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Application of cement modified soils in retaining walls

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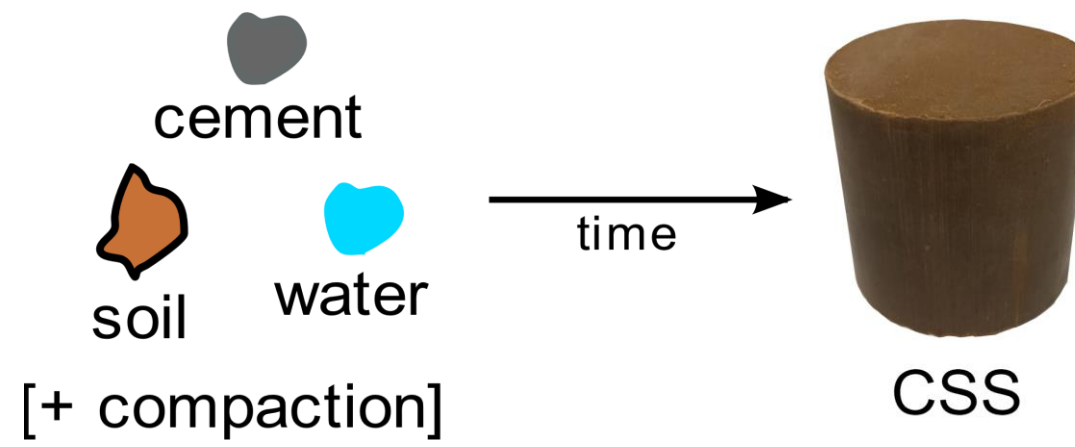
CONTEXT

Cemented-stabilized soils (CSS)^[1]

in situ soil + hydraulic binder

- Reduction of environmental impact
- low-cost technique

Applications: embankments, foundations, pavement construction, retaining wall (RW)^[2]



$$\text{Factor of Safety (FOS)} = \frac{\text{shear strength } \uparrow (?)}{\text{applied stress } \downarrow}$$

Failure criteria^[2,3]
Commonly not determined (empirical)
Performance: tensile + compressive properties

CSS-RW analysis methods^[2,4]

Conventional vs Finite Element Modelling
External vs internal stability

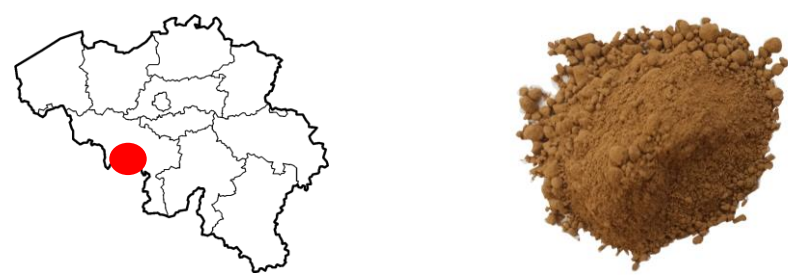
Empirical oversized design

Objective: Understand and verify consistency between mechanical characteristics of CSS and the stress states when employed as RW

MATERIALS AND METHODS

1 Materials and treatment

"BC soil"



Soignies (Belgium)
Covering soil - aggregate quarry

USCS %	LL = 30 %, IP = 13 %
Gravel 1	A = 0.29 (↓)
Sand 5	
Silt 70	
Clay 24	

[CL]

Standard proctor [3% cement content, CC]
Optimum Moisture Content (OMC)
Maximum Dry Density (MDD)

Binder [FR]	Mixture
Cement CEM II/A LL 42.5R CE CP 2	3% CC, 96%MDD, OMC

2 Experiments

- (A) Indirect Tensile Strength, ITS (NF EN 13286-42)
- (B) Unconfined Compression Strength, UCS (NF EN 13286-41)
- (C) Direct Shear, DS (NF EN ISO 17892-10)

