3DEC analysis of crosswise tension resistance in masonry structures

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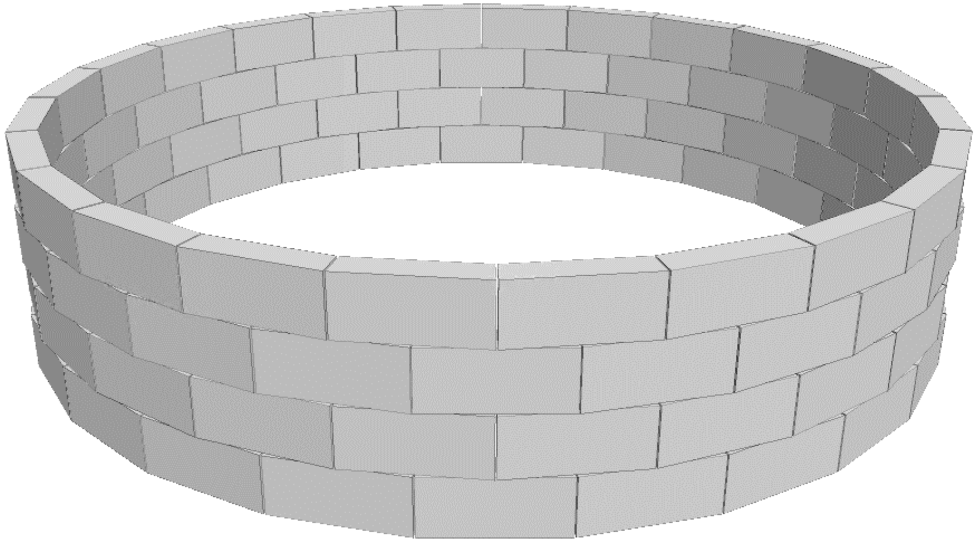
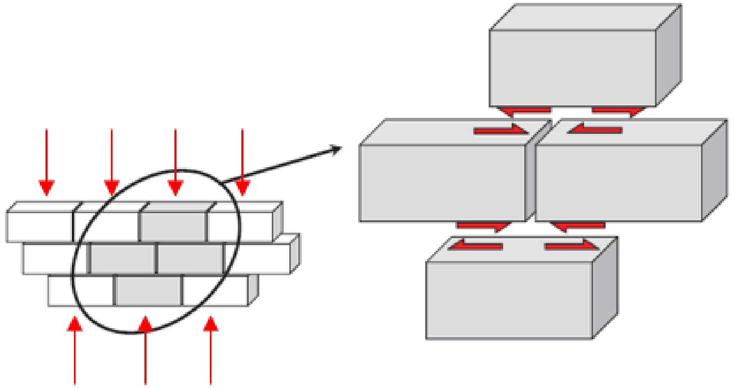


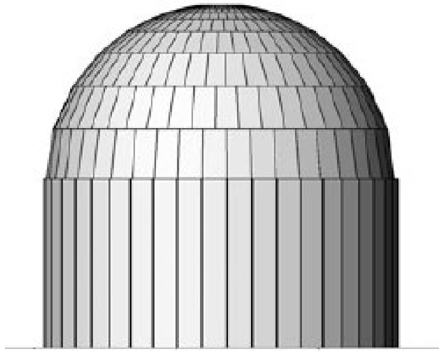
The Crosswise Tension Resistance

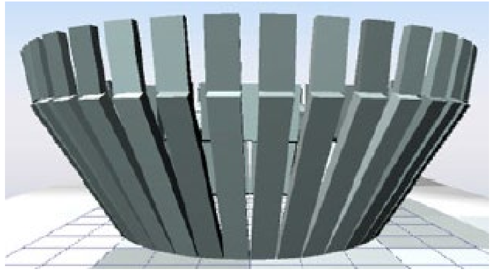
The phenomenon:

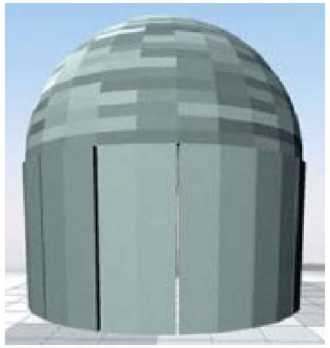


(Simon & Bagi, 2016)

Its importance:







