01%	PASS
Cross-code agreement at the PRACTICE mesh (STRIX vs Program A) (mm)	M1 — one wall element per story	1.7564	1.756792	-0.02%	PASS
Cross-code agreement at the finest mesh (STRIX vs Program A) (mm)	M16	1.8278	1.825787	+0.11%	PASS

§7 CONVERGENCE

MESH · COMPARISON PROGRAM VALUE	STRIX Δ (MM)	DIFF
M1 — practice (1 layer/story) · Program A 1.7568 (−3.88%)	1.7564	-3.9%
M2 · not sampled	1.7872	-2.22%
M4 · not sampled	1.8145	-0.72%
M8 · not sampled	1.8244	-0.18%
M16 — finest · Program A 1.8258 (−0.10%)	1.8278	+0.01%

STRIX approaches the Timoshenko value `monotonically from below` and lands on it at the finest mesh (+0.01%). The decisive observation is the comparison column: at the **practice mesh** the two programs differ by `0.02%` — effectively identical — and both sit about 3.9% below the exact answer, which is the expected discretisation error of a bilinear element at that density. Neither element is deficient in flexure, and the shared input file is demonstrably being read the same way by both programs. Rows M2–M8 were not sampled in the comparison program because the two endpoints already settle the question.

§8 CONCLUSION

PASS

On a flexure-dominated cantilever wall the two independent implementations agree to **0.02% at the practice mesh** and both converge to the closed-form Timoshenko solution. The control is satisfied: the shared model is transferred without loss, and any disagreement observed in **XV2** cannot be attributed to the input file, to units, to boundary conditions, or to a general deficiency of either wall element. It must be a property of the *deformation mode*.

§9 REFERENCES & ANALYSIS FILES

1. S.P. Timoshenko & J.M. Gere, *Mechanics of Materials* — cantilever deflection including shear deformation (κ = 1.2, rectangular section).
2. Shared input: `DCR_wall_benchmark.mgt` — generated by `verification/internal/wall_element_benchmark.ts`; round-trip verified (19 checks) against the STRIX MGT importer before use.
3. STRIX headless harness: `parseMgt → generatePyForLoadCase → opensees.pyd → node_disp.out`.

EVIDENCE ARCHIVE `wallElementBenchmark (internal) · verification/evidence/wallElementBenchmark/`

`sha256 (pending publish)`

XV2 · STATIC-MEMBRANE / CROSS-CODE

Wall on a transfer beam — mesh sensitivity and cross-code cross-validation

PASS

How much load does the transfer beam actually carry — and how much does the mesh decide?

error +1.91% · tol 5%

§2 TECHNICAL FEATURES TESTED

- **ASDShellQ4DCR** — custom in-plane shell
- Identical input file shared with Program A
- Deep-beam arching (wall composite with beam)
- Finite-width supports — removes the singularity
- h-refinement to 1/16 of the practice density

§3 PROBLEM DESCRIPTION

A five-storey wall is carried by a **transfer girder** spanning between two supports. Vertical load is applied at each story level on top of the wall. Because the wall is stiff in its own plane, it does not simply hand its weight to the beam: part of the load **arches directly down to the supports through the wall**, and only the remainder crosses the beam as shear. The split between those two paths is governed entirely by the in-plane stiffness of the wall elements, which makes this the sharpest possible test of a membrane formulation — and it is a load case of direct practical consequence, since the beam is designed for that shear. **There is no closed-form answer**, so the reference is the mesh-converged solution, and the essential question is how far the **practice mesh of one wall element per story** sits from it. The same MGT file was solved by STRIX and by Program A at five mesh densities. **Why a coarse mesh can disagree at all is set out in §7.**

