



DESIGN AND OPTIMISATION OF GABION WALLS

Date October 20, 2022

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5' *Introduction*

10' *Overview of the main technical performances*

15' *Live training: GAWAC 3.0*

10' *Conclusions*

Q&A Session

Speaker: Stefano Rignanese

DT Business Unit Business Developer



SERVICEABILITY IN RETAINING WALLS

A photograph of an industrial facility, likely a power plant or refinery, with several tall smokestacks emitting thick, dark plumes of smoke. The sky is a bright, hazy orange-yellow, suggesting a sunrise or sunset. The industrial structures are silhouetted against the bright sky.

Civil engineering structures are exposed to increasingly
aggressive conditions

A wide-angle photograph of a large-scale quarrying or mining operation. In the center, a massive, billowing cloud of white and grey dust or smoke rises from a deep excavation site. The ground is a mix of reddish-brown soil and grey rock debris. In the background, there are rolling hills under a clear blue sky. The overall scene depicts a significant environmental impact from industrial activity.

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The **over-use** of natural materials is becoming an environmental issue



“Engineers are required to “meet the needs of the **present** without compromising the ability for **future** generations to meet theirs” [International Institute for Sustainable Development (IISD)]

A LONG LASTING COMMITMENT IN IMPROVING MATERIALS AND SOLUTIONS FOR CIVIL ENGINEERING



Maccaferri has a centre of excellence entirely dedicated to **research and development**, concentrating in a single place the capital of **knowledge** and **know-how**: in Bolzano (Italy) the Maccaferri Innovation Center (M.I.C.) is constantly working to innovate our products and solutions





THE R&D

*Long term performance
of walls*



RESEARCHING THE LONG TERM EFFECTIVENESS

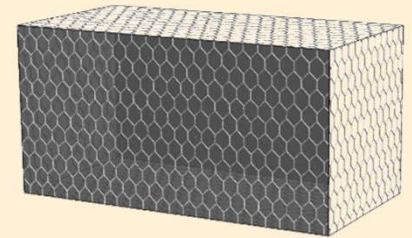
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Design The Change

represents an innovative development in the engineering features of **Gabion** structures, which was possible through a thorough investigative testing campaign aimed at quantifying their performance limits when used as mass gravity retaining walls.

Main scope of the research was to monitor the performance of Gabions under the most severe conditions. This raised 2 questions:

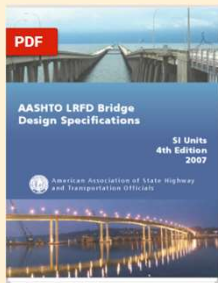
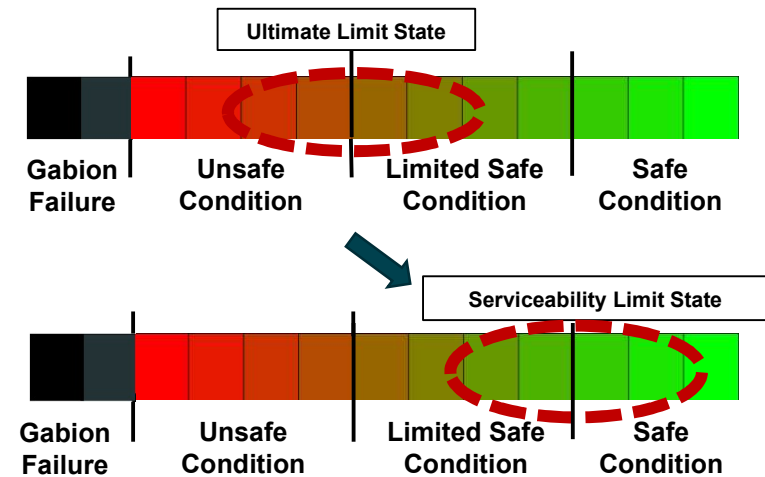
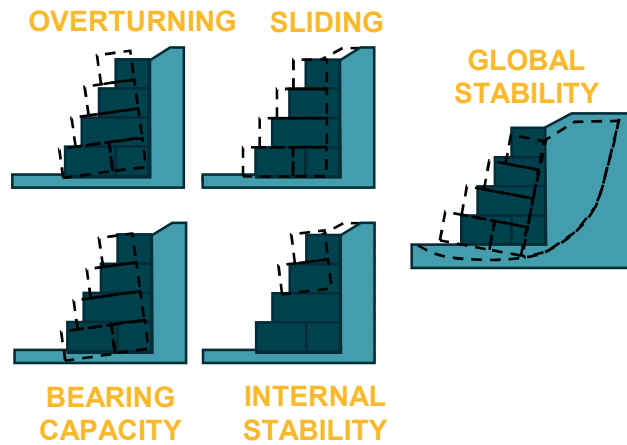
- M** How can we define a long-term performance for a Gabion Structure?
- M** How can we make a Gabion Structure more cost-effective?



