CUSTOMER SUPPORT NOTE

Smooth Contact Joints

Note Number:	**CSN/LUSAS/1009**

This support note is issued as a guideline only.

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1. Introduction

Smooth contact joints are used in a range of applications, including modelling lift-off and tension-only members. This support note provides guidance on the inputs required to define a smooth contact joint and demonstrates how such joints can be applied within an analysis.

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Help menu > **Help Topics** > **Contents** > **Theory Manual 1** > **Chapter 4 – Constitutive Models** > **4-12 Joint Models**

Help menu > **Help Topics** > **Contents** > **Modeller Reference Manual** > **Chapter 5 – Model Attributes** > **Material Properties** > **Joint Material Models (General)**

2. Using smooth contact joints

2.1 Smooth contact joint material attribute

A smooth contact joint material attribute can be created by navigating to Attributes > Material > Joint > Smooth contact. The properties required to define a smooth contact joint are shown in Figure 1. Smooth contact joints can be assigned to points, line ends, lines, or surfaces. They can have only translational degrees of freedom (*joint no rotational stiffness*) or both translational and rotational degrees of freedom (*joint for beams*).

The required inputs are described in detail in Section 2.2. Joint masses can also be specified if required for static or dynamic analyses.

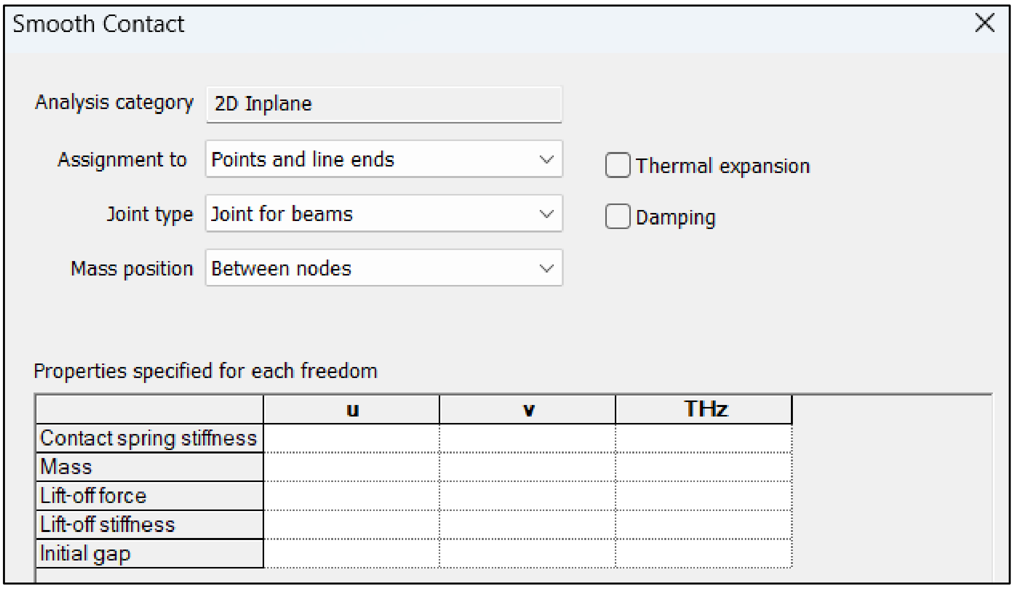


Figure 1 – Material attribute dialog: Smooth contact joint.

The orientation of a joint's element axes and the order of its nodes determine its behaviour. Proper axis orientation ensures that the joint behaves as intended. The recommended approach for controlling joint orientation is to define an appropriate local coordinate attribute (Attributes > Local Coordinate…) and select it using the *By specified local coordinates* option in the *Mesh Assignment* dialog. The element axes of joints can be visualised and checked via Treeview > Layers tab > Mesh > Show element axes (tick to display).

