Composite section

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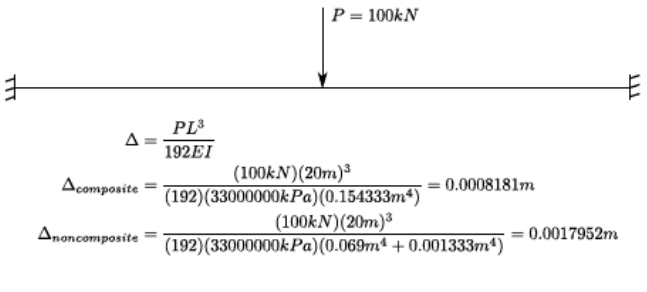
Tutorial	
Name:	Composite section
Description:	Several approaches to model composite section as discussed in this tutorial (originally developed by rs).
Program:	SAP2000
Version:	12.0.0
Status:	Finalize
Id:	ondrej/test_problems/composite section

There are various ways of modeling composite behavior of beam-and-slab assembly in SAP2000. For your reference and study, we have attached four SAP2000 models that show different ways for modeling composite action for girder-and-slab assembly. The model description used for the comparison is as follows:

- The Slab width = 2 m
- Slab thickness = .2 m
- Girder total height = 1.2 m
- Top and bottom flanges width = 1 m
- Top and bottom flange thickness = .1 m
- Web thickness = .1 m
- The applied load at mid span is 100 kN
- Modules of elasticity E= 33000000 kN/m2
- Span length = 20 m, fixed at both ends

The deflection at mid-span is calculated for the naked girder and composite girder as 0.0018m and 0.00083m respectively.

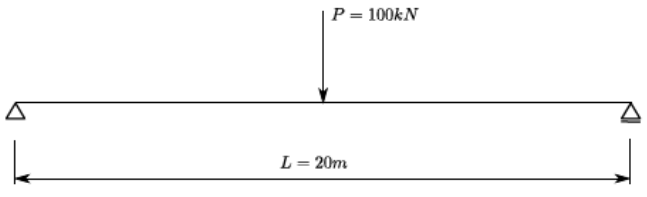
Model Overview



$$\Delta = \frac{PL^3}{192EI}$$

$$\Delta_{composite} = \frac{(100kN)(20m)^3}{(192)(33000000kPa)(0.154333m^4)} = 0.0008181m$$

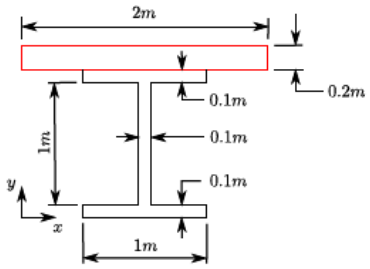
$$\Delta_{noncomposite} = \frac{(100kN)(20m)^3}{(192)(33000000kPa)(0.069m^4 + 0.001333m^4)} = 0.0017952m$$



$$\Delta = \frac{PL^3}{48EI}$$

$$\Delta_{composite} = \frac{(100kN)(20m)^3}{(48)(33000000kPa)(0.154333m^4)} = 0.0032725m$$

$$\Delta_{noncomposite} = \frac{(100kN)(20m)^3}{(48)(33000000kPa)(0.069m^4 + 0.001333m^4)} = 0.0071808m$$



Geometric properties:

$$A_{girder} = (1m)(1.2m) - (0.9m)(1m) = 0.3m^2$$

$$I_{girder} = \frac{1}{12}(1m)(1.2m)^3 - \frac{1}{12}(0.9m)(1m)^3 = 0.069m^4$$

$$y_{cg(girder)} = 0.6m$$

$$A_{deck} = (0.2m)(2m) = 0.4m^2$$

$$I_{deck} = \frac{1}{12}(2m)(0.2m)^3 = 0.001333m^4$$

$$y_{cg(deck)} = 1.3m$$

$$y_{cg(composite)} = \frac{(0.6m)(0.3m^2) + (1.3m)(0.4m^2)}{0.3m^2 + 0.4m^2} = 1m$$