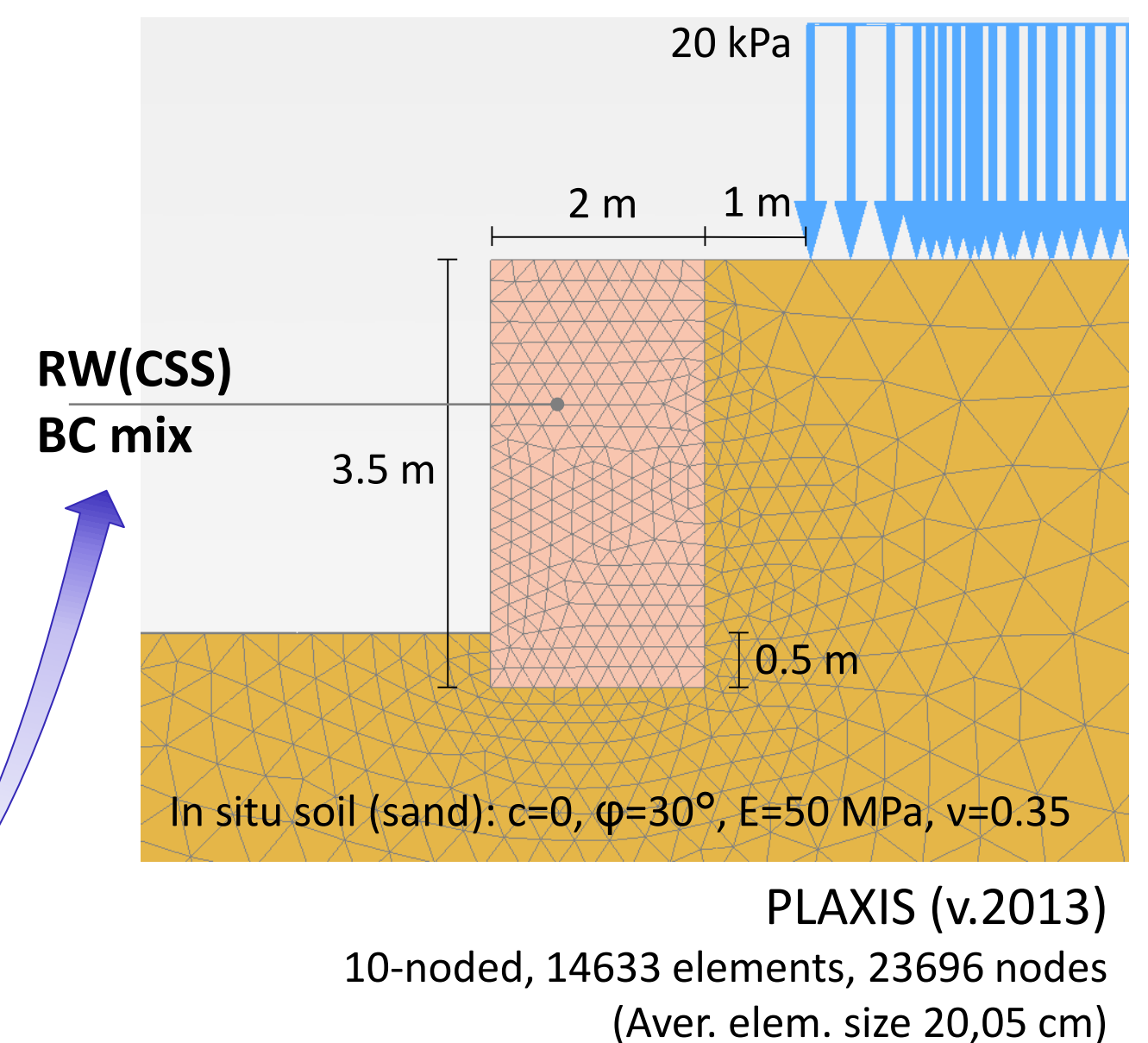


(D) Curing time (CT):
7, 28, 90, 180, 360 days

ITS+UCS → Construction of failure criteria ← DS
UCS → elastic parameters: elastic modulus (E), Poisson ratio (ν)