2.2 Force-displacement graph

Figure 2 presents the nonlinear response curve of a smooth contact joint. The relative displacement (or rotation) of the joint, defined as the difference between the displacements (or rotations) at its two nodes, is plotted on the horizontal axis, while the force (or moment) in the joint is plotted on the vertical axis. As shown, smooth contact joints allow different stiffness values to be specified for compression (contact – stiffness Kc) and tension (lift-off – stiffness K1). Figure 1 shows the inputs required to define a smooth contact joint, while Figure 2 graphically defines each input. Smooth contact joints can be used only in nonlinear analyses because their response is nonlinear.

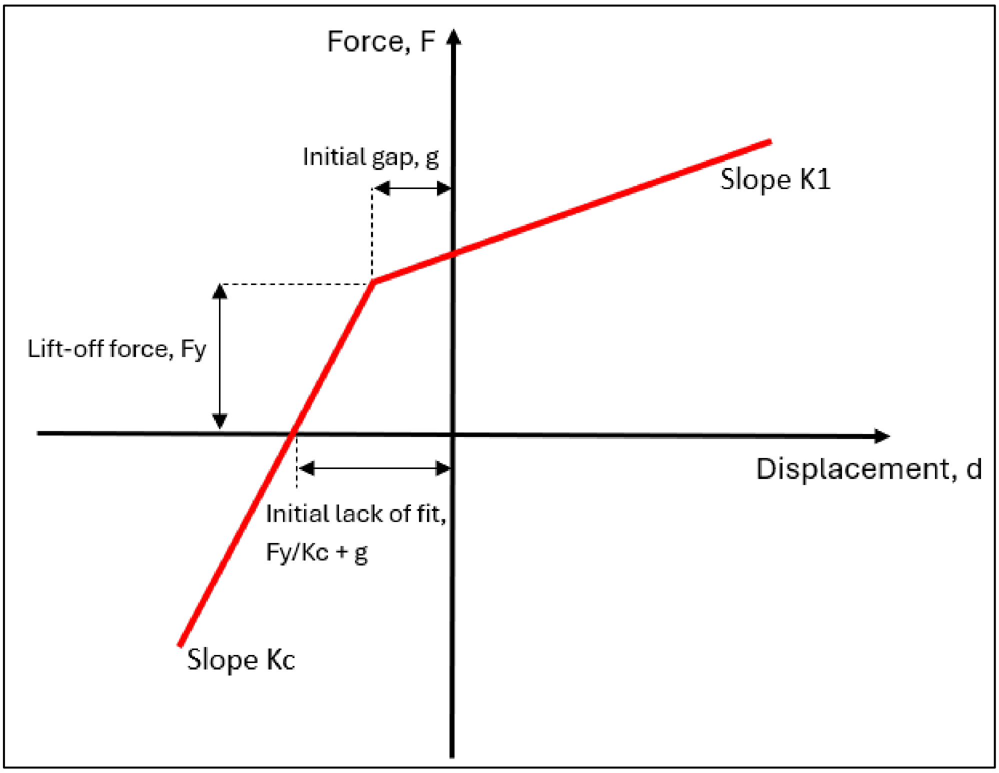


Figure 2 – Response curve of smooth contact joint.

Using Figure 2, the initial gap and lift-off force are defined as follows:

Initial gap (g): the displacement at which the stiffness changes from Kc to K1.

Lift-off force (Fy): the force at which the stiffness changes from Kc to K1.

Consequently, the equations governing the response of the joint are as follows:

When **F < Fy:** d = - (Fy/Kc + g)+ F/Kc

At **F = Fy:** d = - g

When **F > Fy:** d = (F – Fy)/K1 - g

3. Examples

3.1 Deriving a smooth contact joint response curve

The properties of a smooth contact joint with a single degree of freedom are:

Kc = 2, K1 = 0.5, g = 2, Fy = 6

Therefore:

At F = 0, F < Fy: Displacement, d = - (6/2 + 2) = - 5

At F = 6, F = Fy. Displacement, d = - 2

At F = 10, F > Fy. Displacement, d = (10 – 6)/0.5 – 2 = 6

The response curve is shown in Figure 3.

