

CUSTOMER SUPPORT NOTE

Modelling Steel-Concrete Composite Members Using Beam Elements

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This support note is issued as a guideline only.



Forge House, 66 High Street, Kingston upon Thames, Surrey, KT1 1HN, UK
Tel: +44 (0)20 8541 1999 Fax: +44 (0)20 8549 9399
Email: info@lusas.com www.lusas.com

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1. Introduction

Steel-concrete composite members can be modelled using beam elements, shell elements, solid elements, or a combination of these element types. This technical note presents three methods for modelling steel-concrete composite members using beam elements.

2. Example

2.1 Description

In this example, a composite section is considered, comprising a concrete slab and a steel girder. Three methods for modelling composite members using beam elements are presented in Table 1.

Methods	Geometric properties	Material properties
Method 1	Arbitrary Section Property Calculator (ASPC)	Reference material attribute
Method 2	Arbitrary Section Property Calculator (ASPC)	Arbitrary section material attribute
Method 3	Bridge Deck (Grillage) geometric attribute	Bridge Deck (Grillage) material attribute

Table 1 – Three methods for modelling composite members using beam elements.

2.2 Methods 1 and 2

2.2.1 Arbitrary Section Property Calculator

The *Arbitrary Section Property Calculator* can be accessed via Utilities > Section Property Calculator > Arbitrary Section. Sections created using the *Arbitrary Section Property Calculator* are stored as utilities under the *Utilities* treeview.

Section Geometry

The section geometry can be created manually or imported (Figure 1). The surface representing the top flange of the steel girder and the overlying concrete slab surface must share a common line to model composite action.

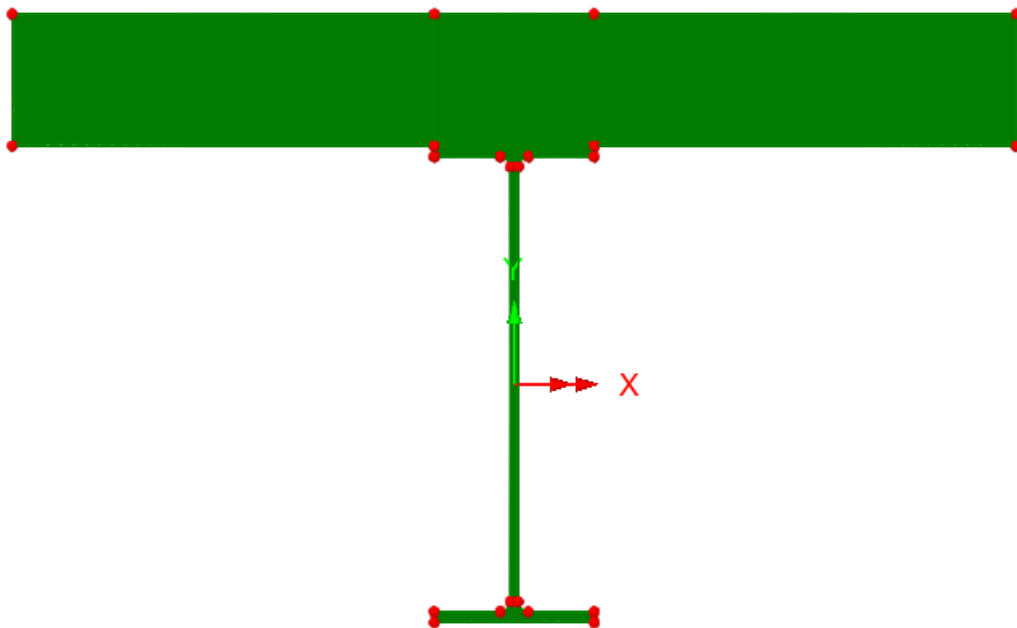


Figure 1 – ASPC – Section geometry.

Material assignments

Two material attributes are required: one for the steel section and another for the concrete slab. The material assignments, along with the colour-coded section, are shown in Figure 2. In this example, steel is taken as the reference material, and the composite section is transformed into an equivalent steel section.