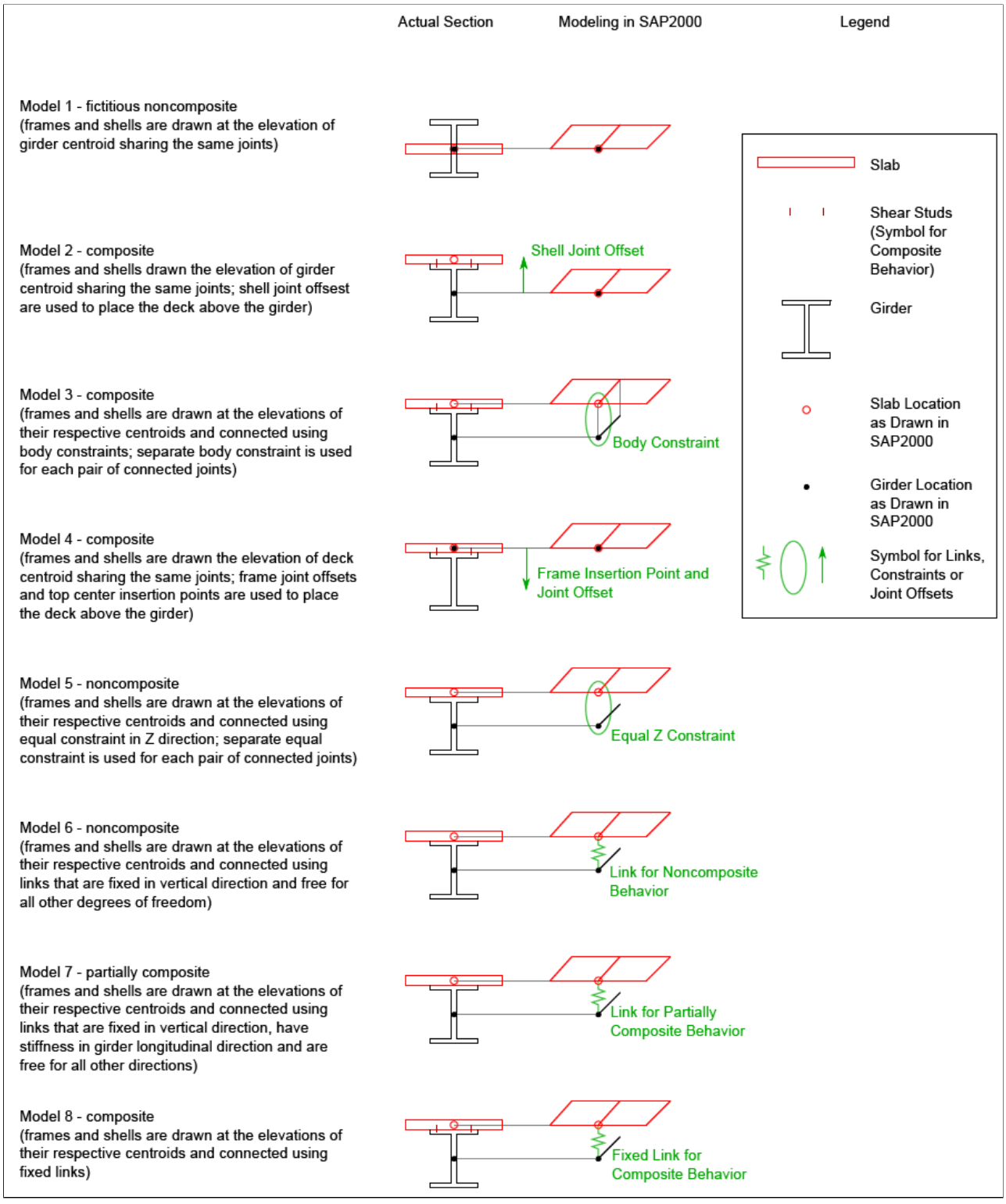
$$I_{composite} = I_{girder} + I_{deck} + \left[(0.3m^2)(0.4m)^2\right]_{Ar^2girder} + \left[(0.4m^2)(0.3m)^2\right]_{Ar^2deck} = 0.154333m^4$$

$$A_{composite} = A_{girder} + A_{deck} = 0.7m^2$$

Material Properties:

$$E = 33GPa$$

Various Approaches to Modeling Composite Behavior



Fixed Beams Model

The model contains contains 8 beams that are fixed at their both ends and the composite behavior is modeled using the 8 approaches outlined in the figure above.