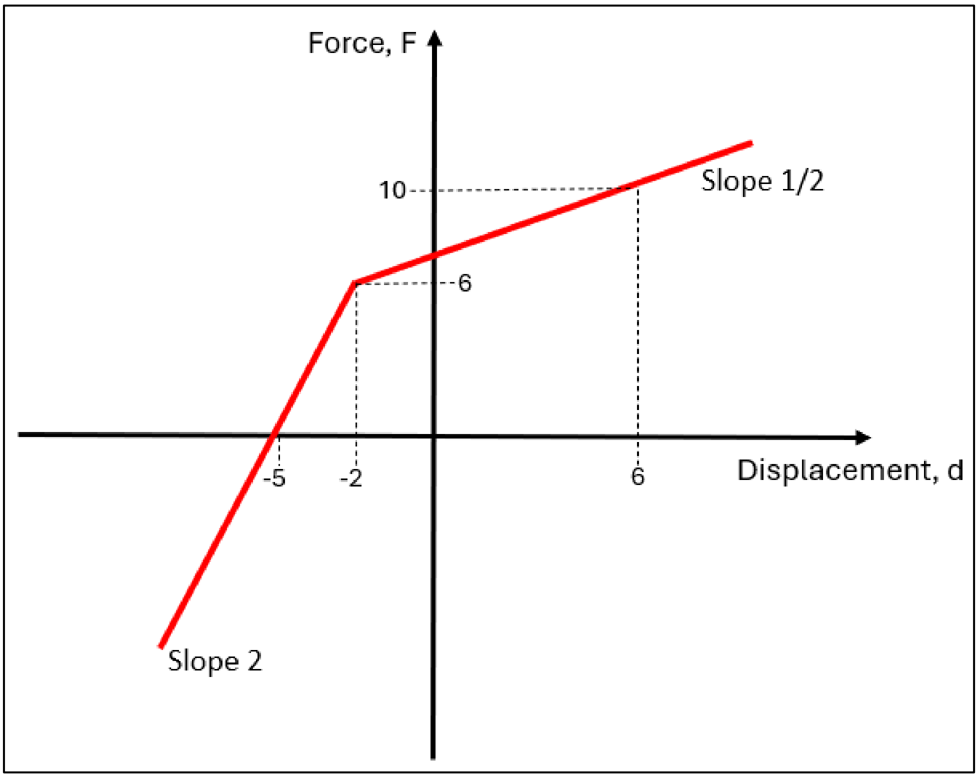


Figure 3 – Response curve of the smooth contact joint considered in the example.

3.2 Cantilever with a compression-only prop

The left end of the beam in Figure 4 is fixed, while the right end is supported by a compression-only prop. The beam is modelled using beam elements, while the compression-only prop is modelled as a smooth contact joint. It is assumed that the prop is relatively stiff.

Figure 4 – Cantilever with a compression-only prop.

Contact is modelled using a relatively large contact stiffness. When modelling “stiff” behaviour, the chosen stiffness should be large relative to the stiffness of the structural members connected to the joint; values that are too high may cause convergence issues.

Similarly, lift-off is modelled using a relatively small lift-off stiffness. A value of zero should be avoided, as it may also lead to convergence problems. The lift-off force, which defines the boundary between tension and compression, is set to zero.

Scenario 1: UDL in the −Y-direction

A uniformly distributed load acting in the −Y-direction results in compression in the joint. Consequently, there is contact and the deflection at the right end is very small (Figure 5).