The research was carried out in various Engineering Centers, under the coordination of the **Maccaferri Innovation Center**

A MODERN ENGINEERED CONCEPT

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Effects of chemical **CORROSION**

Effects of **TIME & ENVIRONMENT**

Sensitivity of structures to **DEFORMATION**

Avoid **BRITTLE FAILURES**

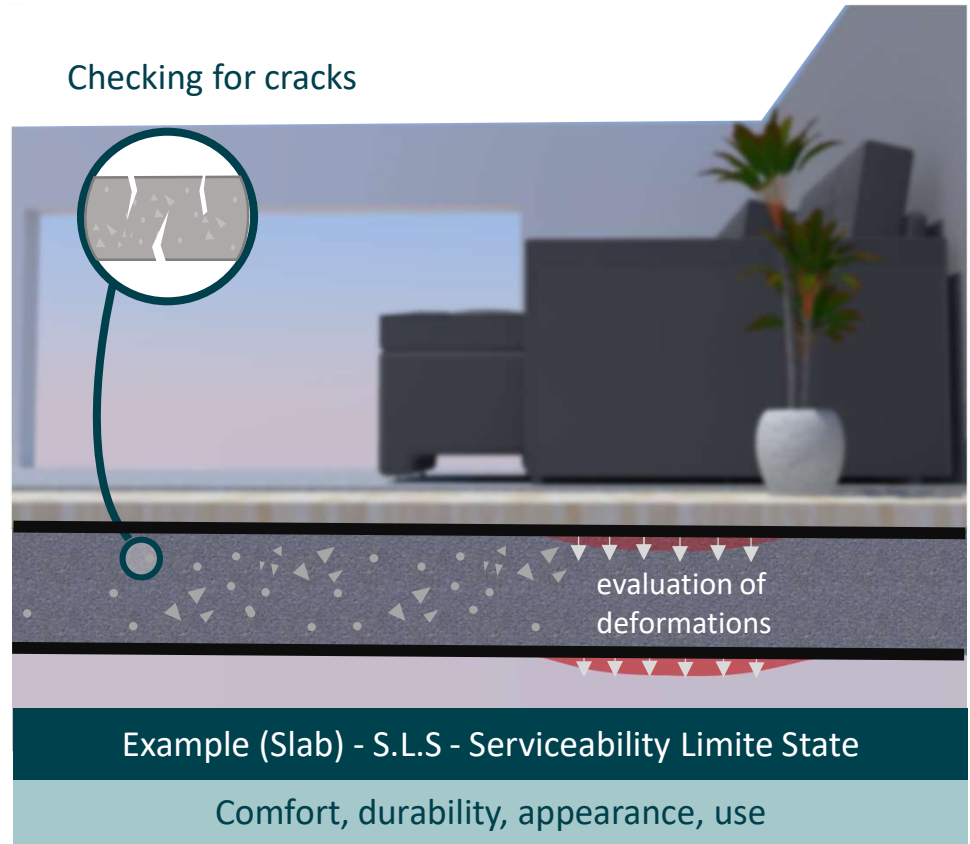
Avoid excessive **DISPLACEMENTS**

ENGINEERING LIMITE STATES

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Serviceability limite state (SLS) is related to user comfort and **durability, appearance** e **good use** of the structures, whether in relation to users, or in relation to the machines and equipment supported by the structures.