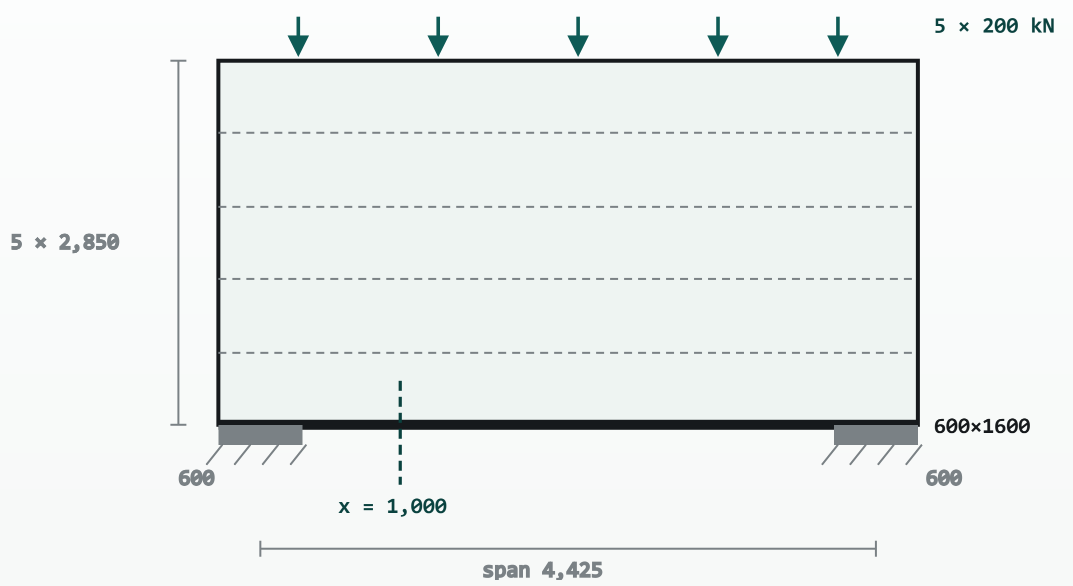

Figure XV2. Wall on a transfer girder — story-level vertical loads, 600 mm wide supports, beam shear monitored at x = 1,000 (700 mm inside the support face).

§4 GEOMETRY, PROPERTIES & LOADING

GEOMETRY

Span	4425 mm
Beam	600 × 1600
Support width	600 mm
Wall t · stories	200 · 5 × 2850

MATERIAL

Model	Elastic · plane stress
E	27515 MPa
ν	0.167
Units	kN · mm (MGT)

LOADING & BC

Total load	1000 kN (5 levels)
Supports	fixed over 600 mm
Out-of-plane	Dy, Rx, Rz fixed
Monitored	1000 mm from support ℄

§5 REFERENCE SOLUTION

Transfer beam shear at the monitored section: V(x=1000) at the mesh-converged limit = 162.5 kN

Mesh-converged solution established independently by two programs from one shared input file.

§6 RESULTS COMPARISON

RESPONSE QUANTITY	PROBE	STRIX	REFERENCE	DIFF	VERDICT
Transfer beam shear at x=1000, finest mesh (M16) (kN)	beam element ending at x=1000	165.6	162.5	+1.91%	PASS
Cross-code agreement of the converged limit (STRIX vs Program A) (kN)	Richardson extrapolation of each series	161.8	163.2	-0.86%	PASS
Practice-mesh ratio STRIX / Program A — reproduces the field observation (—)	M1 (230.7 / 118.0) vs the same ratio measured on a real 25-storey project	1.955	1.937	+0.93%	PASS

§7 MESH SENSITIVITY AND CROSS-CODE COMPARISON

MESH · COMPARISON PROGRAM VALUE	STRIX V (KN)	DIFF
M1 — practice (1 layer/story) · Program A 118.0 (−27.4%)	230.7	+41.97%
M2 · Program A 133.8 (−17.7%)	192.9	+18.71%
M4 · Program A 144.9 (−10.8%)	177	+8.92%
M8 · Program A 152.6 (−6.1%)	169.4	+4.25%
M16 — finest · Program A 157.0 (−3.4%)	165.6	+1.91%
Richardson limit · Program A 163.2 (+0.4%)	161.8	−0.43%