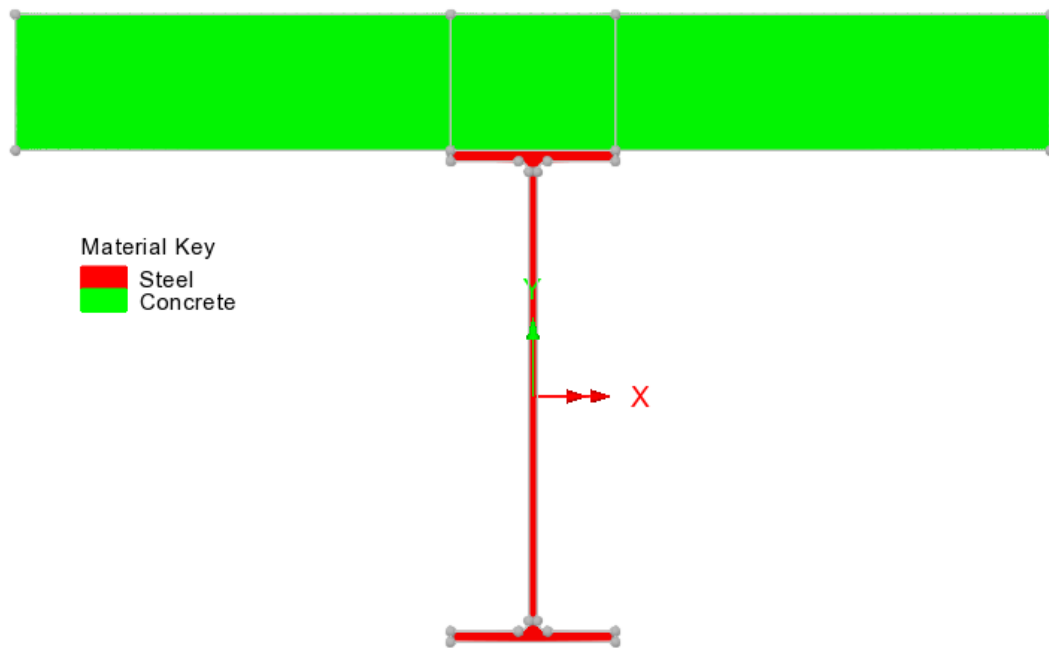


Figure 2 – ASPC – Material assignments.

Section properties

Clicking the *Compute Properties* button discretises the section geometry using triangular elements and computes the corresponding section properties. The discretisation of the section is shown in Figure 3, and the resulting properties are presented in Figure 4.

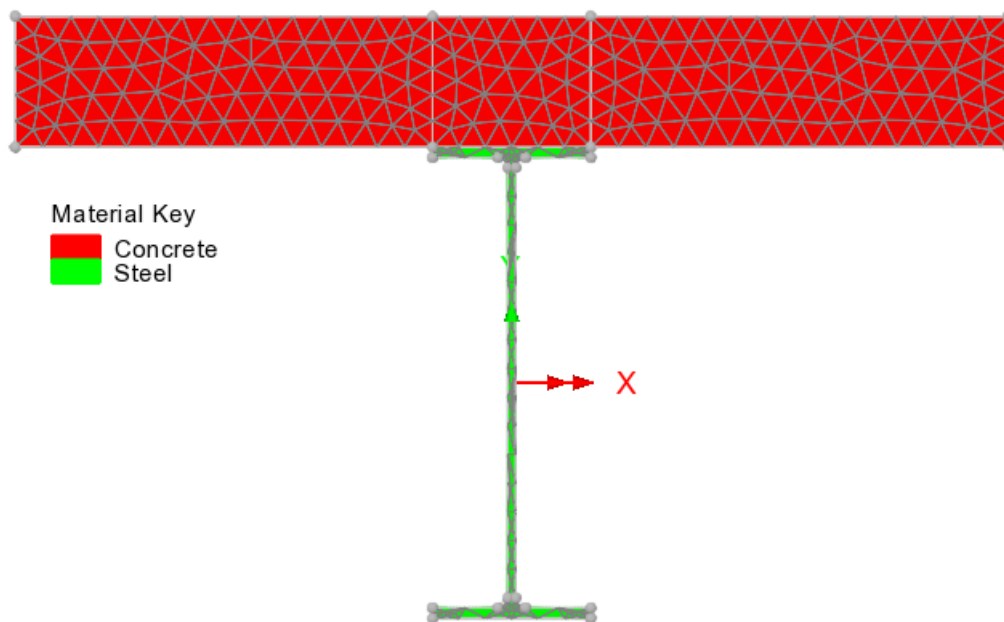
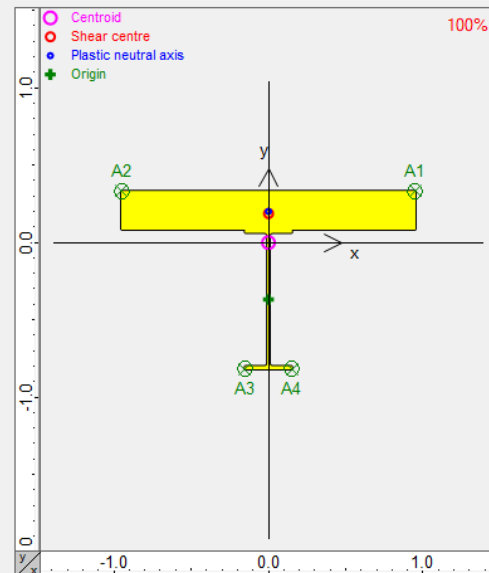