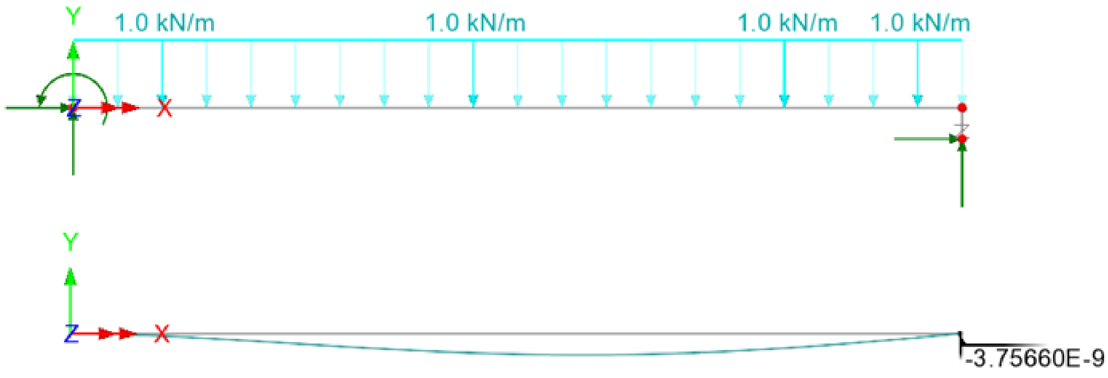


Figure 5 – Scenario 1: Deformed mesh.

Scenario 2: UDL in the +Y-direction

A uniformly distributed load acting in the +Y-direction results in lift-off. Consequently, the structure behaves as a cantilever (Figure 6).

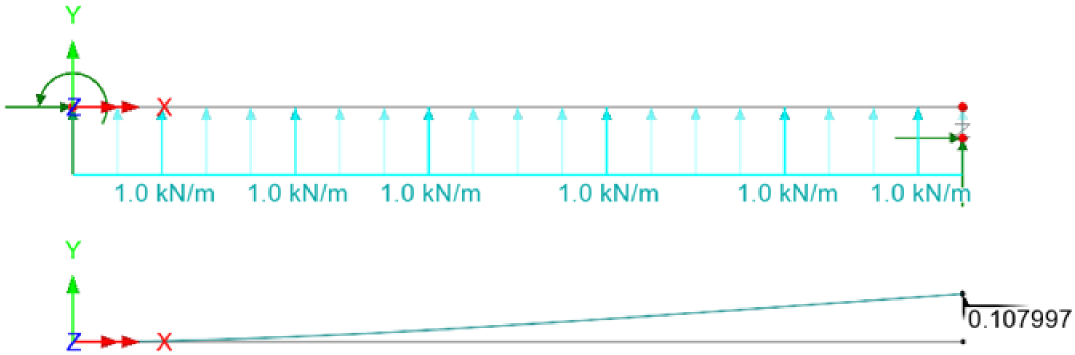


Figure 6 – Scenario 2: Deformed mesh.

