EXAMPLE 1-027

FRAME – CONSTRUCTION SEQUENCE LOADING

EXAMPLE DESCRIPTION

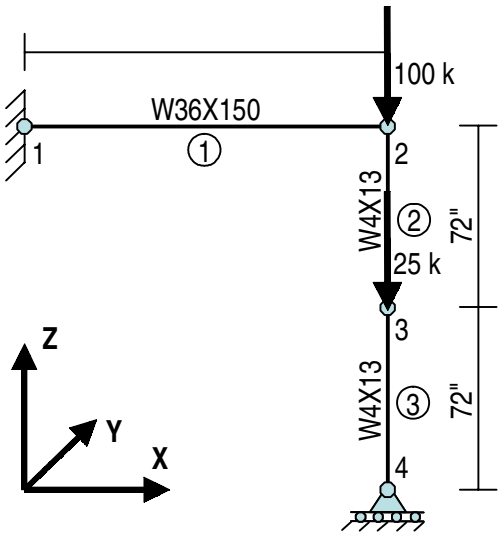
This example applies construction sequence loading to a three-element frame to test the SAP2000 staged construction capabilities.

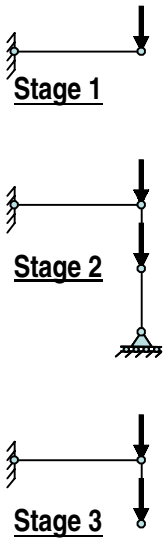
The first construction stage includes frame object 1 only. Stage 2 adds frame objects 2 and 3 to the model. Finally, stage 3 removes frame object 3 from the model.

For each stage of the construction, the vertical reaction at joint 1 and the vertical displacement at joint 2 are compared with independent hand calculated results.

Important Note: Bending, shear and axial deformations are all included in this example. Only the U_x, U_z and R_y degrees of freedom are active in this two-dimensional example.

GEOMETRY, PROPERTIES AND LOADING





Material Properties
- E = 29,900 k/in^2
- v = 0.3
- G = 11,500 k/in^2

Section Properties

W36X150
- I = 9040 in^4
- A_v = 22.4375 in^2 (shear area)

W4X13
- A = 3.83 in2

Loading
- **Joint 2:** F_z = -100 k
- **Joint 3:** F_z = -25 k

TECHNICAL FEATURES OF SAP2000 TESTED

- Nonlinear static analysis using the construction sequence loading option
- Frame end releases

RESULTS COMPARISON

Independent results are hand calculated using the unit load method described on page 244 in Cook and Young 1985 together with basic deflection formulas.

Stage	Output Parameter	SAP2000	Independent	Percent Difference
1	U_z (jt 2) in	-0.42404	-0.42404	0%
	F_z (jt 1) kips	100	100	0%
2	U_z (jt 2) in	-0.43617	-0.43617	0%
	F_z (jt 1) kips	102.859	102.859	0%
3	U_z (jt 2) in	-0.53005	-0.53005	0%
	F_z (jt 1) kips	125	125	0%

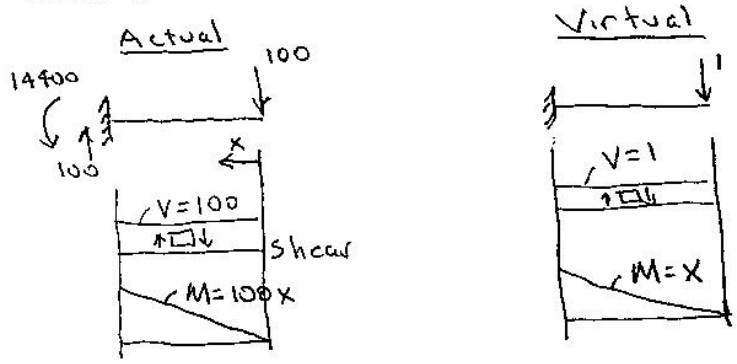
COMPUTER FILES: Example 1-027

CONCLUSION

The SAP2000 results show a exact comparison with the independent results.

HAND CALCULATION

Stage 1



$$\Delta = \int_0^L \frac{100X^2}{EI}dx + \int_0^L \frac{100\,dx}{GA_v} = \frac{100X^3}{3EI}\Big|_0^{144} + \frac{100X}{GA_v}\Big|_0^{144}$$

$$\Delta = \frac{100 \times 144^3}{3 \times 29900 \times 9040} + \frac{100 \times 144}{11500 \times 22.4375}$$

$$\Delta = 0.368236 + 0.055807$$

$$\Delta = \underline{0.424043 \text{ in} \downarrow}$$

Stage 2

Δ of W36x150 cantilever under 1^k tip load = 0.00424043 in

For W4x13 $\Delta = \frac{PL}{EA} = \frac{1 \times 72}{29900 \times 3.93} = 0.000628873$ in

Portion of 25^k load that goes down to joint 4 $= \frac{0.000628873 + 0.00424043}{2(0.000628873) + 0.00424043} \times 25^k$

$= 22.14104^k$

Portion of 25^k load that goes to joint 1 $= 25 - 22.14104 = 2.85896^k$

F_z at joint 1 $= 100 + 2.85896 = 102.85896^k$

Δ_z at jt 2 $= \frac{102.85896}{100} \times 0.424043 = 0.436166$ in ↓

Stage 3

$F_z = 100 + 25 = 125^k$

$\Delta_z = \frac{125}{100} \times 0.424043 = 0.530054$ in ↓