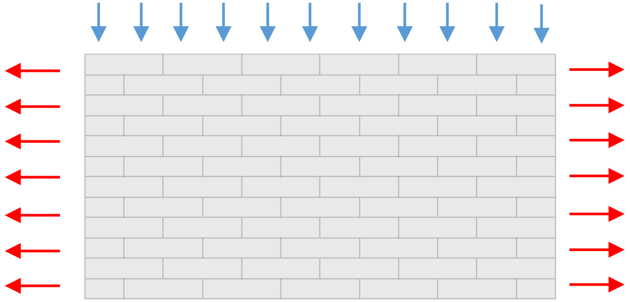
(Beatini et al, 2018)

Overview of the research

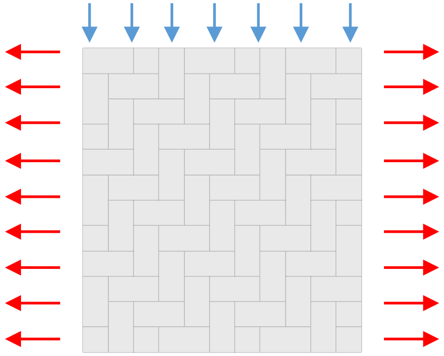
Practical experience:

Bond pattern strongly affects crack formation and hence the load bearing capacity.

Analyzed patterns:



Running bond pattern



Herringbone pattern

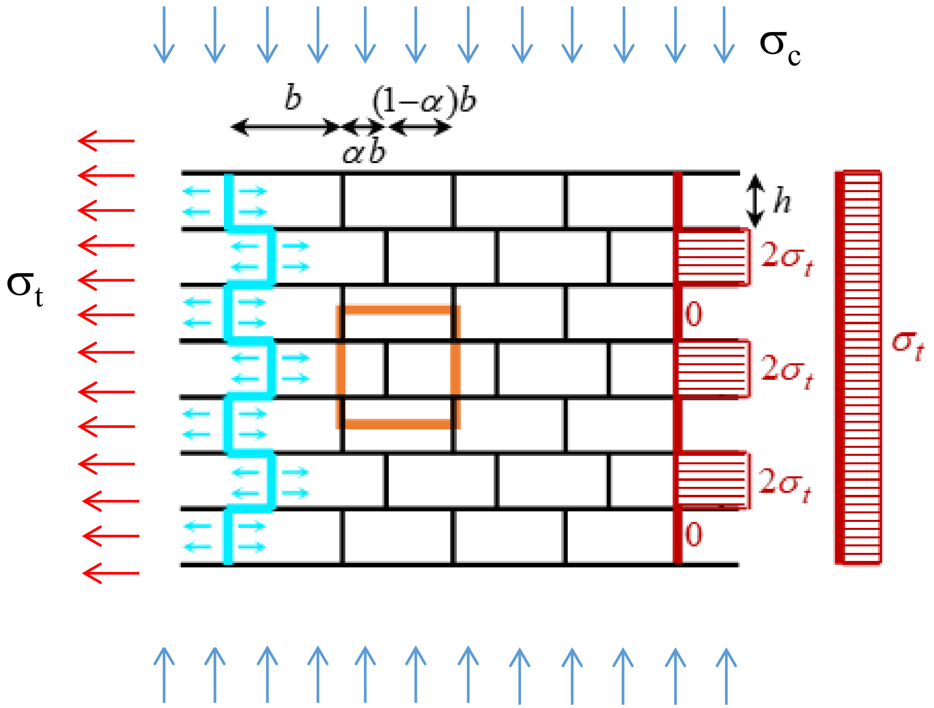
Main steps of the analysis of each pattern:

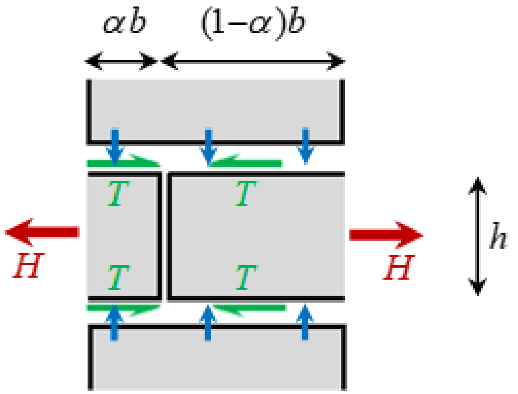
Step 1: Theoretical prediction on the suitably chosen elementary cell of the pattern

Step 2: Run discovery DEM simulations to figure out how different bond patterns fail