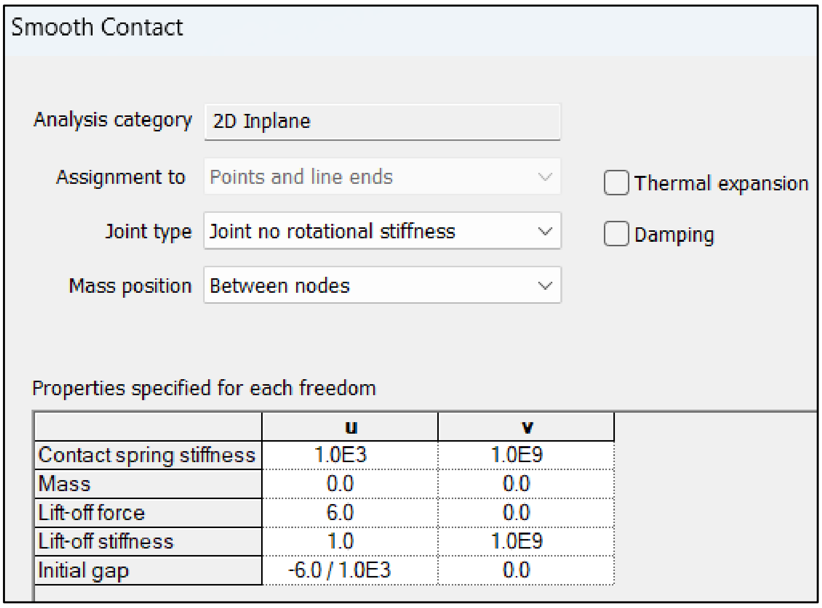
3.3 Tension-only members in a 3D model

A tension-only member can be represented using a smooth contact joint, with properties derived from the characteristics of the member itself. Its tension-only behaviour can be modelled using an approach similar to that adopted for the compression-only prop in the previous example. Since a tension-only member carries only tensile forces, the contact stiffness should be assigned a very low value (approaching zero), while the lift-off stiffness must be set to an appropriate magnitude.

3.4 Nonlinear elastic spring

The nonlinear response of an elastic spring can be modelled using a smooth contact joint. This is achieved by specifying an appropriate non-zero “yield” force together with a suitable initial gap. The word “yield” is in quotation marks because the spring is elastic; in this context, “yield” denotes the point at which the joint’s stiffness changes.

The beam from the second scenario described in Section 3.2 is considered. The spring support at the right end is assumed to “yield” in tension when the tensile force reaches 6 kN. For forces less than the “yield” force, the spring stiffness is 1000 kN/m, while for forces greater than the “yield” force, the stiffness reduces to 1 kN/m. The smooth contact joint exhibits the expected behaviour when the properties shown in Figure 7 are adopted. The corresponding joint response is presented in Figure 8.



	u	v
Contact spring stiffness	1.0E3	1.0E9
Mass	0.0	0.0
Lift-off force	6.0	0.0
Lift-off stiffness	1.0	1.0E9
Initial gap	-6.0 / 1.0E3	0.0

Figure 7 – Nonlinear elastic spring modelled using a smooth contact joint.

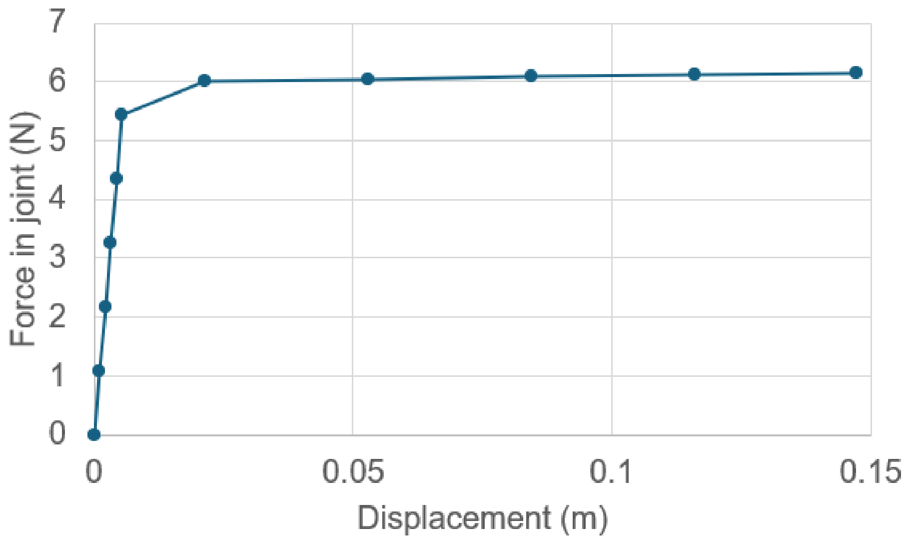


Figure 8 – Nonlinear elastic spring: Force-displacement curve.

3.5 Oversize spring introduced as a temporary support

An oversize spring is introduced at the midspan of a beam with fixed ends (Figure 9). Both the contact stiffness and the lift-off stiffness are set to 1000 kN/m. The initial gap is specified as −0.1 m, and the “yield” force is set to zero.

