Overview

Gabions are made by a steel cage filled with rock materials.

Advantages:

- Can be built quickly
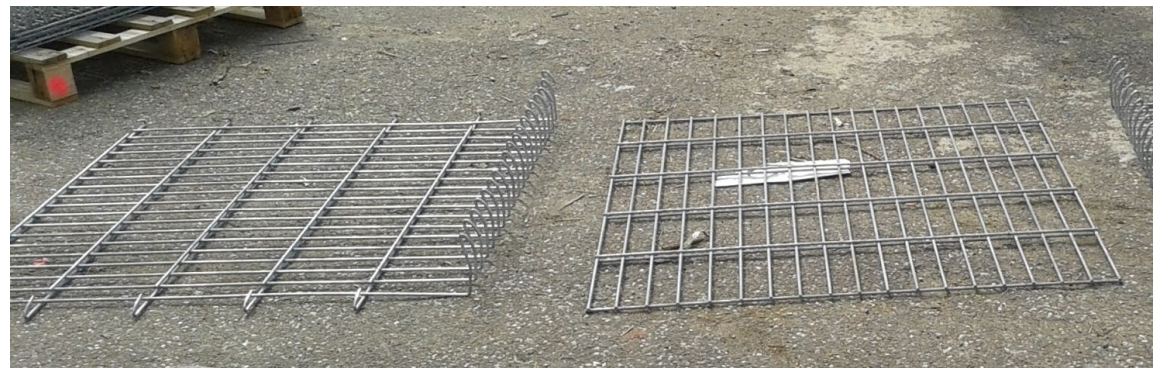- Can be moved easily
- Low environmental impact

Overview

Rigid gabions LedroSteel Box

Steel cage:

- Formed by welded steel grids hooked to each other to form a box.

- Grids have their own bending resistance (structural element)

3

Overview

Rigid gabions LedroSteel Box

Filling material:

- The steel box is then filled with
  rock aggregates.

Objective

The response of the steel cage can be studied breaking down the grids into vertical columns and studying the behaviour of a single steel wire column.

The objective of the preliminary studies was to investigate the compressive behaviour of a vertical steel wire of the grid.

The problem carries on the analysis presented in the Verification Problems of the PFC 6.0 Interactive Help.

Numerical model

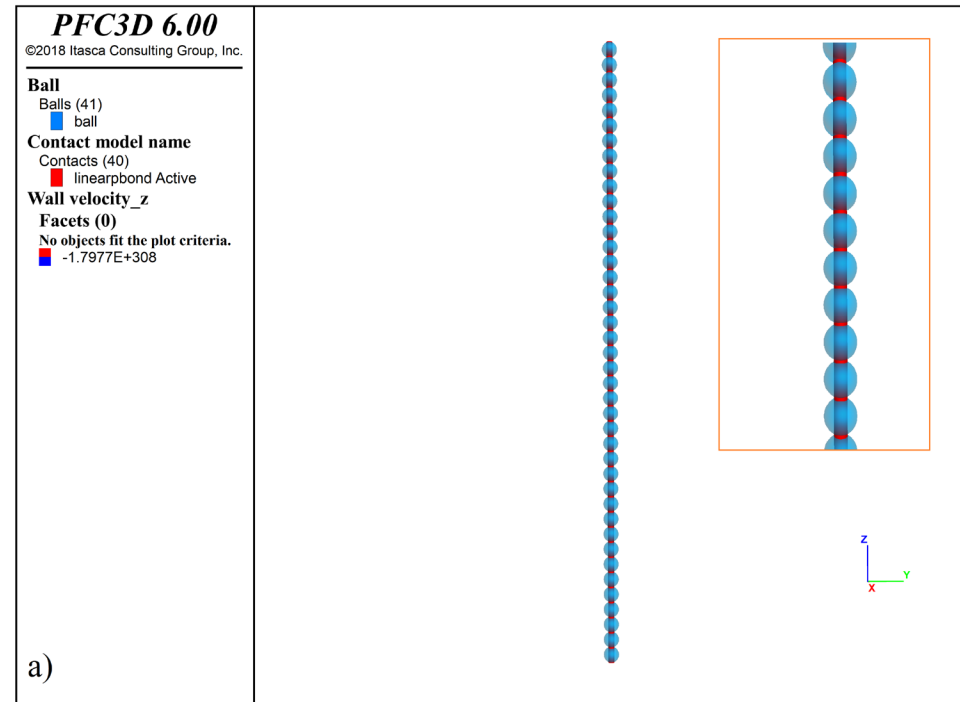The gabion taken as a reference has a steel cage made as follows:

- Formed by 6 panels with dimensions of 1m x 1m ($V=1$ m^3), hooked together at the corners.

- Panels are made by 6 mm steel wires welded together in order to form a grid with a mesh 5 cm-wide and 20 cm-high.

Numerical model

A single wire steel was modelled as:

- 1 m-high simply supported column loaded.

- Formed by 41 particles of 25 mm of diameter in contact to each other.

- Counting 40 contacts Linear Parallel Bond between the particles to carry force and moment.


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Ball
Balls (41)
ball

Contact model name
Contacts (40)
linearpbond Active

Wall velocity_z
Facets (0)
No objects fit the plot criteria.
-1.7977E+308

a)

Numerical model

- Bending behaviour: the simply supported column was loaded by a horizontal point load (P=100 N) acting in the middle section.

- Tensile/compressive behaviour: the simply supported column was loaded with a vertical load of Q=±1000 N acting on the top particle.