3 Finite Element Modelling, FEM

Elastic analysis, 2D



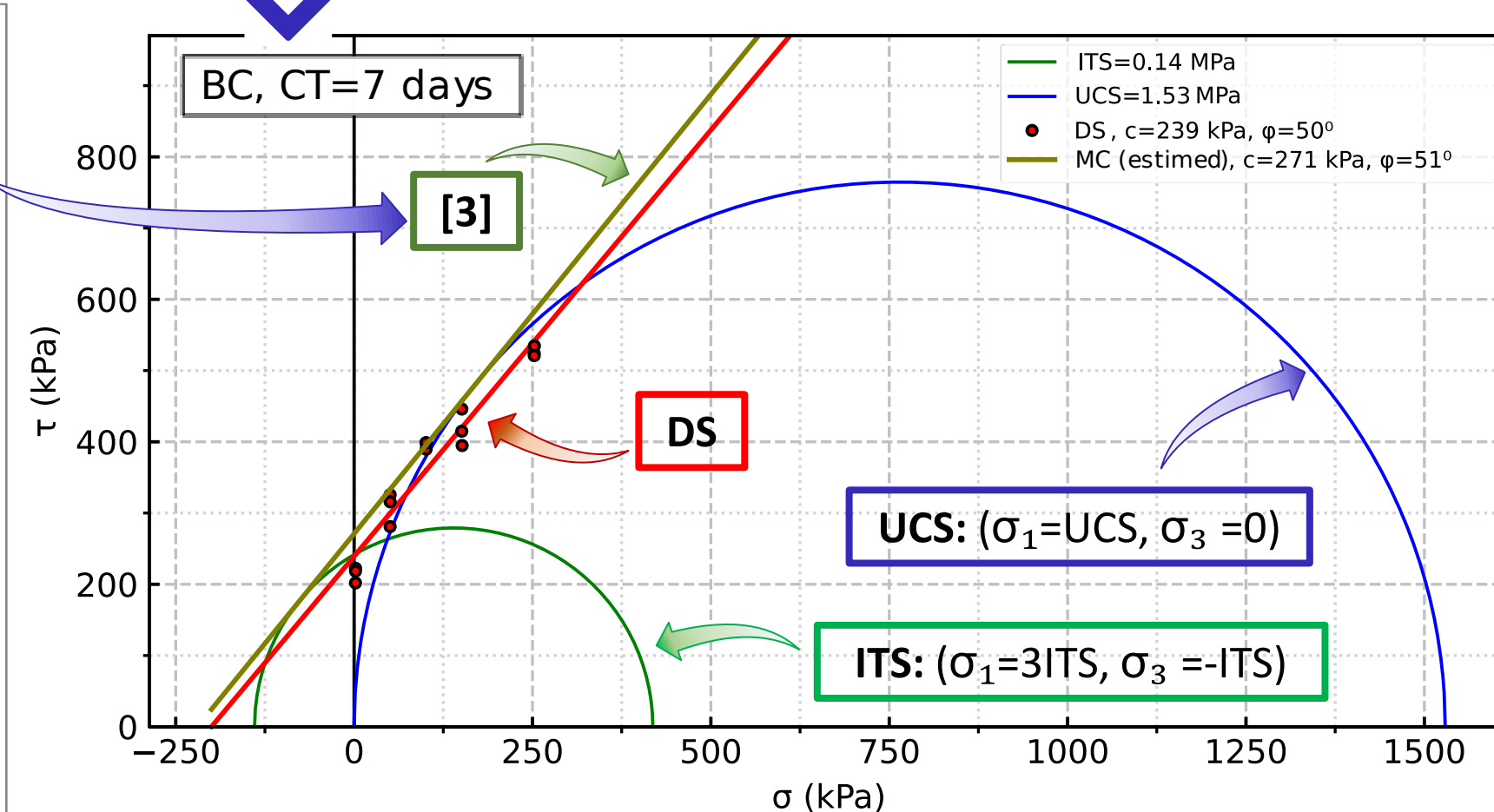
RESULTS

1 Experimental results + assessment of MC failure envelope

CT (days)	7	28	90	180	360
ITS (MPa)	0.14	0.15	0.18	0.23	0.22
USC	UCS/E (MPa) 1.53 / 1459	1.65 / 1281	2.41 / 1672	1.77 / 969	2.11 / 1271
DS	c (MPa) 0.24 / 0.27	0.31 / 0.29	0.37 / 0.37	0.38 / 0.40	0.34 / 0.41
Experiment/[3]	φ' (°) 50.1 / 51.0	49.2 / 50.8	55.9 / 56.0	35.2 / 41.0	61.9 / 48.0

Simplified method for MC assessment^[3]

If
 $ITS = \lambda \times UCS$
Then,
 $\phi = f(\lambda)$
and
 $c = \begin{cases} f(\lambda, ITS) \\ \text{or} \\ f(\lambda, UCS) \end{cases}$