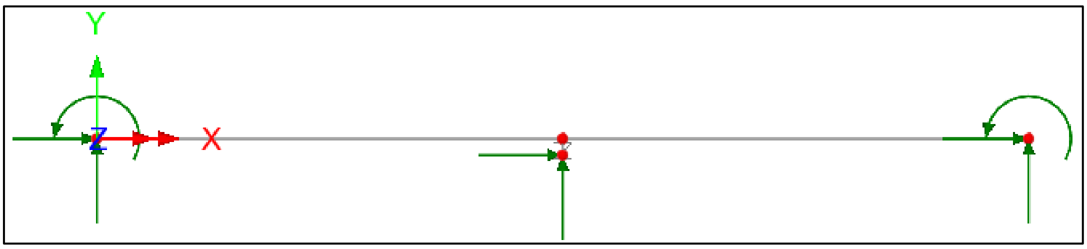
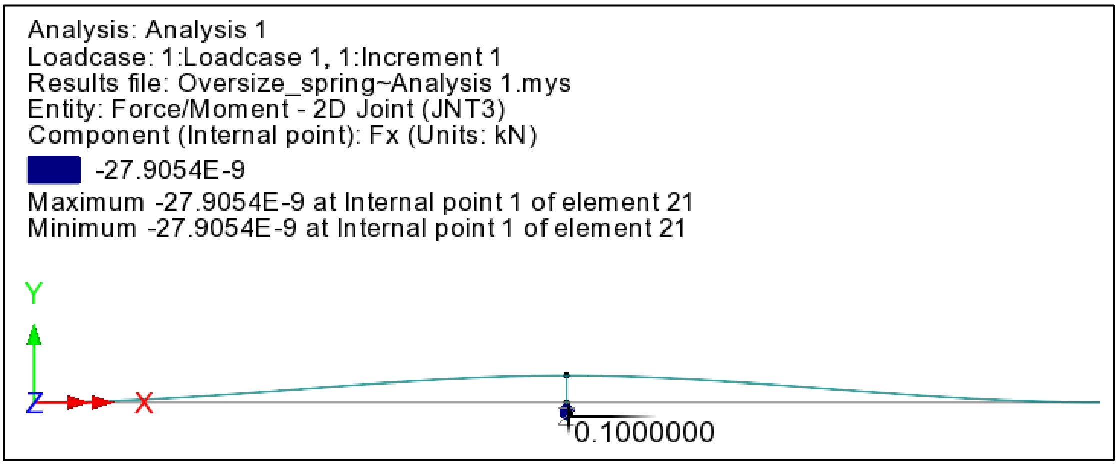


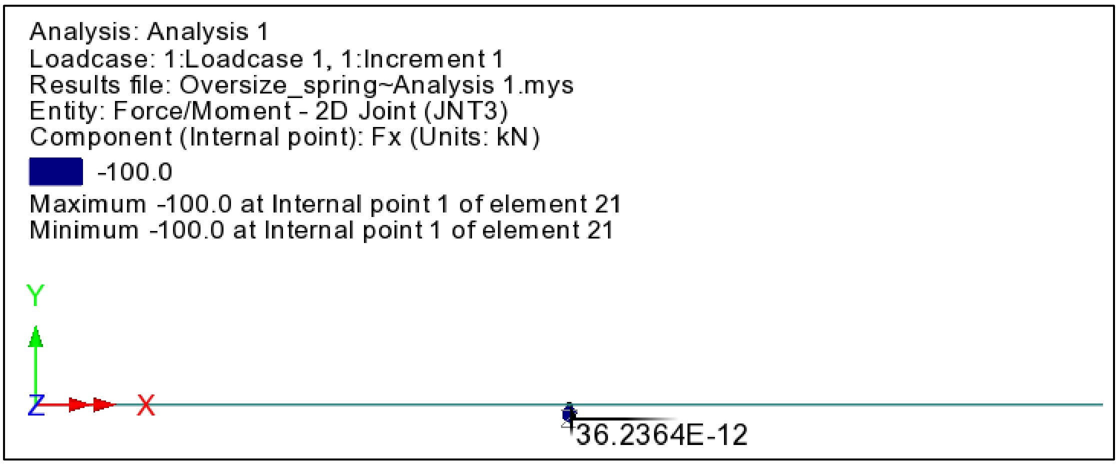
Figure 9 – Oversize spring at midspan.