Tensile and shear strengths set to the ultime tensile strength of the steel. The normal and shear stiffness were calculated according to the verification example 'Tip-loaded cantilever beam'.

$$\bar{k}_n = \bar{E}/\bar{L}; \quad \bar{k}_s = \bar{G}/\bar{L}; \quad k_n = k_s = (AE)/R$$
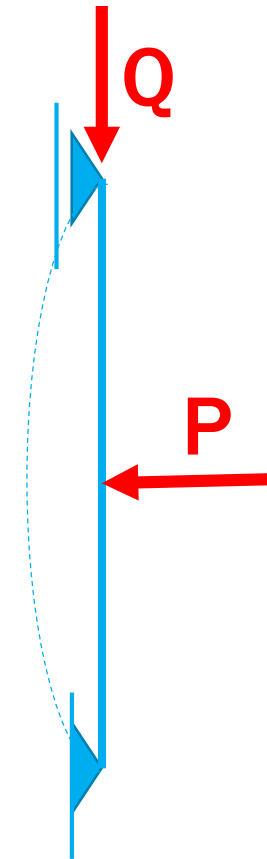
Numerical model

The radius multiplier determines the radius of the bond: $R_{bond} = \bar{\lambda}R_{particles}$

The bond radius defines the flexural stiffness of the vertical column, thus its dimension

determines how much the column will bend.

The radius multiplier was calibrated with the analytical solution of a simply supported

bending column with a horizontal point load of 100 N acting in the middle section

$\bar{\lambda} = 0.2337$: value that determined the same middle section horizontal

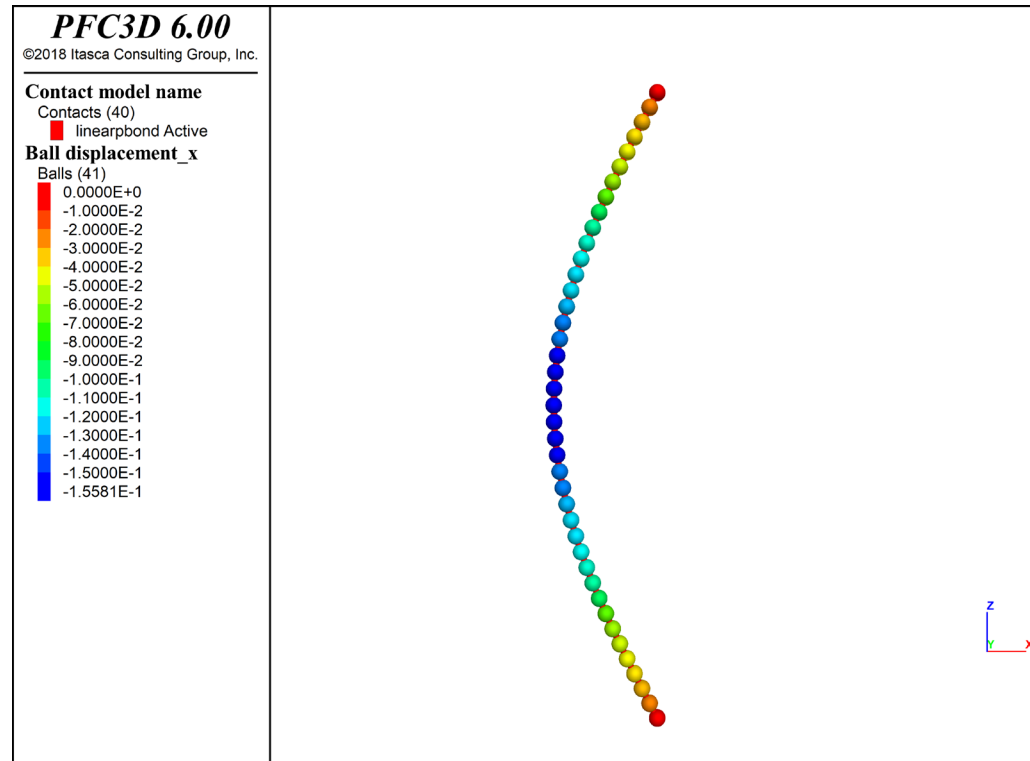displacement between the numerical and the analytical solution

Numerical model

Parallel bond group		
Normal stiffness (N/m^3)	$\overline{k_n}$	8.40×10^{12}
Shear stiffness (N/m^3)	$\overline{k_s}$	3.23×10^{12}
Tensile strength (Pa)	$\overline{\sigma_c}$	5.53×10^8
Cohesion (Pa)	$\overline{c}$	5.53×10^8
Radius multiplier	$\overline{\lambda}$	0.2337
Linear group		
Normal stiffness (N/m)	k_n	4.50×10^8
Shear stiffness (N/m)	k_s	4.50×10^8
Particle density (kg/m^3)	ρ	7850

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Contact model name
Contacts (40)
■ linearpbond Active
Ball displacement_x
Balls (41)
0.0000E+0
-1.0000E-2
-2.0000E-2
-3.0000E-2
-4.0000E-2
-5.0000E-2
-6.0000E-2
-7.0000E-2
-8.0000E-2
-9.0000E-2
-1.0000E-1
-1.1000E-1
-1.2000E-1
-1.3000E-1
-1.4000E-1
-1.5000E-1
-1.5581E-1

10

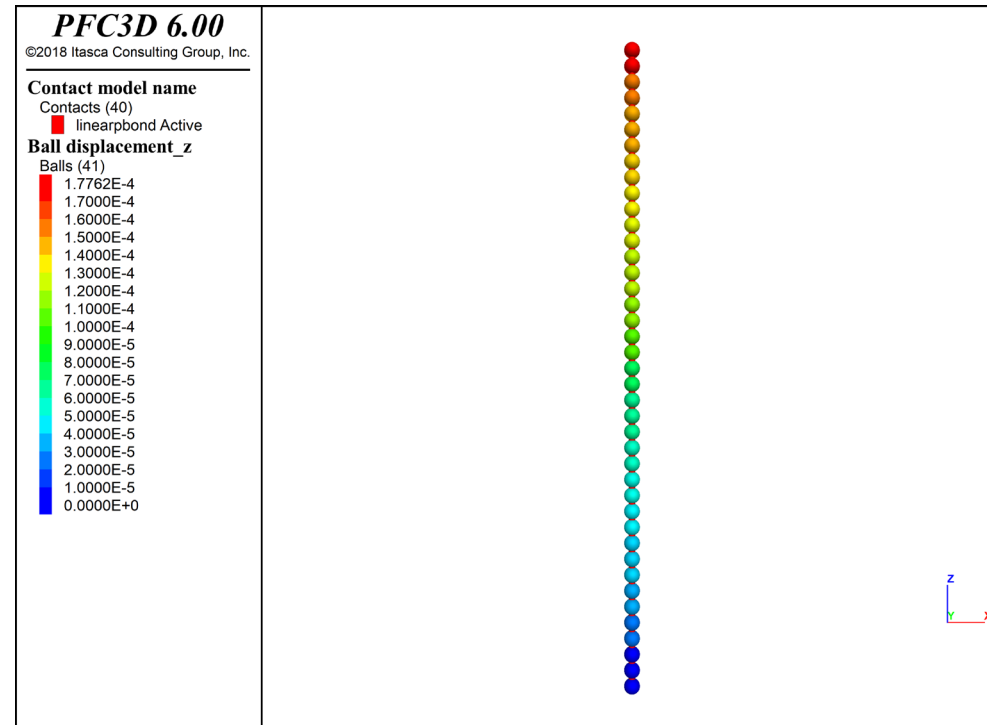# Results and discussion: Compression vs Tension