Step 3: Check the theoretical derivations with DEM experiments

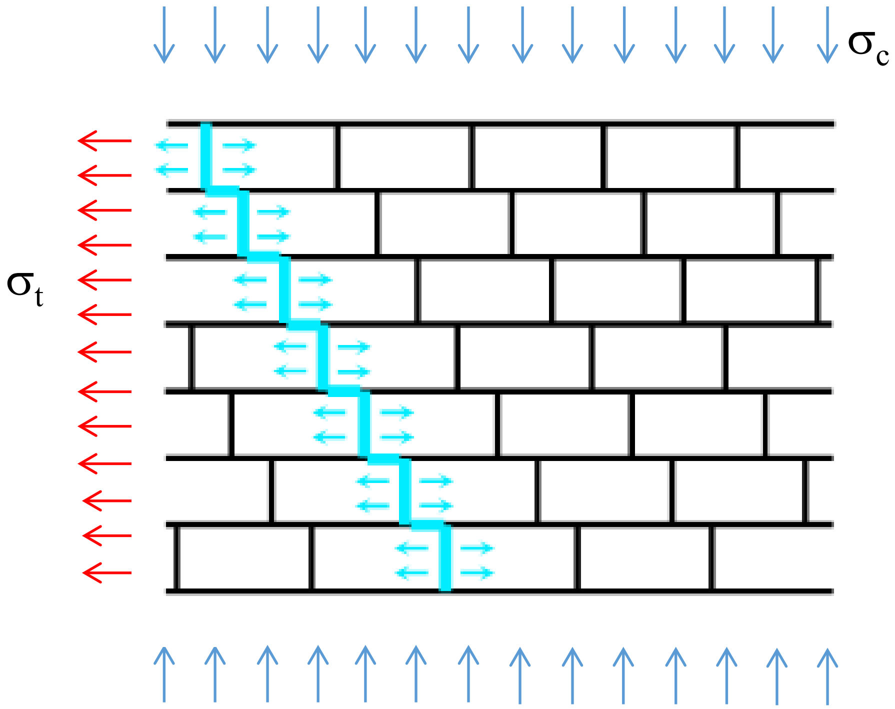
Theoretical derivations: 1. The straight running bond pattern

