Validation Case: Fixed Beam Under Gravitational Load

This bonded contact gravitational load validation case belongs to solid mechanics. This test case aims to validate the following parameter:

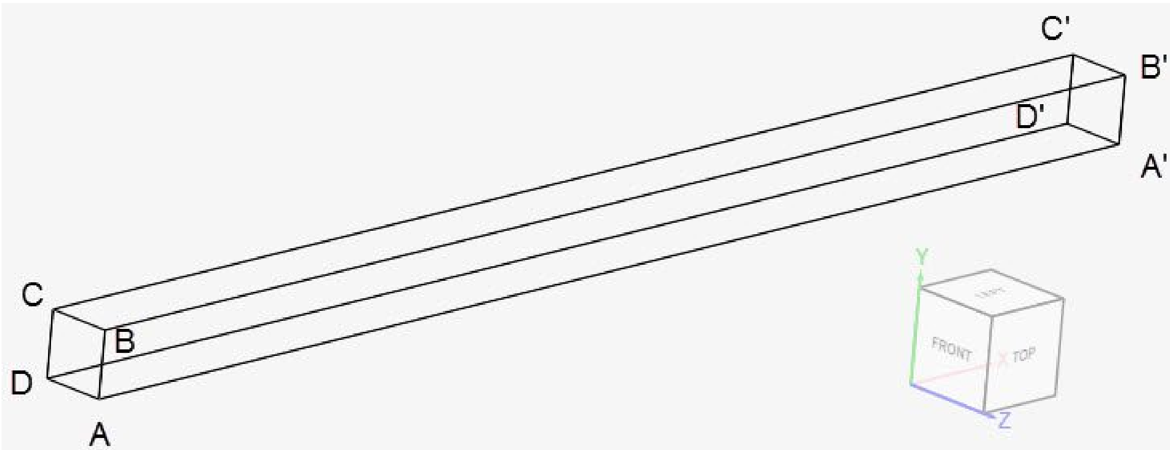
- Gravitational load

The simulation results of SimScale were compared to the analytical results derived from [Roark][1].

View Project (https://www.simscale.com/workbench/?pid=5496884749683545991&mi=geometry%3A653&mt=GEOMETRY)

Geometry

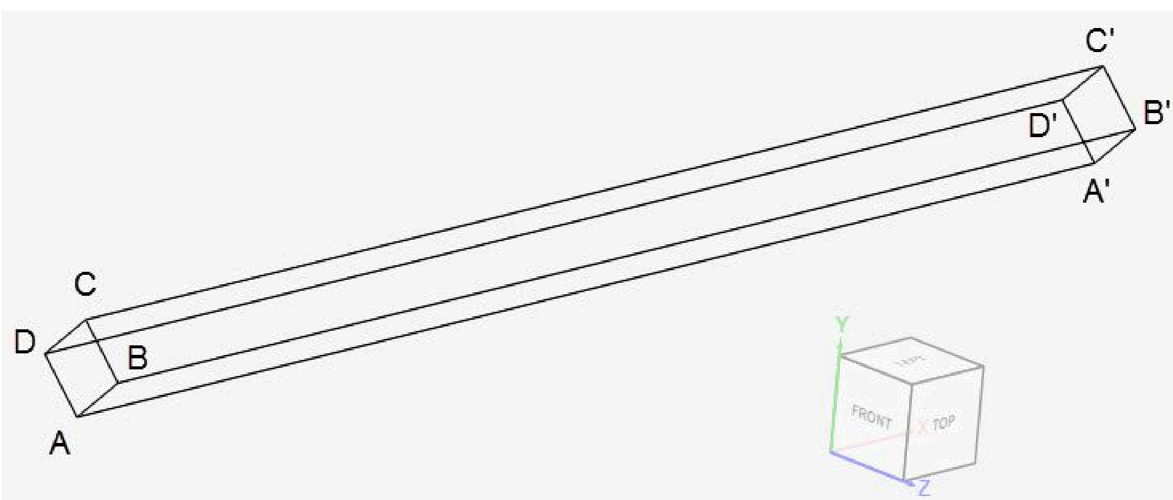
Two beam geometries are used for this gravitational load validation. They have a cross-section of 0.05 x 0.05 m^2 and 1 m length (l). The first one consists of unrotated beam geometry, shown below:



(https://www.simscale.com/wp-content/uploads/2020/06/2020-06-16_19-48-28-1.jpg)

Figure 1: Unrotated beam geometry

The second geometry is rotated 45° around the positive x-axis:



(https://www.simscale.com/wp-content/uploads/2020/06/2020-06-16_19-52-32-1.jpg)

Figure 2: Rotated beam geometry

The coordinates for the points in the first geometry are as tabulated below:

	A	**B**	**C**	**D**	**A'**	**B'**	**C'**	**D'**
x	0	0	0	0	1	1	1	1

[illegible]	0	0.05	0.05	0	0	0.05	0.05	0
z	0.05	0.05	0	0	0.05	0.05	0	0

Table 1: Unrotated beam dimensions in meters

Similarly, for the rotated geometry, we have:

	A	B	C	D	A'	B'	C'	D'
x	0	0	0	0	1	1	1	1
y	-0.03536	0	0.03536	0	-0.03536	0	0.03536	0
z	0.03536	0.0707	0.03536	0	0.03536	0.0707	0.03536	0

Table 2: Rotated beam dimensions in meters

Analysis Type and Mesh

Tool Type: Code Aster (https://code-aster.org/V2/)

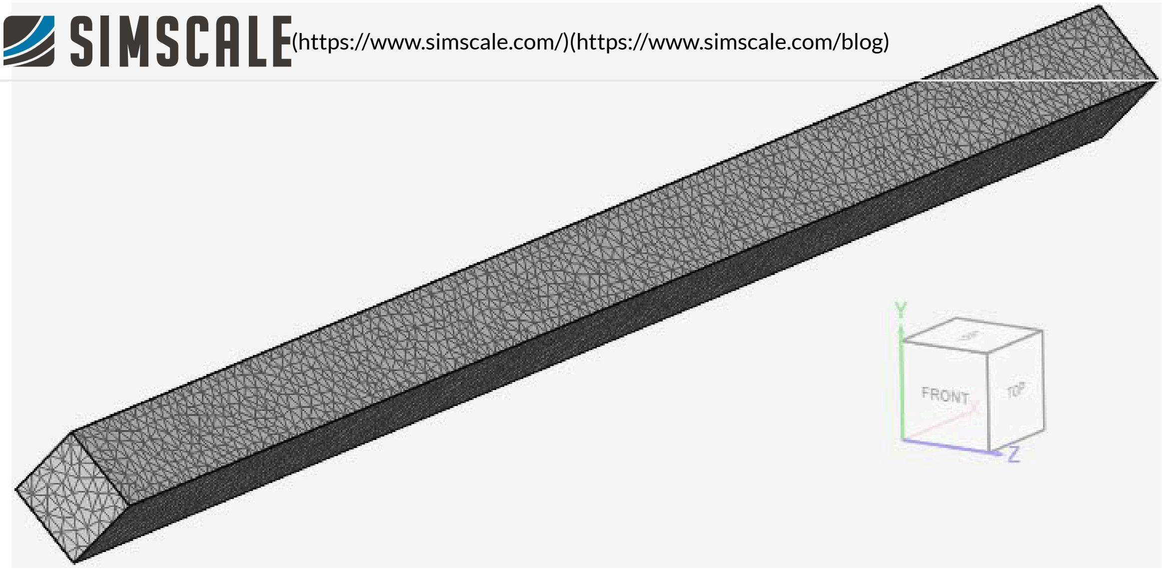
Analysis Type: Linear static (https://www.simscale.com/docs/analysis-types/static/)

Mesh and Element Types: The meshes for cases A and B were created in SimScale. The standard algorithm (https://www.simscale.com/docs/simulation-setup/meshing/standard/) was used. The meshes from case A and B were downloaded, rotated by 45° around the positive x-axis, and imported to SimScale. They were used for cases C and D, respectively. With this method, we achieve the same meshes for the rotated and unrotated cases.

Case	Geometry	Mesh Type	Number of Nodes	Element Type
(A)	Beam – original	Standard – tetrahedral cells	12737	1st order
(B)	Beam – original	Standard – tetrahedral cells	91499	2nd order
(C)	Beam – rotated	Standard – tetrahedral cells	12737	1st order
(D)	Beam – rotated	Standard – tetrahedral cells	91499	2nd order

Table 3: Mesh characteristics

Find below the mesh used for case D. It's a standard mesh with second-order tetrahedral cells.