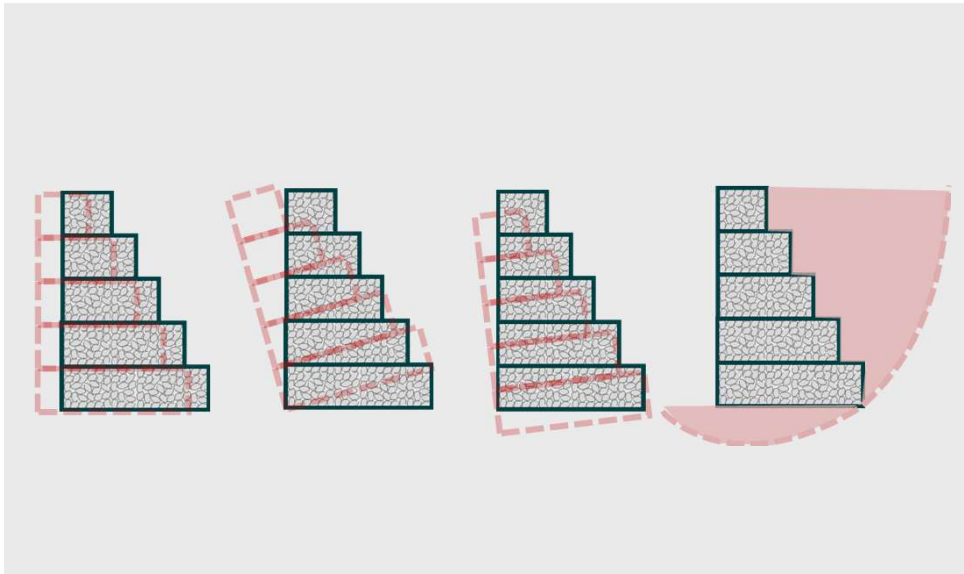
Checking for cracks



ULTIMATE LIMITE STATE

Security check against collapse

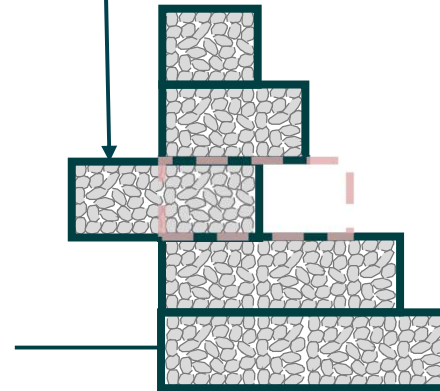
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The use of ULS for external stability analysis considers the gabion as a rigid block.

External stability
(Ultimate Limite State)

Checking for U.L.S.
Considering **rigid blocks**!



The analysis of internal stability through the ULS, **does not represent** the aspects of durability, appearance and use of the structure.

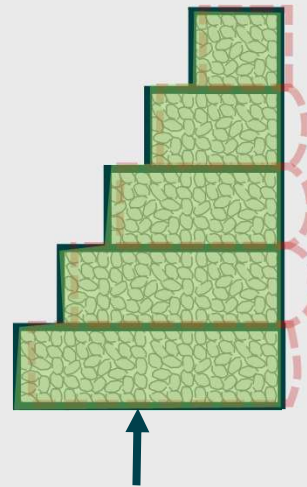
Internal stability
(Ultimate Limite State)

SERVICEABILITY LIMITE STATE (SLS)

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Analysis of comfort, durability, appearance and use

Even considering the ULS analysis, gabion structures can present deformations, which affect their performance and are identified in the SLS analysis..



SLS – OK!

(Internal stability considering mesh influence)



ULS – It is not acceptable!

Structures may be subject to deformation over time, and this cannot be analysed by using conventional Limit Equilibrium Methods.