Tension: Q=1000 N

→only the contact bonds act (parallel bond group). The linear contact group do not resist in tension.

$$\rightarrow \Delta x = \frac{Q}{K} = \frac{PL}{EA}$$

$$\Delta x = 1.7762e - 4\, m$$

$$\Delta x_{PFC} = 1.7762e - 4\, m$$

$$(error = 0.001\%)$$

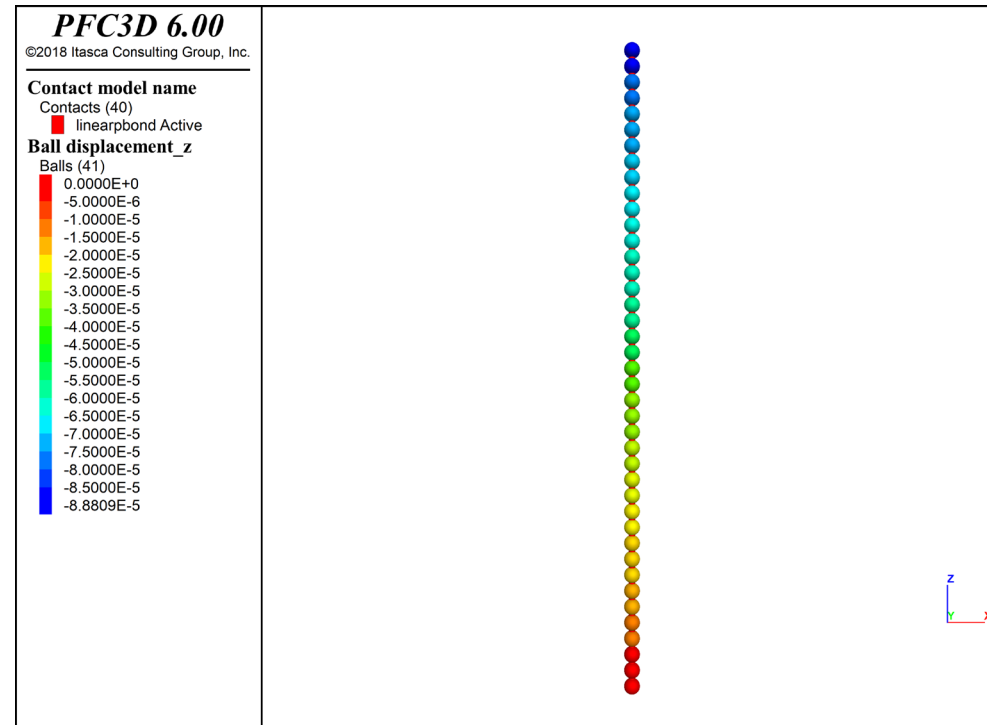# Results and discussion: Compression vs Tension

Compression: Q= -1000 N

→both the linear and bond parallel groups work. The force applied is divided by the stiffness of two parallel springs.

$$\rightarrow \Delta x = \frac{P}{K}; \; K = \frac{A_{pb}\bar{k}_n}{n} + \frac{k_n}{2n};$$

$$\Delta x = -8.8810e - 5 \; m = \frac{1}{2}\Delta x_{tension}$$

$$\Delta x_{PFC} = -8.8809e - 5 \; m$$

$$(error = 0.001\%)$$

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Contact model name
Contacts (40)
■ linearpbond Active
Ball displacement_z
Balls (41)
0.0000E+0
-5.0000E-6
-1.0000E-5
-1.5000E-5
-2.0000E-5
-2.5000E-5
-3.0000E-5
-3.5000E-5
-4.0000E-5
-4.5000E-5
-5.0000E-5
-5.5000E-5
-6.0000E-5
-6.5000E-5
-7.0000E-5
-7.5000E-5
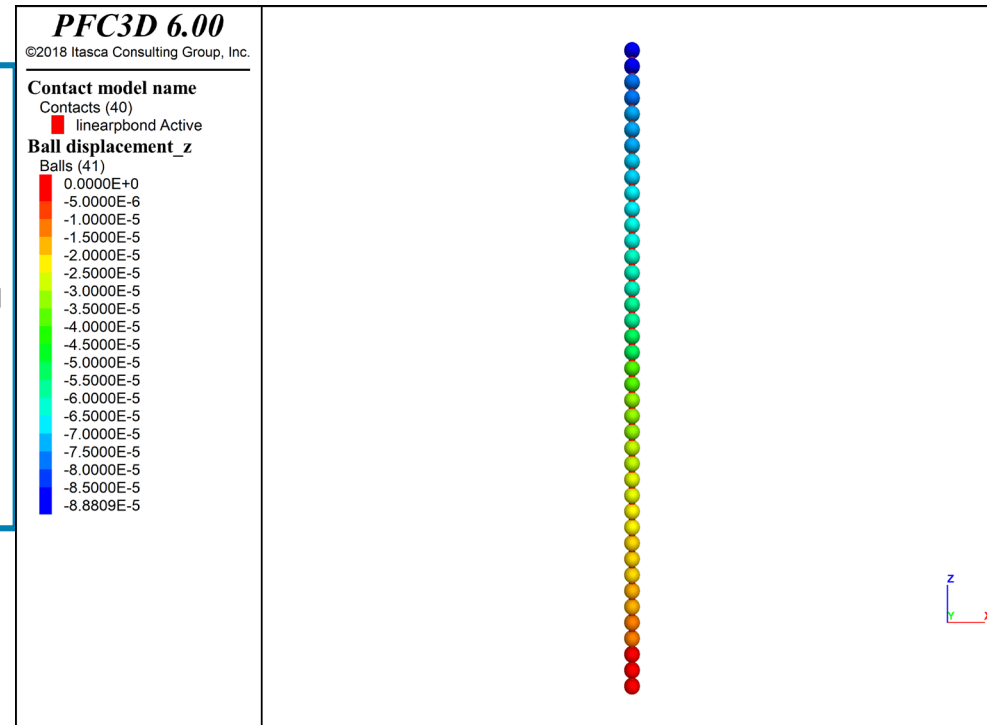-8.0000E-5
-8.5000E-5
-8.8809E-5