(https://www.simscale.com/wp-content/uploads/2020/06/2020-06-16_20-54-06.jpg)

Figure 3: Second order standard mesh used for Case D

Simulation Setup

Material:

- Steel (linear elastic)
  - E = 205 GPa
  - ν = 0.28
  - ρ = 7870 kg/m^3

Boundary Conditions:

- Constraints
  - Fixed support on face ABCD.
- Gravity (defined under *model*):
  - Cases A and B: 9.81 m/s^2 in the negative z-direction (0, 0, -1);
  - Cases C and D: 9.81 m/s^2 rotated 45° around the positive x-direction (0, 1, -1)

Reference Solution

Converting the gravitational load to a line load (w_a):

$$w_a l = V \cdot \rho \cdot g \tag{1}$$

Solving (1), we have:

$$w_a = 193.01175 \ N/m \tag{2}$$

The moment of inertia I is given by:

$$I = \frac{b.\, h^3}{12} = 5.20833 \cdot 10^{-7}\, m^4 \tag{3}$$

The equation (4) below is derived from [Roark][1]

$$y(l) = -\frac{w_a l^4}{8EI} = -2.2597 \cdot 10^{-4}\, m \tag{4}$$

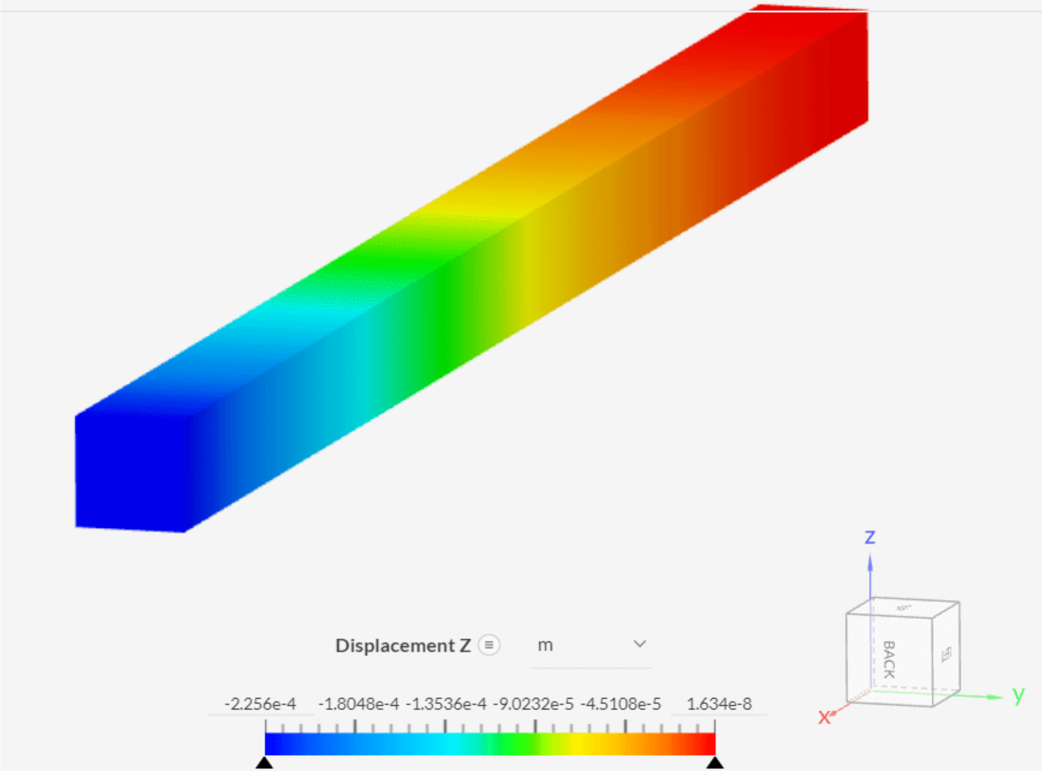
Result Comparison

The table below shows the SimScale results for the displacement at the free end (face A'B'C'D') in the gravity direction. Results are compared to the analytical solution by [Roark].

Case	Quantity	[Roark]	SimScale	Error (%)
(A)	Displacement at the free end $[m]$	-2.2597e-4	-2.1480e-4	-5.20
(B)	Displacement at the free end $[m]$	-2.2597e-4	-2.2560e-4	-0.16
(C)	Displacement at the free end $[m]$	-2.2597e-4	-2.1480e-4	-5.20
(D)	Displacement at the free end $[m]$	-2.2597e-4	-2.2560e-4	-0.16

Table 4: Comparison of SimScale's results against an analytical solution

Inspecting the displacements in the z-direction for case B:



(https://www.simscale.com/wp-content/uploads/2022/10/gravitational-load-beam-results.png)

Figure 4: Case B, showing the displacements in the z-direction

References

[1] W. C. YOUNG, R. G. BUDYNAS. Roark's Formulas for Stress and Strain. Seventh Edition. McGraw-Hill. 2002. p. 191.

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