Three cases are considered:

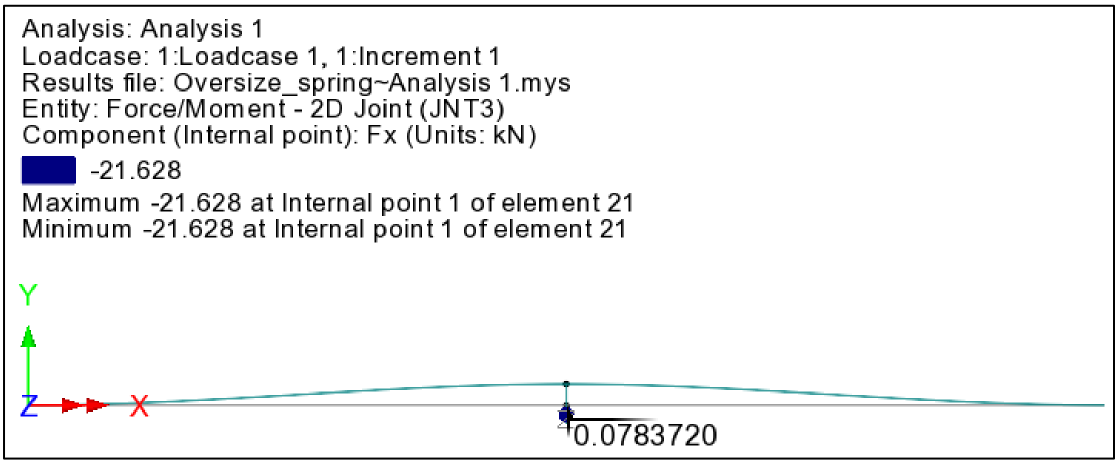
Very flexible beam: The midspan displacement is 0.1 m, and the force in the joint approaches zero.



Very stiff beam: The midspan displacement approaches zero. The force in the joint is compressive and equal to K x g, where K is the joint stiffness.



Beam with an I-section: The midspan displacement lies between the values obtained for the two previous cases. The force in the joint is compressive and lies between zero and K x g.



3.6 Sunken support in a beam model

The beam model shown in Figure 10 behaves as a cantilever when the vertical deflection at its right end is greater than −0.1 m. When the deflection reaches −0.1 m, the right end of the beam comes into contact with a stiff support, which prevents any further downward displacement.

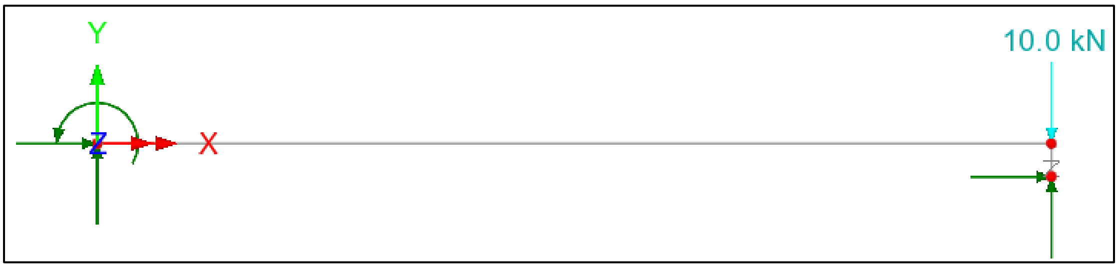
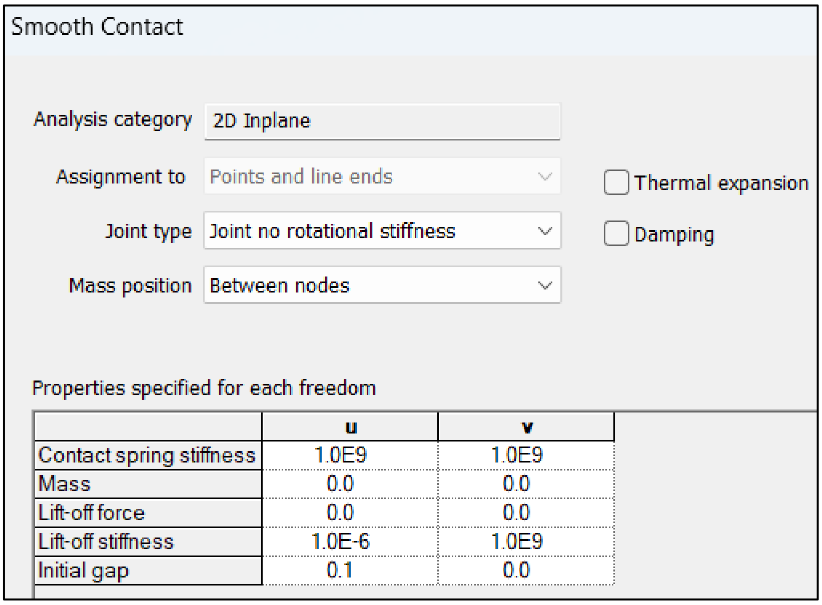