Results and discussion: Compression vs Tension

Compression: Q= -1000N

→ same results in tension and compression

with a null interparticle stiffness

→ increase of the computational time (from

2 to 10 minutes for the compressed

column)

Compromise: Interparticle stiffness

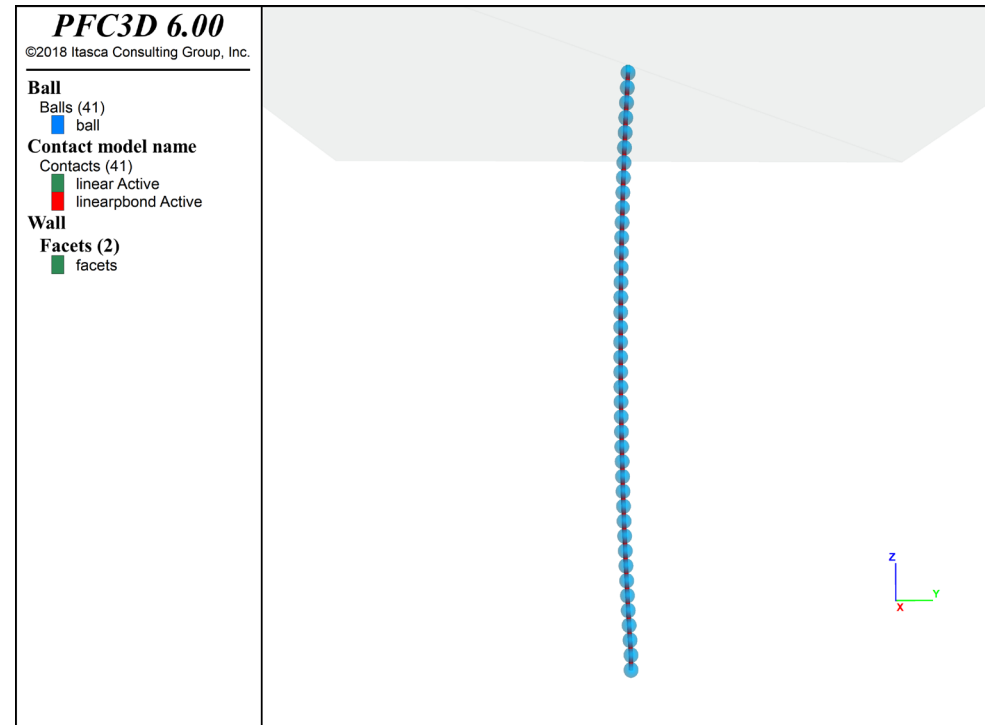$k_n = k_s = 1.0 \times 10^8$ N/m (1.2 stiffness ratio comp-tens)

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Contact model name
Contacts (40)
■ linearpbond Active

Ball displacement_z
Balls (41)
0.0000E+0
-5.0000E-6
-1.0000E-5
-1.5000E-5
-2.0000E-5
-2.5000E-5
-3.0000E-5
-3.5000E-5
-4.0000E-5
-4.5000E-5
-5.0000E-5
-5.5000E-5
-6.0000E-5
-6.5000E-5
-7.0000E-5
-7.5000E-5
-8.0000E-5
-8.5000E-5
-8.8809E-5

Results and discussion: Buckling

Euler critical load: $P_{crit} = \frac{\pi^2 EI}{l_0^2} = 131\ N$

E=210000 MPa , l=l$_0$=1 m, ø=6 mm

$\rightarrow$ Perfect vertical column: <u>Critical Euler load not identified</u> (infinite resistance in compression)

Insertion of an initial geometrical flaw. Longitudinal axis with a parabolic shape (middle horizontal displacement = 1.5 cm)


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Ball
  Balls (41)
    ■ ball
Contact model name
  Contacts (41)
    ■ linear Active
    ■ linearpbond Active
Wall
  Facets (2)
    ■ facets

Results and discussion: Buckling

Instability around a load value of 100 N:

→ small increments of the applied load caused the development of large displacement, meaning that the column was not able to sustain more load