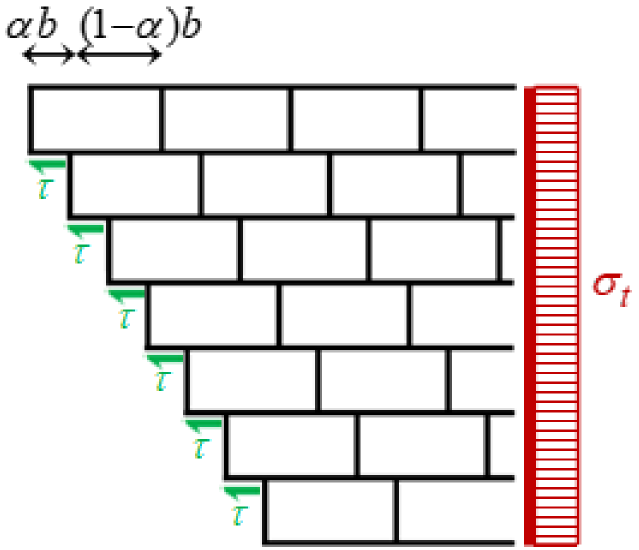




$$\sigma_t \le \mu \cdot \frac{\alpha \cdot b}{h} \sigma_c$$

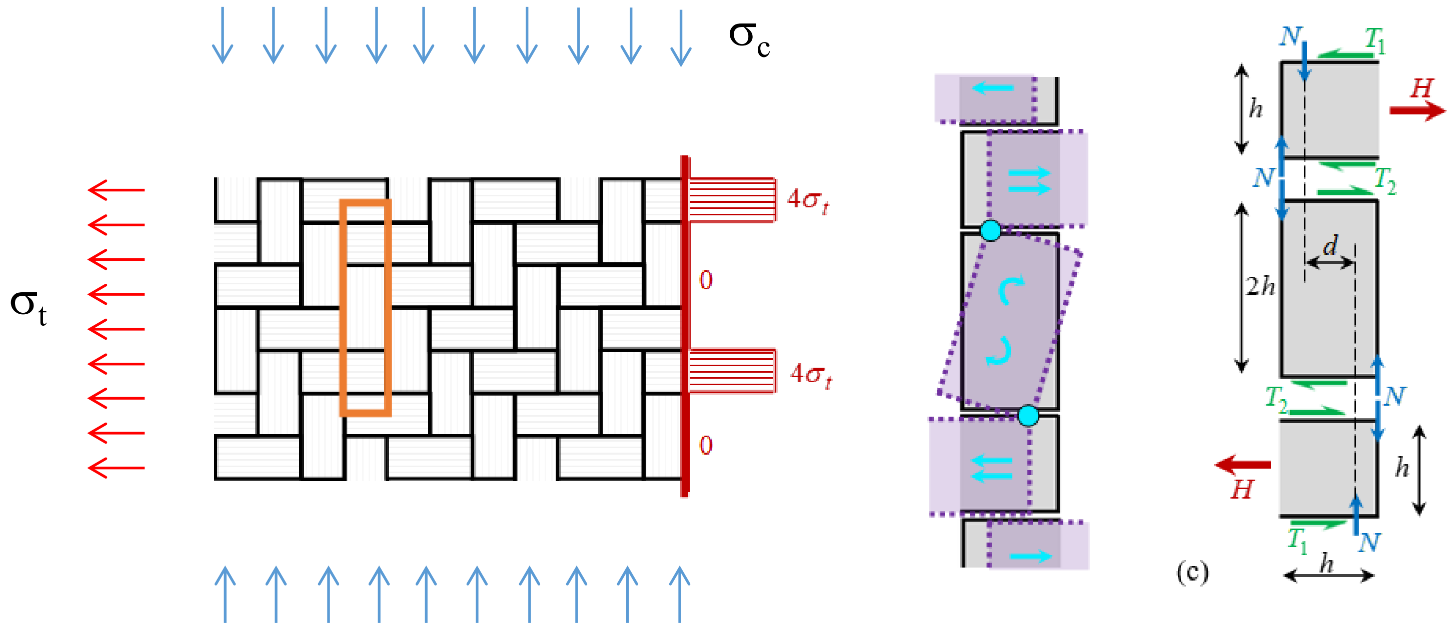
Theoretical derivations: 2. The skew shifted running bond pattern





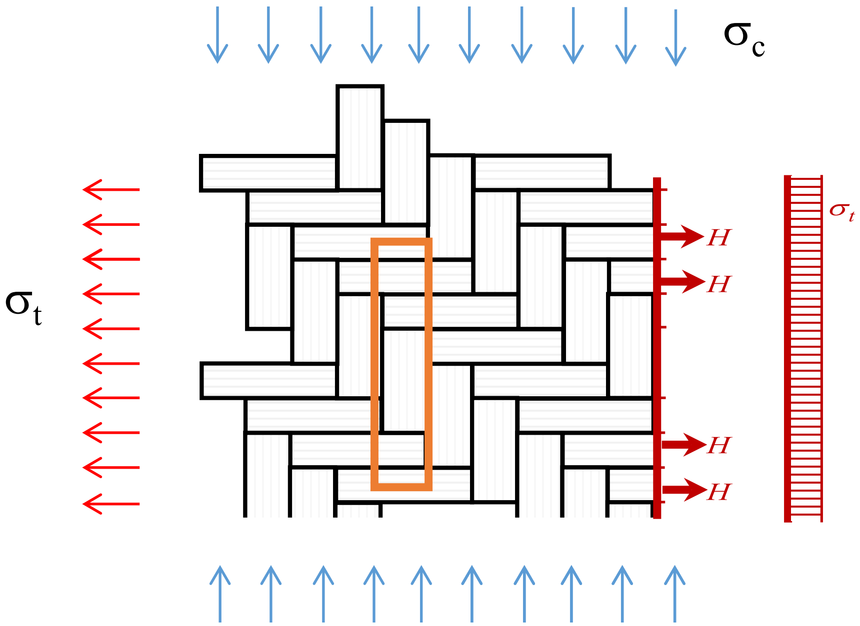
$$\sigma_t \leq \mu \cdot \frac{\alpha \cdot b}{h} \sigma_c$$