2 FEM (CT=7 days): c – φ reduction

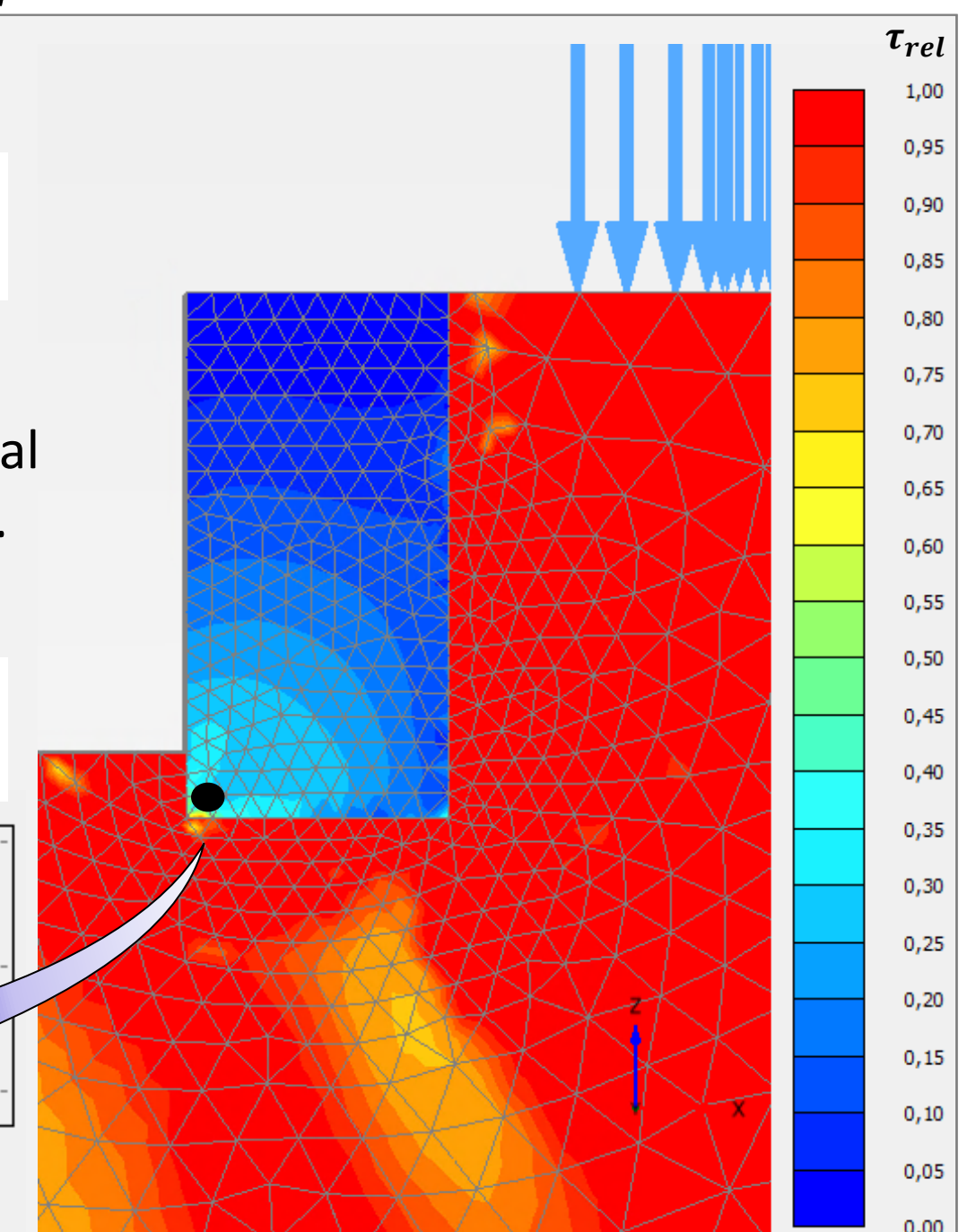
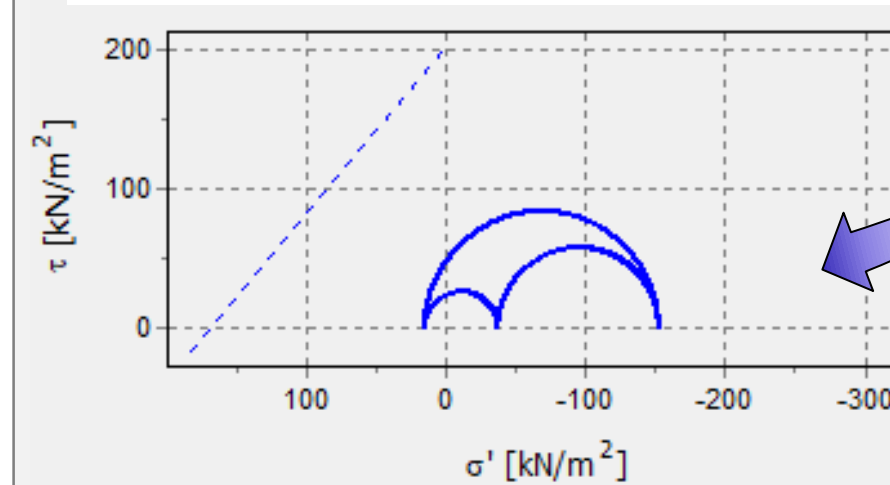
Relative shear stress, τ_{rel}

$$0.0 < \tau_{rel} = \frac{\tau_{max}}{\tau_{mob}} < 1.0$$

- Critical cohesion value (Ccrit.)
- Displac./stress pattern: external
- $C = f(CC=3\%, CT=7\text{days}) > C_{crit.}$

FOS

$$FOS = 1.2 = \frac{c}{c_{red}} = \frac{\tan \phi}{(\tan \phi)_{red}}$$



CONCLUDING REMARKS

- Simplified method for MC assessment ✓
- $\phi = f(\lambda) \rightarrow$ independent of CC
- ITS and UCS interdepend parameters $\rightarrow \lambda$
- $C = f(UCS \text{ or } ITS) \rightarrow$ validation of dosage techniques
- $C = f(\text{degree of cementation, CT})$
- FEM – internal stability: ϕ , cohesion $\rightarrow C_{crit.}$
- CSS-RW: external failure for CT<7 days
- Failure pattern : overturning/bearing capacity (?)

PERSPECTIVES

- Application of the simplified method on others CSS
- Sensibility study for durability evaluation
- Dosage optimization to obtain Ccrit.
- Conventional stability analysis for RW

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