→ the value of the numerical critical Euler load is affected by the initial value of the horizontal deformation inserted in the model.
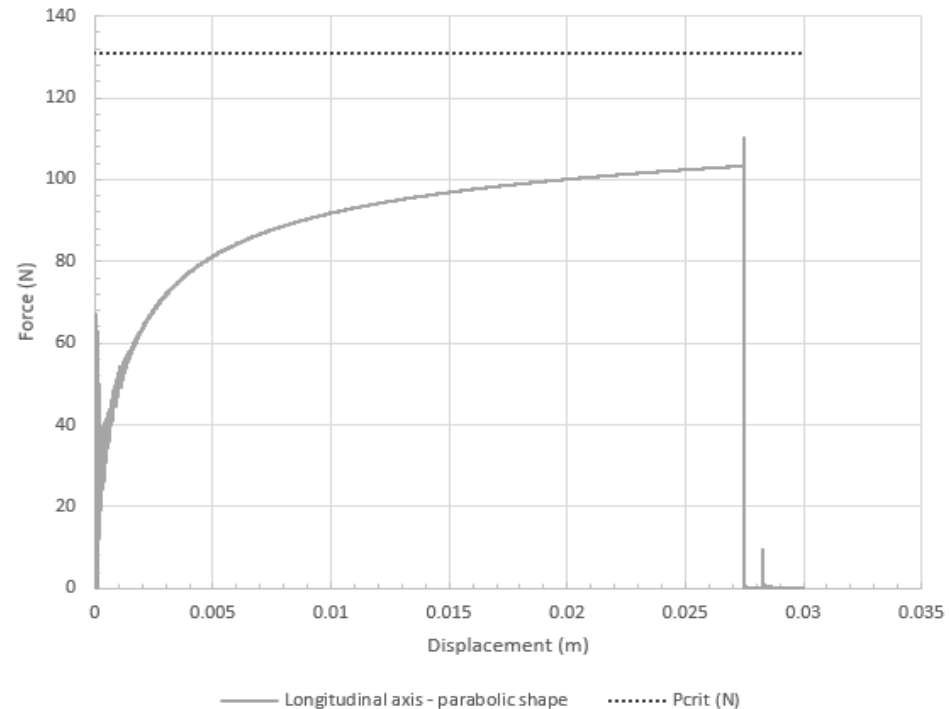
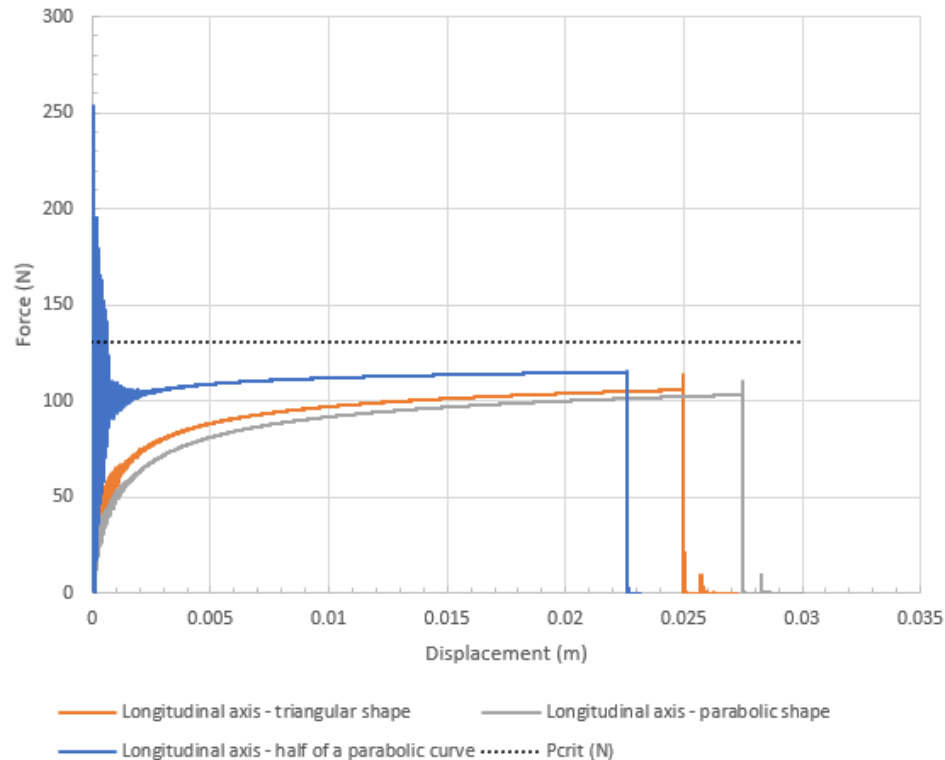# Results and discussion: Buckling
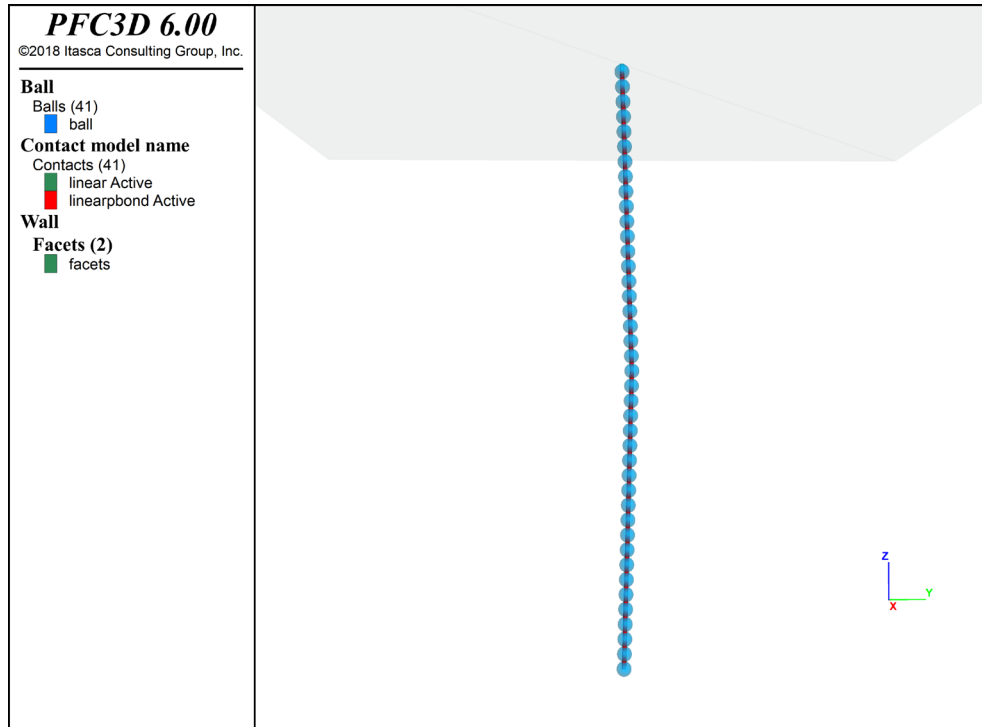
Longitudinal axis with a triangular shape (horizontal middle section disp. = 1.5 cm)
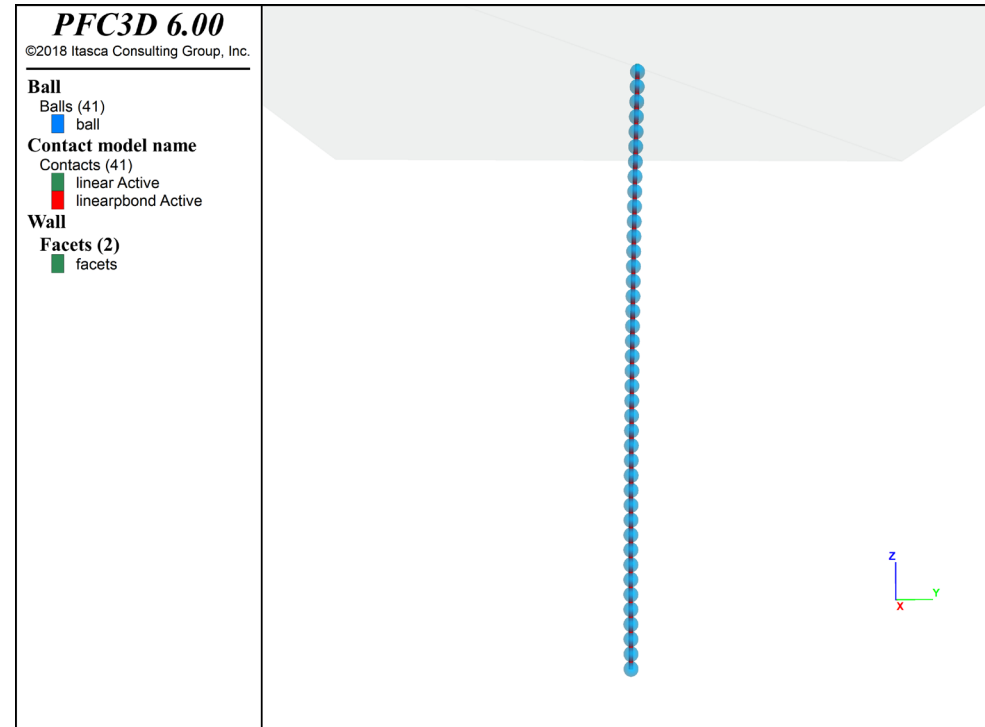
Longitudinal axis with a half parabolic shape (tip horizontal displacement = 1.5 cm)