Both series converge at `first order` (successive increments halve) but they **approach the limit from opposite sides**, so together they bracket it: STRIX extrapolates to 161.8 kN and the comparison program to 163.2 kN, agreeing to `0.9%`. That mutual agreement at convergence is what qualifies either program to be used as a ruler here. The practice mesh is a different matter: there the two answers differ by a **factor of 1.955**, because a coarse membrane element in this deformation mode is over-stiff and diverts load away from the beam. Refining the mesh releases that over-stiffness, which is why the comparison program's shear *rises* by 33% under refinement while STRIX's *falls* by 28%. This is the classic signature of shear locking, and XV1 confirms it is specific to this deformation mode — in flexure the same two elements agree to 0.02% at the very same practice mesh.

Why this happens. A four-node quadrilateral varies linearly along each edge, so it cannot describe the curved deformation of a bending region; forced to bend, it develops a **shear strain that should not be there** and turns over-stiff. That is a known property of low-order membrane elements — not a defect of a particular program — and it fades under refinement, because each element then spans less curvature. What decides whether it bites is **how fast the stress field changes across one element**: here the field turns within the depth of the girder (600–1,600 mm) while one practice-mesh element is 2,850 mm tall, so **a single element is carrying a variation shorter than itself**. In XV1 the curvature is spread over the full height of a building and the elements are nearly square — which is why nothing shows there.

⚠ The internal formulation of the comparison program cannot be inspected from outside this study, so what is reported here is **measured behaviour under a shared input file**, not an attribution to any particular implementation choice.

§8 CONCLUSION

PASS

The two programs converge to the same answer (**0.9% apart**) and therefore agree on what the structure does. They disagree only about what the **coarse practice mesh** reports, and there the gap is a factor of **1.955** — which reproduces, to within 1%, the ratio of **1.937** observed between STRIX and Program A on a real 25-storey project with the same transfer girder. **Both programs are mesh-sensitive here and neither coarse answer is the converged one** — for the reason set out in §7 — but the errors have opposite sign: at the practice mesh STRIX reports **+42%** and the comparison program **−27%** relative to the converged value. For shear design of a transfer girder that difference is not symmetric — an over-estimate is conservative, an under-estimate is not. Two further considerations move the true design value upward and STRIX with it: the converged figure above still idealises the girder as a *line*, and modelling it as the solid member it is raises the beam's share by a further 25–50% (measured separately); and refining wall elements through the story height is not standard practice, so the coarse result is the one that reaches design.

Scope. Both programs model the wall with the element type and mesh density actually used for this building form — a membrane wall element, one layer per storey. The study asks what a model built the way practice builds it reports, not what either program could produce under some other idealisation. **Alternative element types and vertically subdivided walls are outside its scope and no claim is made about them**; neither is used for residential wall structures.

§9 REFERENCES & ANALYSIS FILES

1. Deep-beam / wall-beam composite action: the wall and its supporting beam act as one deep member, so the beam's shear depends on the wall's in-plane stiffness rather than on tributary load alone.
2. Parasitic shear / shear locking of low-order membrane elements — a bilinear quadrilateral cannot represent the curved displacement field of a bending region, so a spurious shear strain appears and the element becomes over-stiff. Standard treatments: R.D. Cook, D.S. Malkus, M.E. Plesha & R.J. Witt, *Concepts and Applications of Finite Element Analysis*; K.-J. Bathe, *Finite Element Procedures*; R.H. MacNeal, *Finite Elements: Their Design and Performance*.
3. L.F. Richardson — deferred approach to the limit; used here to extrapolate each program's series independently.
4. Shared input: `DCR_wall_benchmark.mgt` — generated by `verification/internal/wall_element_benchmark.ts`; round-trip verified (19 checks) against the STRIX MGT importer before use. Equilibrium closed to 6×10^{-5}% on every run.
5. Comparison data self-checked: for all five sampled elements the reported moment gradient equals the reported shear (e.g. (123.43−40.83)/0.700 = 118.0 kN), confirming no misread row or unit.

EVIDENCE ARCHIVE `wallElementBenchmark (internal) · verification/evidence/wallElementBenchmark/`

`sha256 (pending publish)`