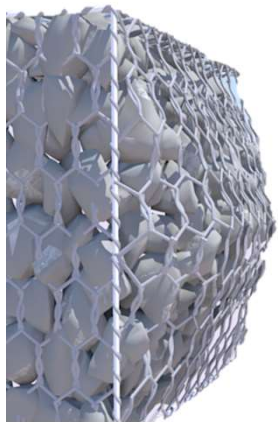


SERVICEABILITY LIMIT STATE CHECK

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How to ensure that the gabion meets the conditions of serviceability?

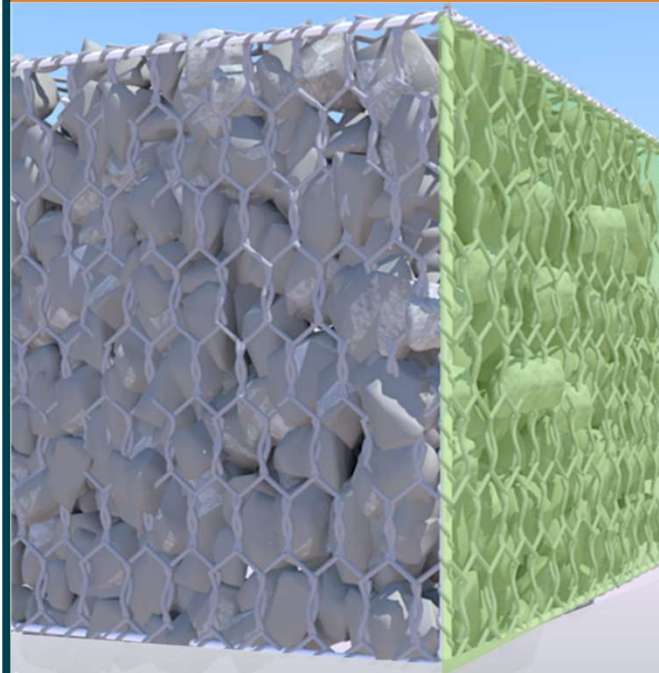
- M** Serviceability analysis through the GSC
- M** Correct installation of gabions
- M** Use of mesh with correct performance on the face (StrongFace)
- M** Use of POLIMAC coating



S.L.S.
satisfied!