Figure 10 – Beam model with a sunken support.

This behaviour is modelled using a smooth contact joint with the properties shown in Figure 11. Figure 12 illustrates that the deflection at the right end increases linearly until it reaches −0.1 m. Beyond this point, the deflection remains constant despite further increases in the applied load, because of the relatively high contact stiffness.



	u	v
Contact spring stiffness	1.0E9	1.0E9
Mass	0.0	0.0
Lift-off force	0.0	0.0
Lift-off stiffness	1.0E-6	1.0E9
Initial gap	0.1	0.0

Figure 11 – Sunken support modelled using a smooth contact joint.

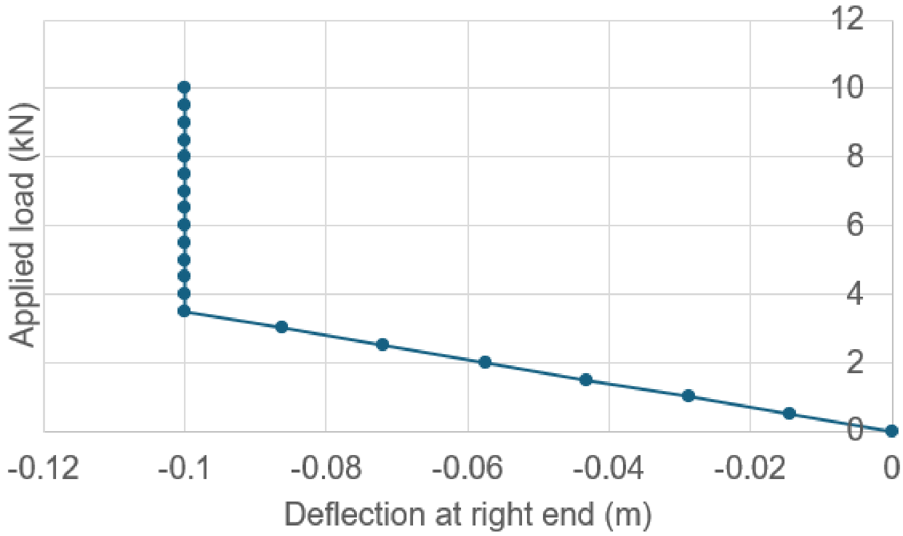


Figure 12 – Applied load versus deflection at right end.

4. Summary

Smooth contact joints are used in a variety of applications, including the modelling of:

- Lift-off and contact
- Tension-only or compression-only members
- Nonlinear elastic springs
- Oversize springs
- Sunken supports

Smooth contact joints can be used only in nonlinear analyses because their response is nonlinear.

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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.