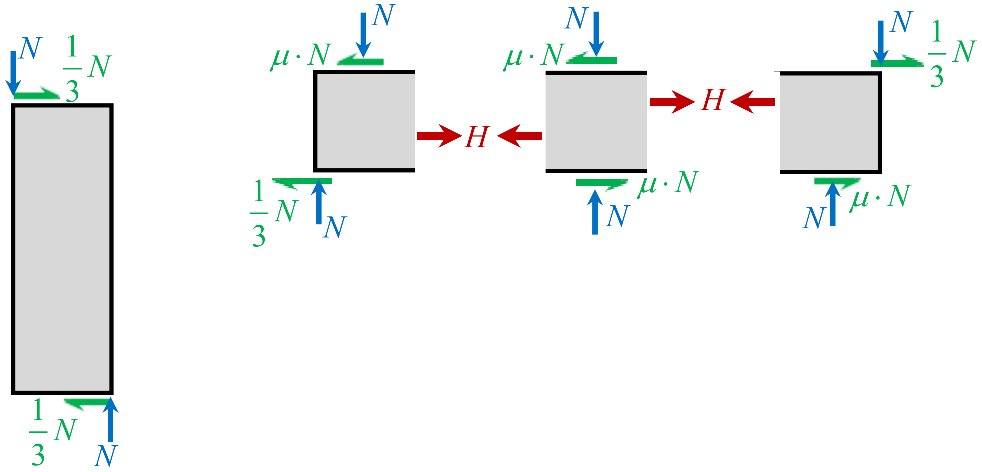
Theoretical derivations: 3. The herringbone pattern (1/2)



$$\sigma_t \leq \frac{0,5+\mu}{4} \cdot \sigma_c$$

Theoretical derivations: 4. The herringbone pattern (1/3)





$$\sigma_t \leq \frac{2/3+2\mu}{6}\cdot\sigma_c$$

DEM simulation to check the predictions: Material, contact, element subdivision

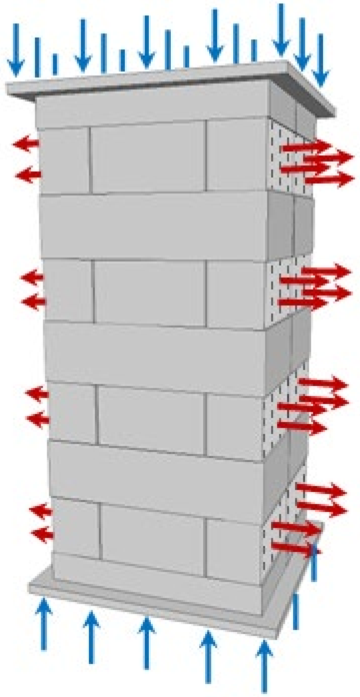
Data of the 3DEC model:

Elements: linearly elastic, density 1428 kg/m^3, bulk modulus: 1.10·10^{10} N/m^2,

shear modulus 0.833·10^{10} N/m^2

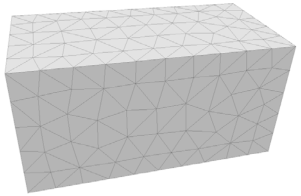
Joints: frictional, cohesionless, friction angle 38°,

normal stiffness: 1.0·10^{10} (N/m^2)/m, shear stiffness: 0.70·10^{10} (N/m^2)/m



Convergence analysis on the necessary density of element subdivision:

Brick size: 0.25 m × 0.125 m × 0.065 m



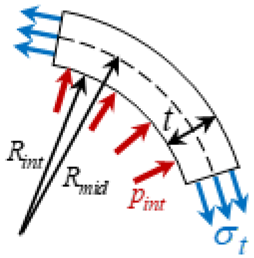
	Mesh size (m)	Computation time (min)	Limit tensile stress (N/m^2)	Deviation from "Very dense meshing"
Rough meshing	0.03	8	5830	1,9 %
Medium meshing	0.02	16	5760	0,7 %
Dense meshing	0.01	171	5730	0,2 %
Very dense meshing	0.005	2838	5720	---

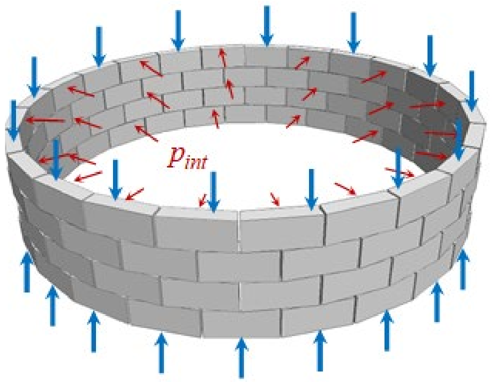
DEM simulation to check the predictions: Validation method