Using the STRONG FACE gabion



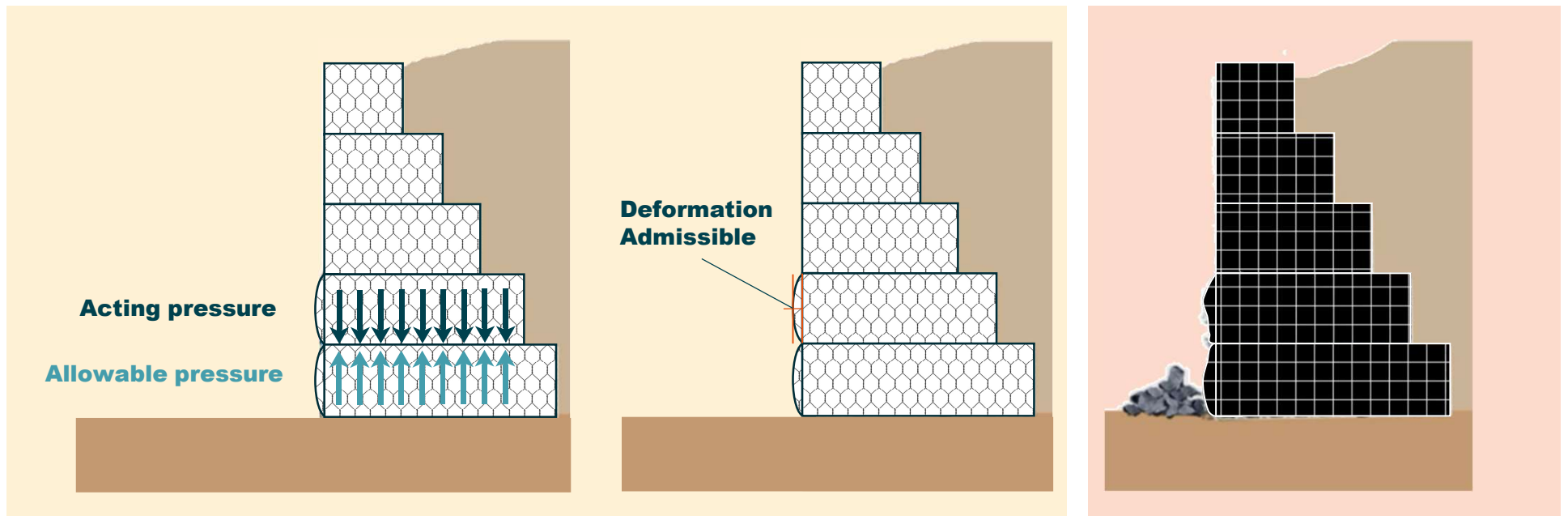
Face with higher
strength mesh

- M** Serviceability condition – OK!
- M** Good appearance – OK!
- M** High durability
- M** Long-term high performance



ANALYSIS OF A GABION STRUCTURE

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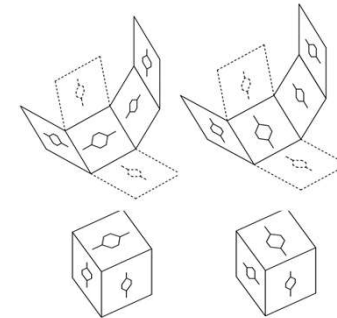
THE RESEARCH

Mesh Type	Wire [mm]	H _{gabion} [mm]
6x8	2.7	1000
8x10	2.7	500, 1000
	3.0	1000
	3.4	1000
10x12	2.7	1000
	3.0	1000



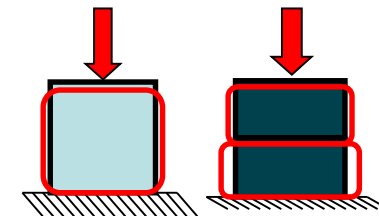
Grand total : approx 70 tests

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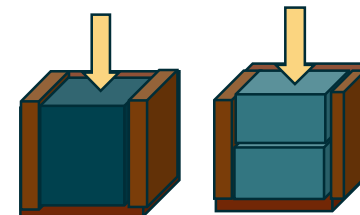