Beam Designation	Behavior	Midspan Deflection [mm]	Comments
Theoretical Beam	composite	0.8181	Theoretical deflection based on the $\frac{PL^3}{192EI}$ formula. Please note that the SAP2000 calculated deflections are slightly higher because the program considers shear deformations.
Beam 1 (top beam)	nocomposite	1.7938	The center line of deck slab coincides with the neutral axis of the section. Hence, the contribution of deck slab to the flexural stiffness of the section will be negligible and the deflection at mid-span for this model should be close to the deflection for naked girder (i.e. no composite action).
Beam 2	composite	0.8313	In this model, the shell elements representing the slab are drawn at the CG of the girder and then offset above the girder to model the composite action. The shells are offset such that the soffit of the slab is at the top of the girder top flange.
Beam 3	composite	0.8313	In this model the girder and slab are drawn at their respective centerlines and then the corresponding joints of the girder and the slab are connected together through body constraints. This is another way to model the composite action.
Beam 4	composite	0.8313	In this model the concept of frame insertion points is used to model the composite action.
Beam 5	noncompostite	1.7938	Equal constrain is used to model noncomposite behavior.
Beam 6	noncomposite	1.7938	Link is used to model noncomposite behavior.
Beam 7	partially composite	1.0302	Link is used to model partially composite behavior
Beam 8 (bottom beam)	composite	0.8313	Link is used to model composite behavior.

In view of the foregoing, you can use either area offsets, body constraints, frame insertion points or links to model composite action of the beam-and-slab assembly.

Simply Supported Beams Model

The model contains contains 8 beams that are simply supported at their both ends and the composite behavior is modeled using the 8 approaches outlined in the figure above.

Beam Designation	Behavior	Midspan Deflection [mm]	Comments
Theoretical Beam	composite	3.2725	Theoretical deflection based on the $\frac{PL^3}{48EI}$ formula. Please note that the SAP2000 calculated deflections are slightly higher because the program considers shear deformations.
Beam 1 (top beam)	nocomposite	7.1752	The center line of deck slab coincides with the neutral axis of the section. Hence, the contribution of deck slab to the flexural stiffness of the section will be negligible and the deflection at mid-span for this model should be close to the deflection for naked girder (i.e. no composite action).
Beam 2	composite	3.2624	In this model, the shell elements representing the slab are drawn at the CG of the girder and then offset above the girder to model the composite action. The shells are offset such that the soffit of the slab is at the top of the girder top flange.
Beam 3	composite	3.2624	In this model the girder and slab are drawn at their respective centerlines and then the corresponding joints of the girder and the slab are connected together through body constraints. This is another way to model the composite action.
Beam 4	composite	3.2624	In this model the concept of frame insertion points is used to model the composite action.
Beam 5	noncompostite	7.1752	Equal constrain is used to model noncomposite behavior.
Beam 6	noncomposite	7.1752	Link is used to model noncomposite behavior.
Beam 7	partially composite	3.5036	Link is used to model partially composite behavior
Beam 8 (bottom beam)	composite	3.2624	Link is used to model composite behavior.

Attachments

- Modeling composite behavior in SAP2000.zip - The zipped file contains the following files:
  - SAP2000 V12.0.0 file for with 8 fixed beams for which the composite behavior is modeled using different approaches.
  - SAP2000 V12.0.0 file for with 8 simply supported beams for which the composite behavior is modeled using different approaches.
  - Sketches illustrating modeling composite, noncomposite and partially composite behavior in SAP2000 (PDF file).

Labels

status-ready-for-review composite-behavior