Figure 3 – ASPC – Discretisation of section.

Section Details

Calculated properties

		Value
Cross sectional area	A	0.0709085
Second moment of area about x axis	I _{xx}	8.92447E-
Second moment of area about y axis	I _{yy}	0.0137744
Product moment of area	I _{xy}	5.7876E-1
Torsional constant	J	1.09602E-
Effective shear area in x direction	A _{sx}	0.0448973
Effective shear area in y direction	A _{sy}	0.0163988
Radius of gyration about x axis	k _x	0.354766
Radius of gyration about y axis	k _y	0.440745
Warping torsional constant about shear centre	C _w	0.113269
Shear centre x distance from centroid	x _o	-0.269743
Shear centre y distance from centroid	y _o	0.187231
Monosymmetry constant about x	betax	3.07862
Monosymmetry constant about y	betay	0.408336
Wagner constant 1st moment of square radius about x	I _{xr}	-1.50789E
Wagner constant 1st moment of square radius about y	I _{yr}	2.05855E-
Wagner constant 4th moment of area about origin	I _{lr}	0.0126594
Wagner constant 2nd moment of warping about origin	I _{wr}	-0.879129
Plastic section modulus about x axis	Z _{px}	0.044407
Plastic section modulus about y axis	Z _{py}	0.227391
Plastic torsional section modulus	Z _{pt}	0.0947996
Plastic neutral axis, distance from centroid along x axis	x _p	-43.577E-
Plastic neutral axis, distance from centroid along y axis	y _p	0.20134
Centroid X from geometry origin	X _c	-25.4173E
Centroid Y from geometry origin	Y _c	-0.368396
Principal axes angle	theta	0.0
Effective mass density	rho	19.608E3



Close Help

Figure 4 – ASPC – Section properties.

2.2.2 Method 1 – Geometric and material attributes

The first method involves selecting the *From arbitrary section* option in the geometric attribute dialog (Figure 5).

Geometric Line

Analysis category: 3D

Definition:

- ☒ From library / calculator
- ☐ Enter properties
- ☐ Optimisable

Rotation about centroid: 0 ° Mirrored about axis: None

Mixed material properties: From arbitrary section

Material for properties (Preview only): <Select>

Reinforcement (only used for RC design checks): None

ez origin: Centroid ey origin: Same as e:

Arbitrary Sections

1: Composite section (2 materials)

Figure 5 – Method 1 – Geometric attribute.

As mentioned earlier, steel is used as the reference material. Therefore, the material properties defined in the material attribute assigned to the line representing the composite beam must be identical to the steel properties used in the *ASPC*.

Additionally, since the section analysed in LUSAS is an equivalent steel section, the concrete slab stress results (Figure 6) must be transformed using the modular ratio.

For example, the stress at the top fibre of the concrete slab (at midspan) is:

$$-466.6\text{E}3 / 10.5 = -44.4\text{E}3 \text{ N/m}^2$$

Analysis: Analysis 1
Loadcase: 1:Loadcase 1
Results file: Composite_section~Analysis 1.mys
Fibre: A1
Cross Section: LGeo1
Entity: Stress - Thin 3D Beam
Component (Internal point): Sx(Fx, My, Mz) (Units: N/m²)

-466.56E3
-414.72E3
-362.88E3
-311.04E3
-259.2E3
-207.36E3
-155.52E3
-103.68E3
-51.8401E3

Maximum 0.0 at node 1 of element 1
Minimum -466.56E3 at node 14 of element 5

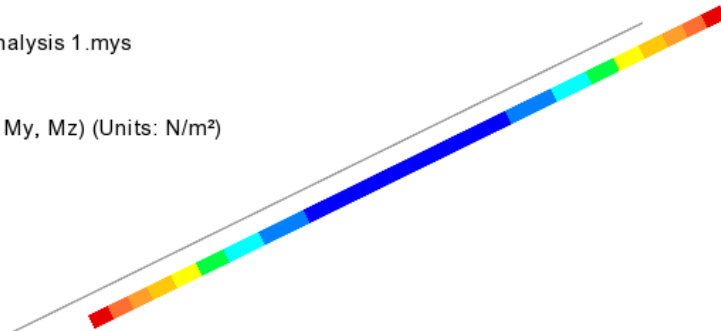


Figure 6 – Method 1 – Stress contour plot – Top fibre of concrete slab.