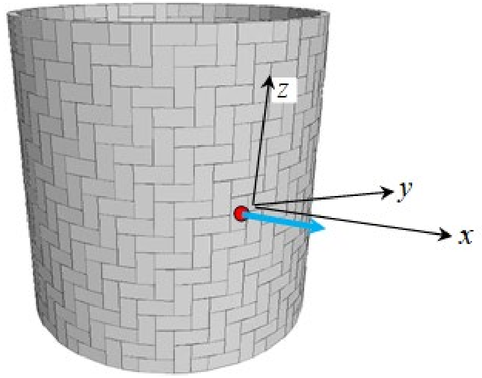
Validation method:

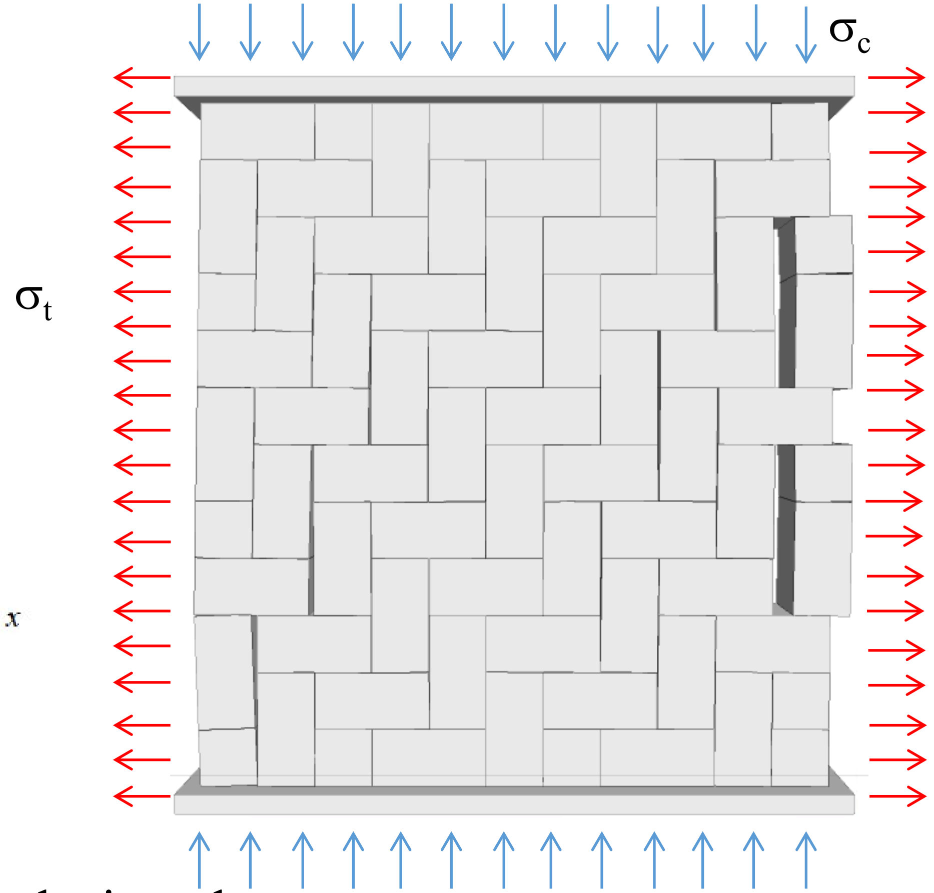
First try: Planar walls, BUT: boundary failure

Instead:





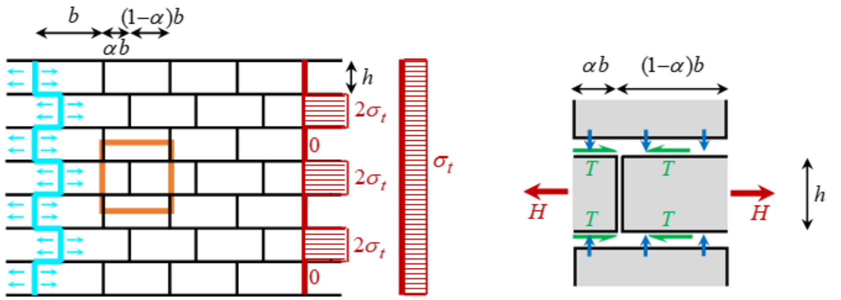


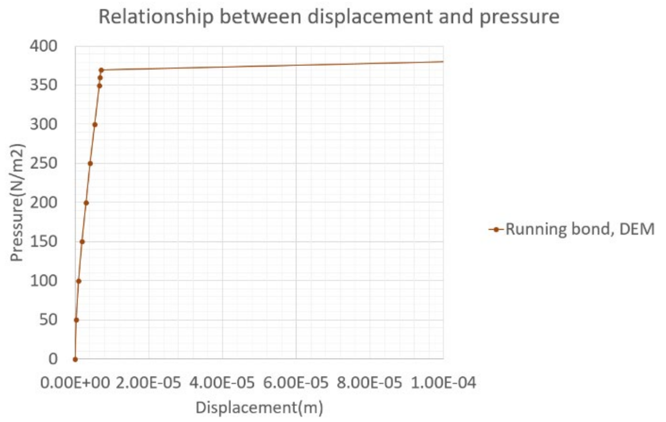


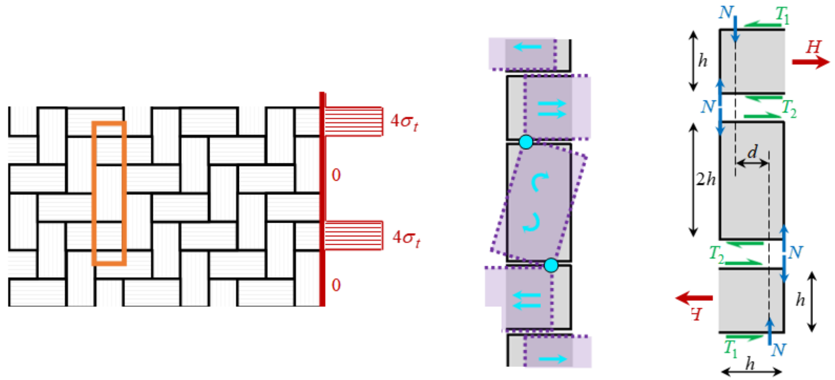
1. Apply vertical compressive stresses.
2. Apply gradually increasing outwards surface load on the intrados.
3. Detect failure and compare to the theoretical predictions.

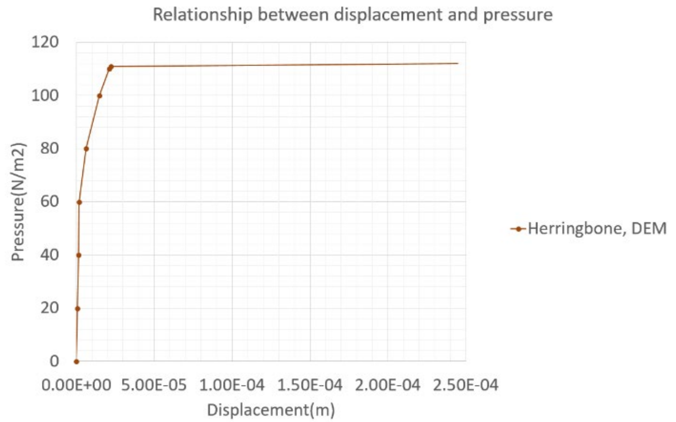
DEM simulation to check the predictions: Load-displacement diagram

Load-displacement diagram:







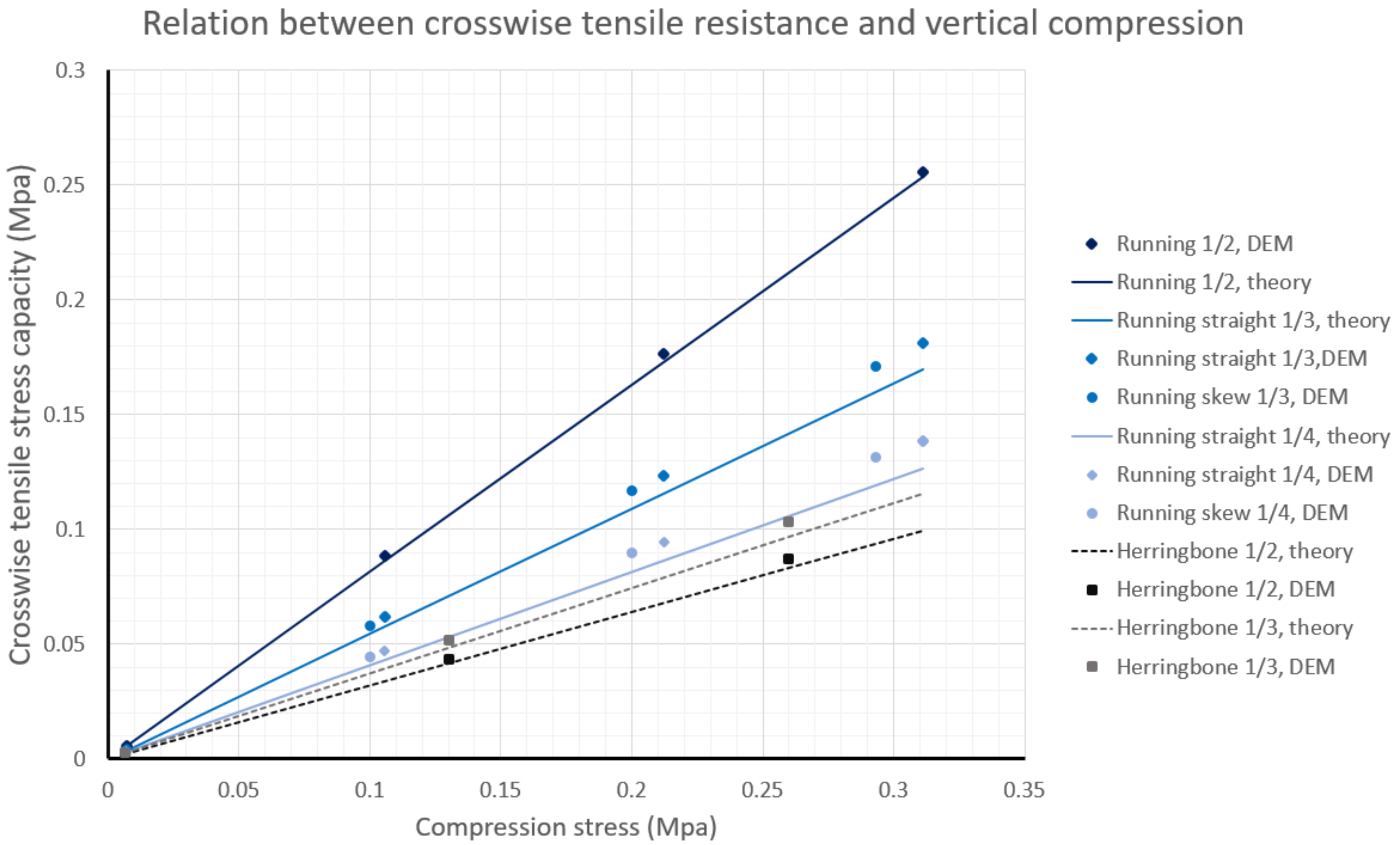


Definition:

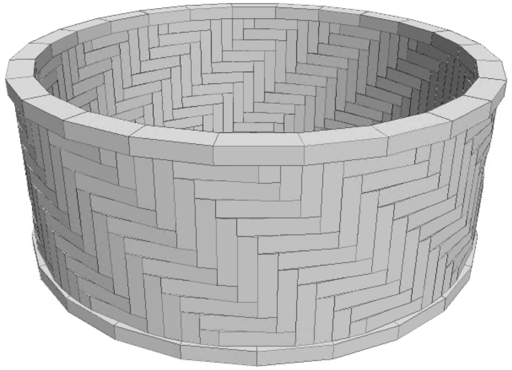
If the measured displacement for 1% load increment exceeds ten times the value that was accumulated until the last load step, then this is failure.

DEM to check the predictions: Results

Validation result:



Further plans

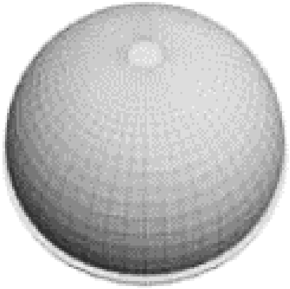


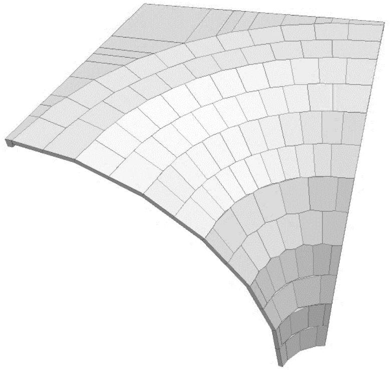
Generalize theoretical predictions:

for herringbone pattern:

extend simulations for 1/4

Application of the results:





domes:

fan vaults:

} by quantifying hoop tension resistance, modify the predictions for their critical thickness

barrel vaults:

bond pattern influences the load bearing capacity, and this can be quantified

Thank you for your attention!

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