MESH ORIENTATION
- vertical
- horizontal

STONEFILL
- limestone
- granite
- rounded



UNCONFINED
lateral expansion



CONFINED
lateral expansion

THE RESEARCH

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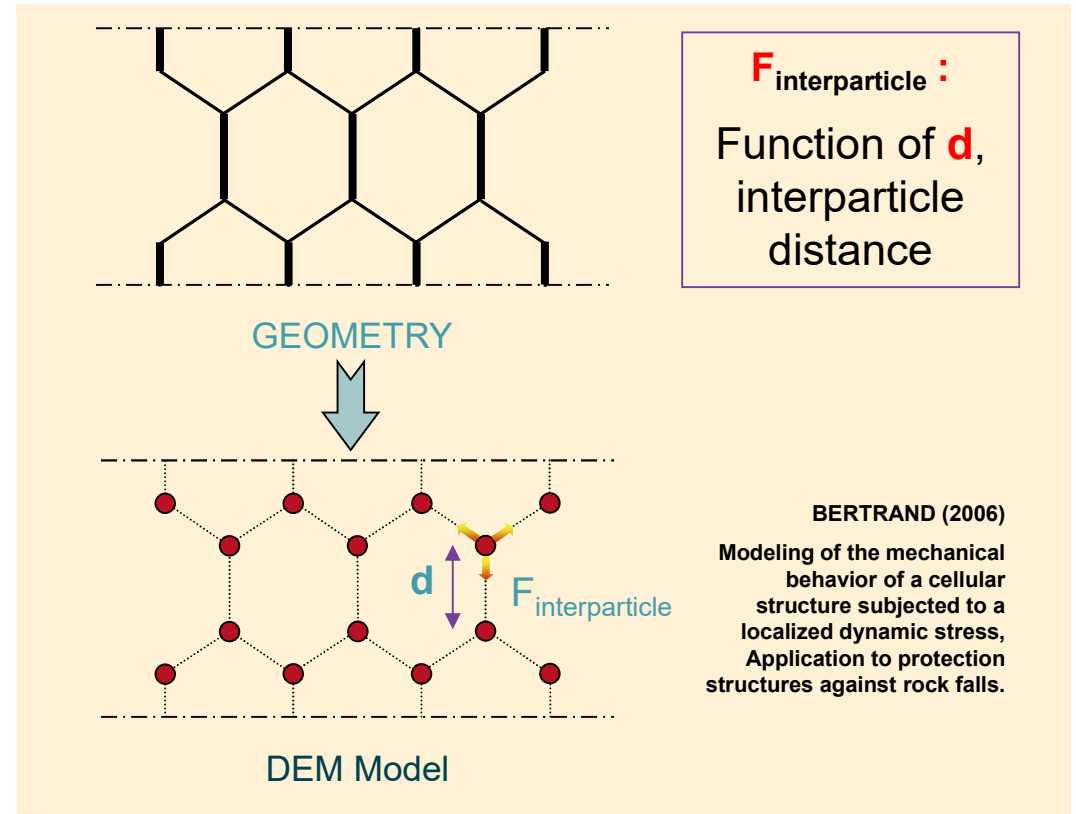
THE NUMERICAL MODEL - CALIBRATION

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Discrete Element Method (DEM)