Results and discussion: Buckling

→ All the three columns behave in a similar manner indentifying the critical Euler load

→ The critical Euler load recorded in the three cases was lower than 131 N

→ The tests performed at the same velocity had different initial force oscillations

Results and discussion: Buckling
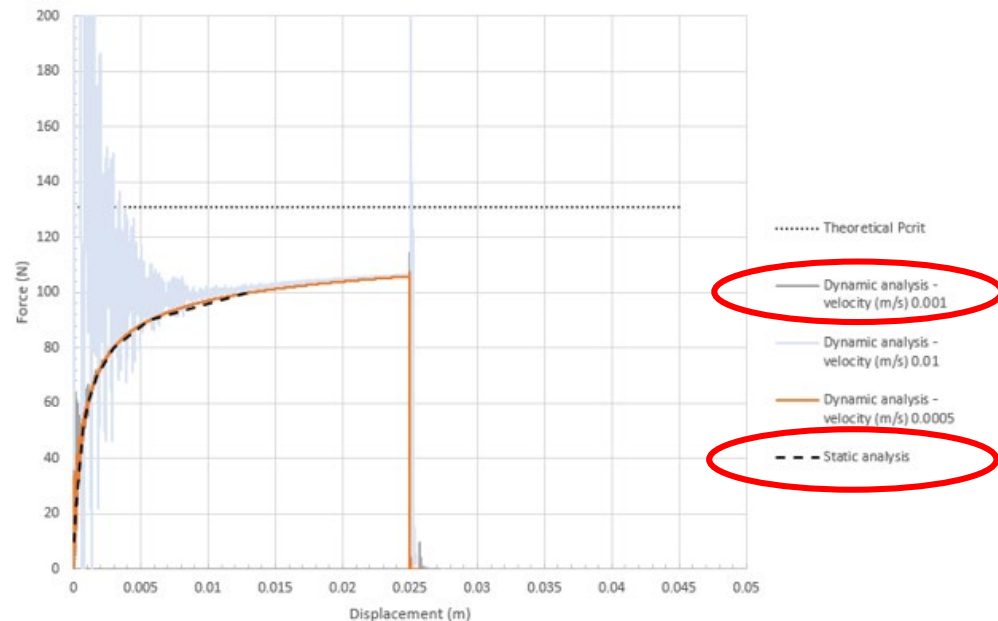
Static analysis:

→ reduction of the initial oscillations

→ behaviour that agreed with that
obtained from a dynamic analysis

→ static analysis manually interrupted
at the application of the 110 N load
increment → the software could not
reach the equilibrium