2.2.3 Method 2 – Geometric and material attributes

The second method involves selecting the *Using assigned compound material* option in the geometric attribute dialog (Figure 7).

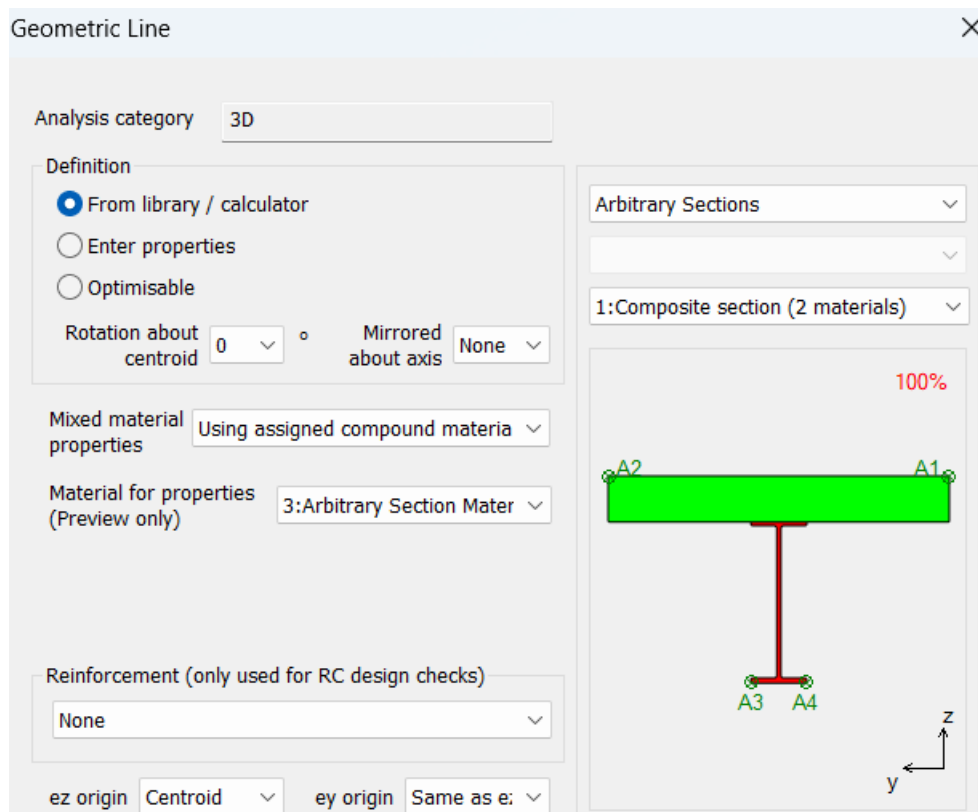


Figure 7 – Method 2 – Geometric attribute.

In this case, an *Arbitrary Section* material attribute (Attributes > Material > Arbitrary Section) must be assigned. The material attribute dialog is shown in Figure 8. In this example, the concrete slab is assumed to be fully cured, and its stiffness is accounted for by ticking the relevant option. The stiffness and mass of individual components can be omitted where appropriate by deselecting the relevant options.

Arbitrary Section Materials X

	Material	Stiffness	Mass	Ref. material
1	1:Steel	☒	☐	☒
2	2:Concrete	☒	☐	☐

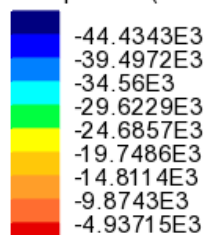
Add Delete

Name (3)

Figure 8 – Method 2 – Material attribute.

Another advantage of Method 2 over Method 1 is that the concrete slab stress results do not require transformation (see Figure 9).