→ advantage: oscillation reductions,
decrease of the computational time

Results and discussion: Buckling
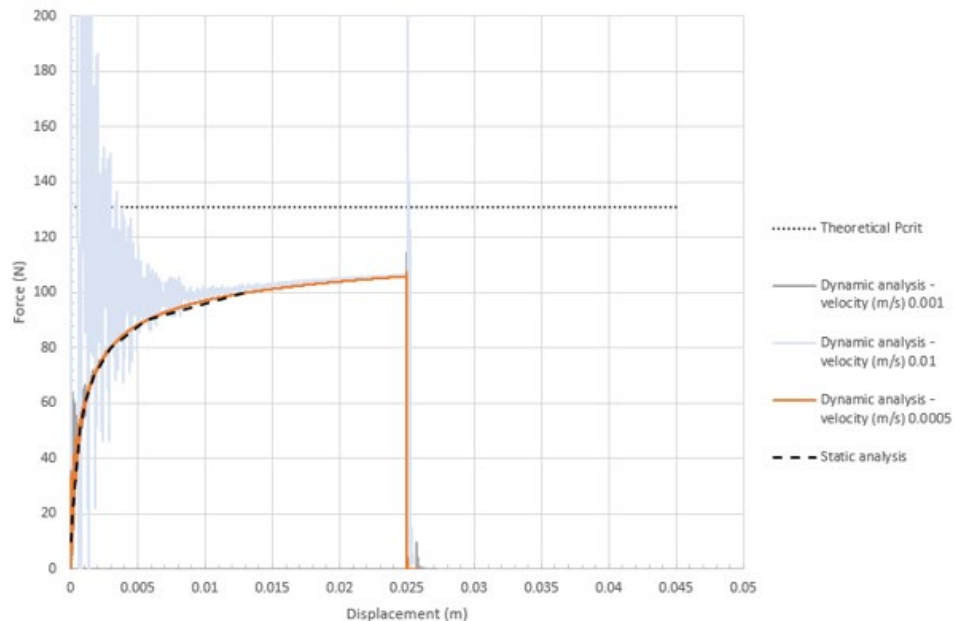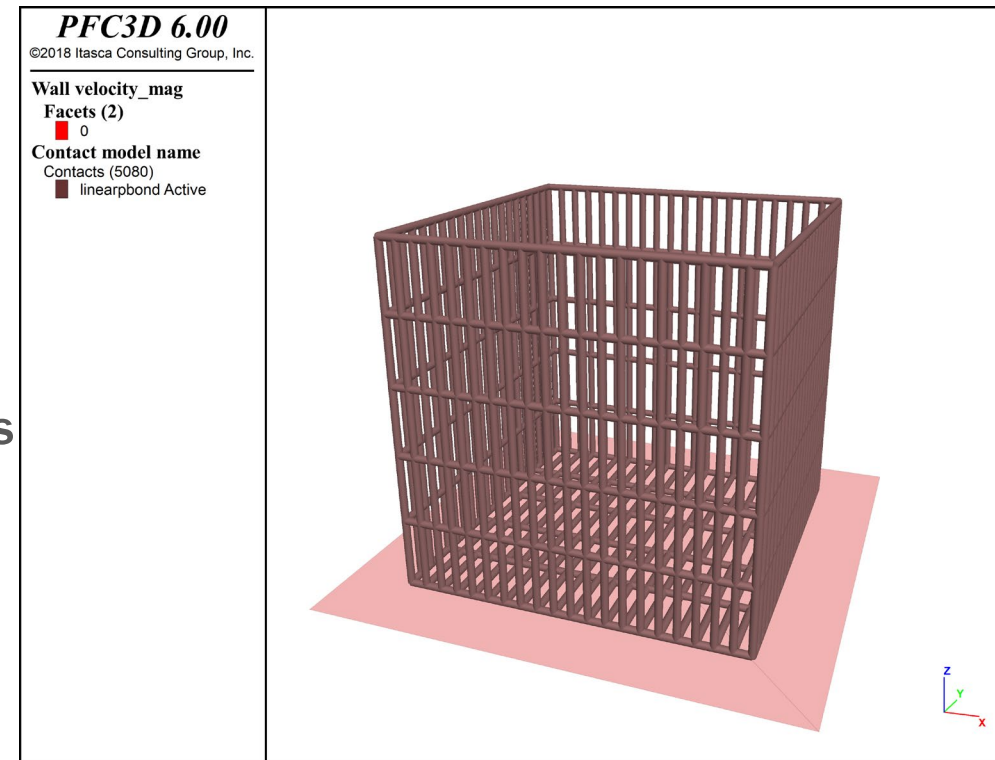

Influence of the applied velocity:

→ imposed wall velocities 0.01, 0.001, 0.0005 m/s

→ same response in terms of force-displacement

→ a high velocity caused large oscillations of the contact force, but same maximum load

→ a small velocity ensured a quasi-static analysis, but raised the computational time

→ compromise between quality of the results and computational time: velocity of 0.001 m/s

→ static analysis: valid alternative

Conclusions

- PFC3D is able to simulate structural steel continuous elements.

- The compression behavior of a column can be modeled using spherical particles with linear parallel bond contacts.

- Calibration in bending, tension and compression is necessary to define the column behaviour. Buckling behaviour has to be imposed to the model inserting an initial geometrical flaw.

- The numerical compression behaviour is different from the theorical response due to the presence of the bonded contacts. A compromise between interparticle stiffness and computational time is chosen in order to have similar compressive/tensile behaviour.

- Buckling analyses are independent from the loading rate, but high velocities cause large initial oscillations. Small velocities cause a raise in the computational time; thus a static analysis can be used as a valid alternative for compression simulations.

Next steps

- steel wires were assembled to form the metal cage of the gabion (grid mesh 5x20 cm)
- the box so formed was tested in compression and the response was compared with that obtained from the tests performed in the laboratory.
- compression behaviour affected by the value assigned to the initial flaw of the vertical wire (rigid/flexible box)
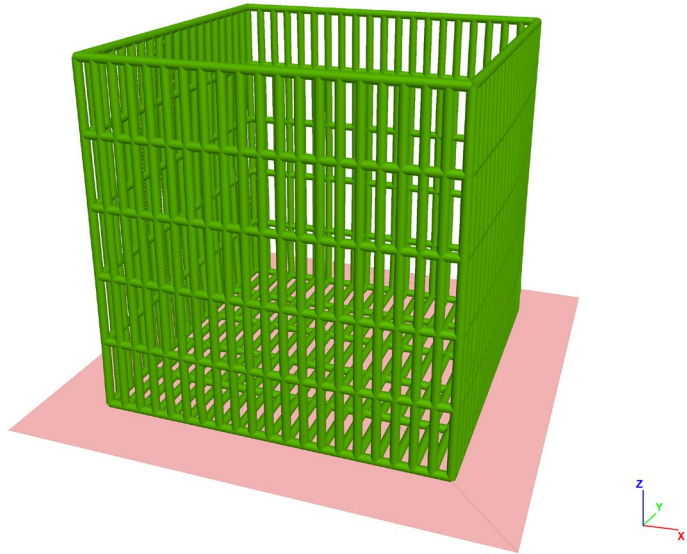

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Wall velocity_mag
Facets (2)
   ■ 0
Contact model name
Contacts (5080)
   ■ linearpbond Active

Next steps

- the cage was then filled with spherical particles having diameter of 12 cm to model the rock aggregates.
- compression and shear tests were performed to compare the numerical response with that found during the laboratory tests.
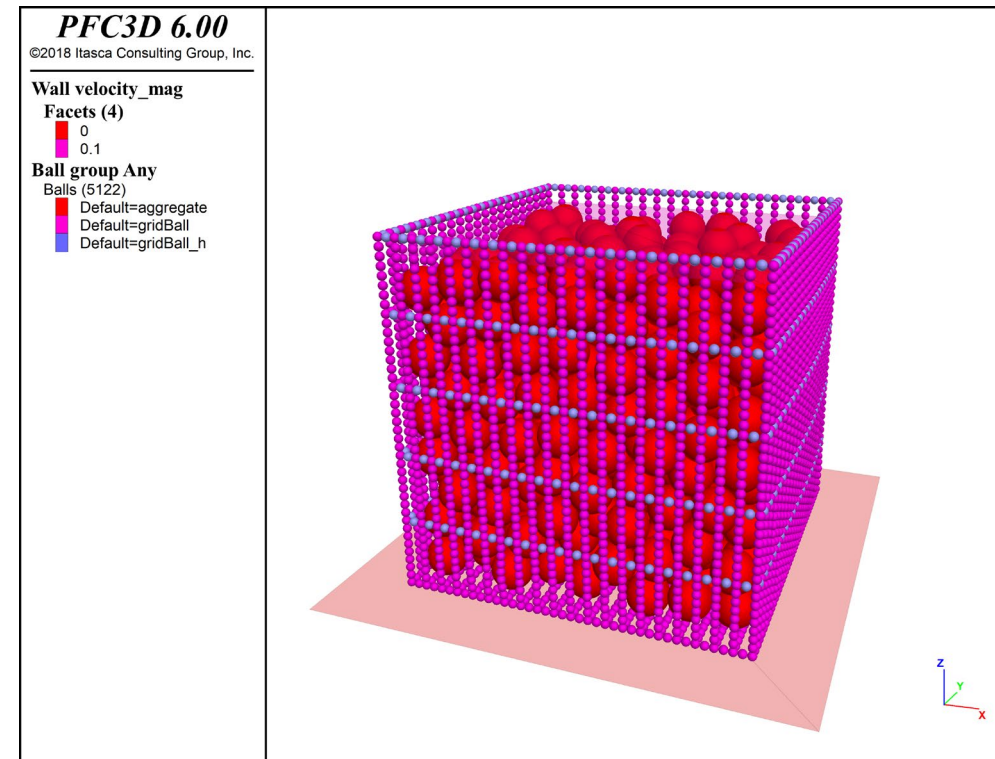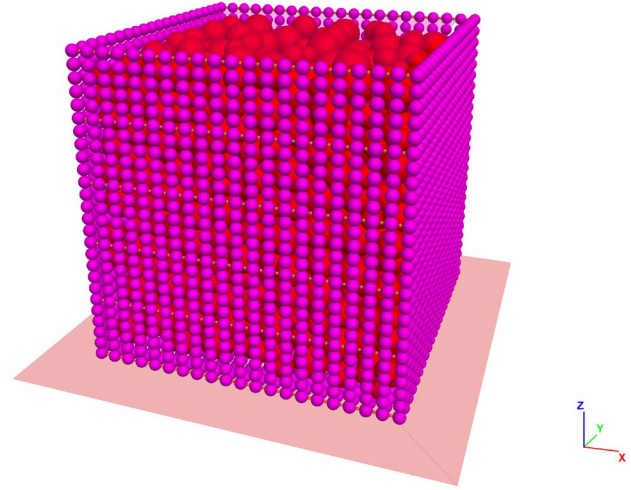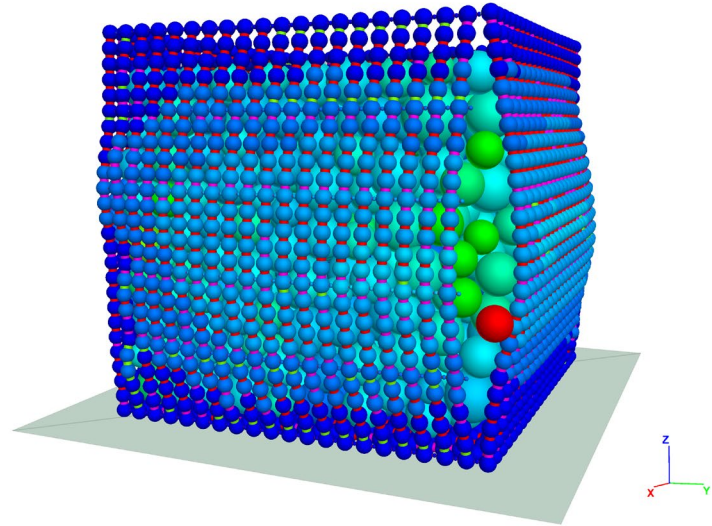

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Wall velocity_mag
Facets (4)
0
0.1
Ball group Any
Balls (5122)
Default=aggregate
Default=gridBall
Default=gridBall_h

Thanks for your attention