Analysis: Analysis 1
 Loadcase: 1:Loadcase 1
 Results file: Composite_section~Analysis 1.mys
 Fibre: A1
 Cross Section: LGeo2
 Entity: Stress - Thin 3D Beam
 Component (Internal point): Sx(Fx, My, Mz) (Units: N/m²)



Maximum 0.0 at node 11 of element 20
 Minimum -44.4343E3 at node 45 of element 15

Figure 9 – Method 2 – Stress contour plot – Top fibre of concrete slab.

2.3 Method 3

2.3.1 Bridge Deck (Grillage) geometric attribute

Method 3 requires a *Bridge Deck (Grillage)* geometric attribute (Attributes > Geometric > Bridge Deck (Grillage)). In this example, the *Girder with Top Slab* option is used (see Figure 10). Method 3 can be particularly useful when code provisions or recommendations from the literature need to be considered. For example, the torsional constant may be taken as either the sum of the torsional constants of the slab and girder, the torsional constant of the girder alone, or a user-defined value. The available options are described in detail in the Help system.

Bridge Deck (Grillage) Geometric Attribute - Girder with Top Slab

Analysis category: 3D Bridge deck type: Steel I-girder

Girder Slab Girder & Slab

Slab: Uncracked - concrete only

Torsion constant
Option: Sum slab and girder
User value: 0.0

Warping restraint for Girder: None (use St Venant)
Unbraced length: 0.0

Alignment
☐ Include eccentricity from nodal plane to centroid
 Additional eccentricity: 0.0
☒ Ignore eccentricity from nodal plane to centroid

Figure 10 – Method 3 – Geometric attribute.

In this example, the *Uncracked – concrete only* option is used because the slab is in compression. Cases in which the slab is in overall tension and the concrete does not contribute to stiffness are covered by the *Cracked in tension* option. In addition, Method 3 allows reinforcement to be included in a relatively straightforward manner. Including reinforcement in Methods 1 or 2 is more complex and time-consuming.

2.3.2 Bridge Deck (Grillage) material attribute

Method 3 requires a *Bridge Deck (Grillage)* material attribute (Attributes > Material > Bridge Deck (Grillage)). Figure 11 shows the material attribute dialog, which is similar to that presented in Figure 8.

Bridge Deck (Grillage) Material

Sections

Ref	Material	Stiffness	Mass
Slab	2:Concrete	☒	☐
Girder / Bracing	1:Steel	☒	☐

Reinforcement (for cracked sections and design)

Ref	Material
Rebar	None

Name: Bridge Deck (Grillage) Material (4)

Figure 11 – Method 3 – Material attribute.

The stiffness or mass of individual components may be ignored if required. In addition, Method 3 allows reinforcement material to be defined for determining cracked section properties and for performing design calculations. As in Method 2, the concrete slab stress results do not require transformation (see Figure 12).

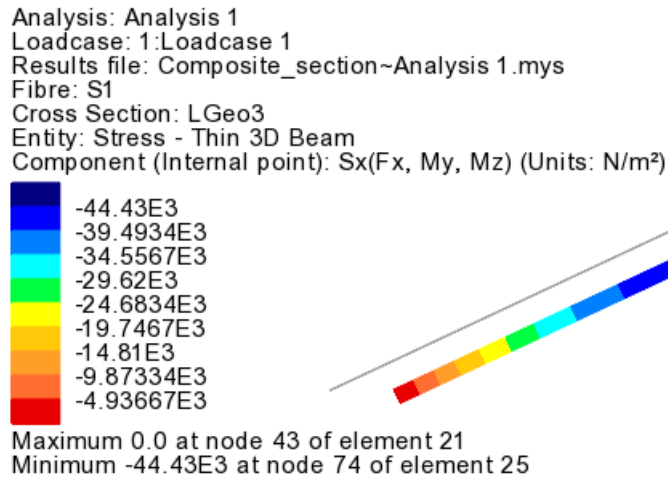


Figure 12 – Method 3 – Stress contour plot – Top fibre of concrete slab.

3. Summary

This technical note presents three approaches for modelling steel-concrete composite members using beam elements.

Method 2 is similar to Method 1 but offers greater versatility, as it allows stiffness and mass contributions from individual components to be selectively omitted where appropriate (for example, in a “bare steel” condition, the concrete slab of a composite beam contributes to its mass but not to its stiffness). Method 2 is also useful when considering section shapes not supported by Method 3.

Method 3 is more suitable for applications where design code provisions or recommendations from the literature are to be considered. In this method, cracked section properties and reinforcement can be included in a relatively straightforward manner.

If you have any doubts or require specific advice for your type of analysis, please contact the LUSAS Technical Support team at support@lusas.com.