Compression Test
UNICAMP - IIT - ISMGEO



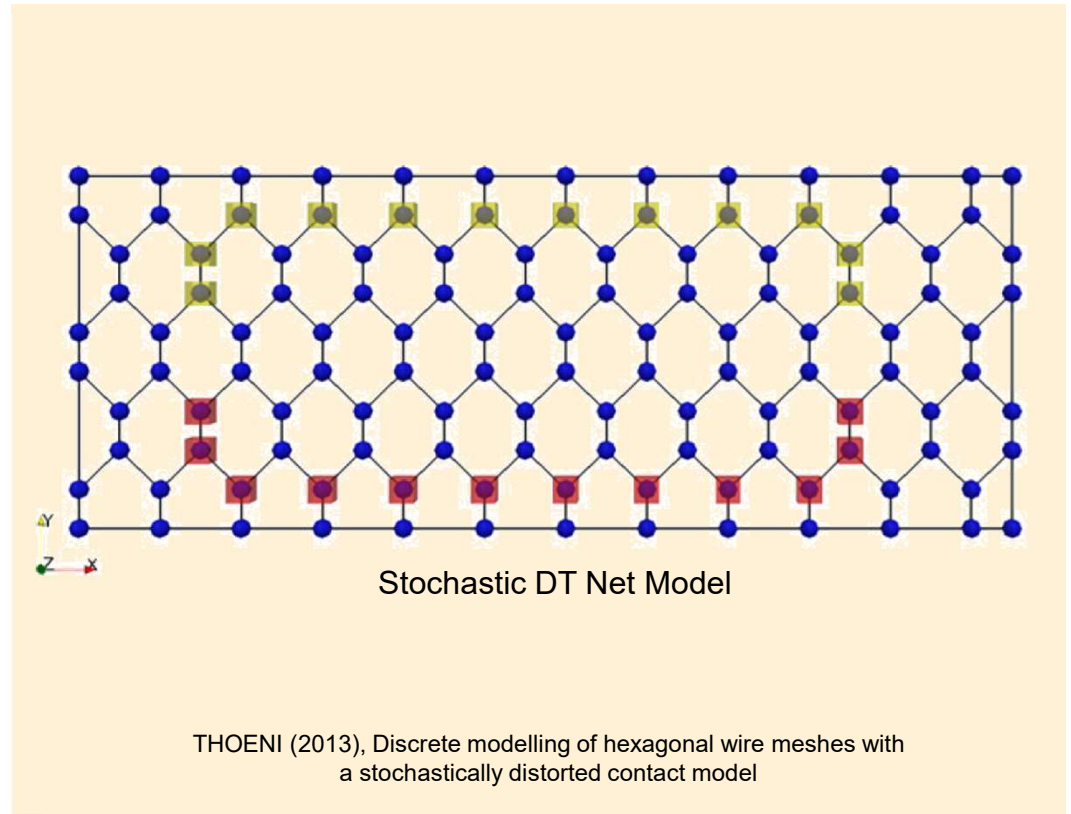
THE NUMERICAL MODEL - CALIBRATION

MACCAFERRI

Discrete Element Method (DEM)



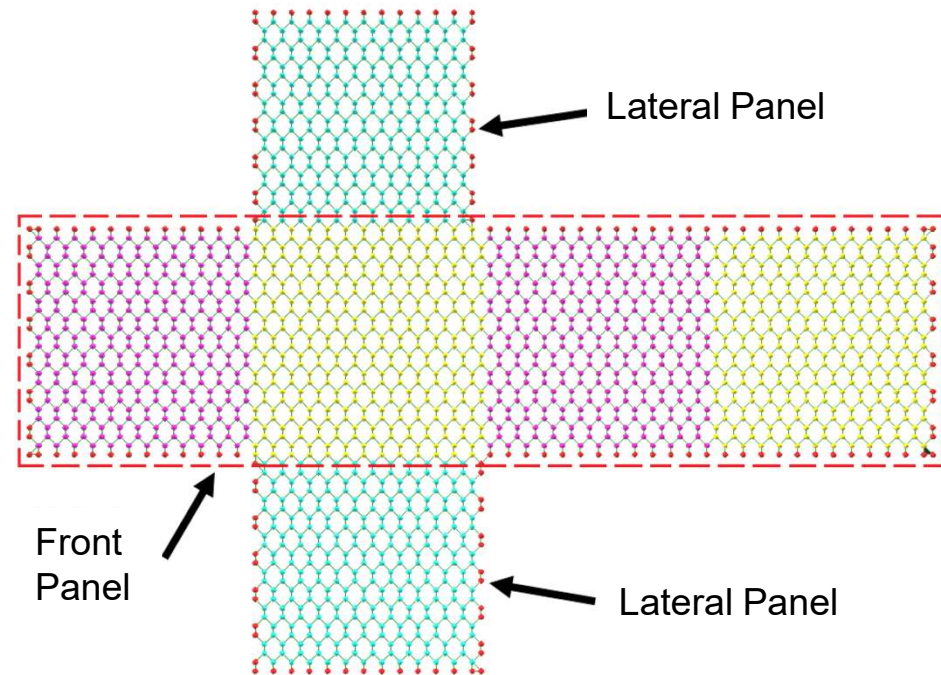
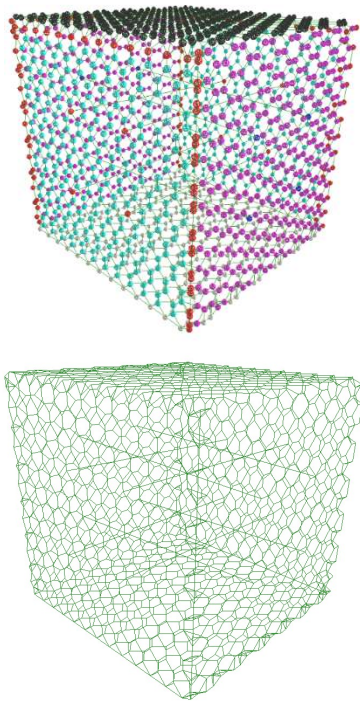
Compression Test
UNICAMP - IIT - ISMGEO



THE NUMERICAL MODEL - CALIBRATION

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Discrete Element Method (DEM)

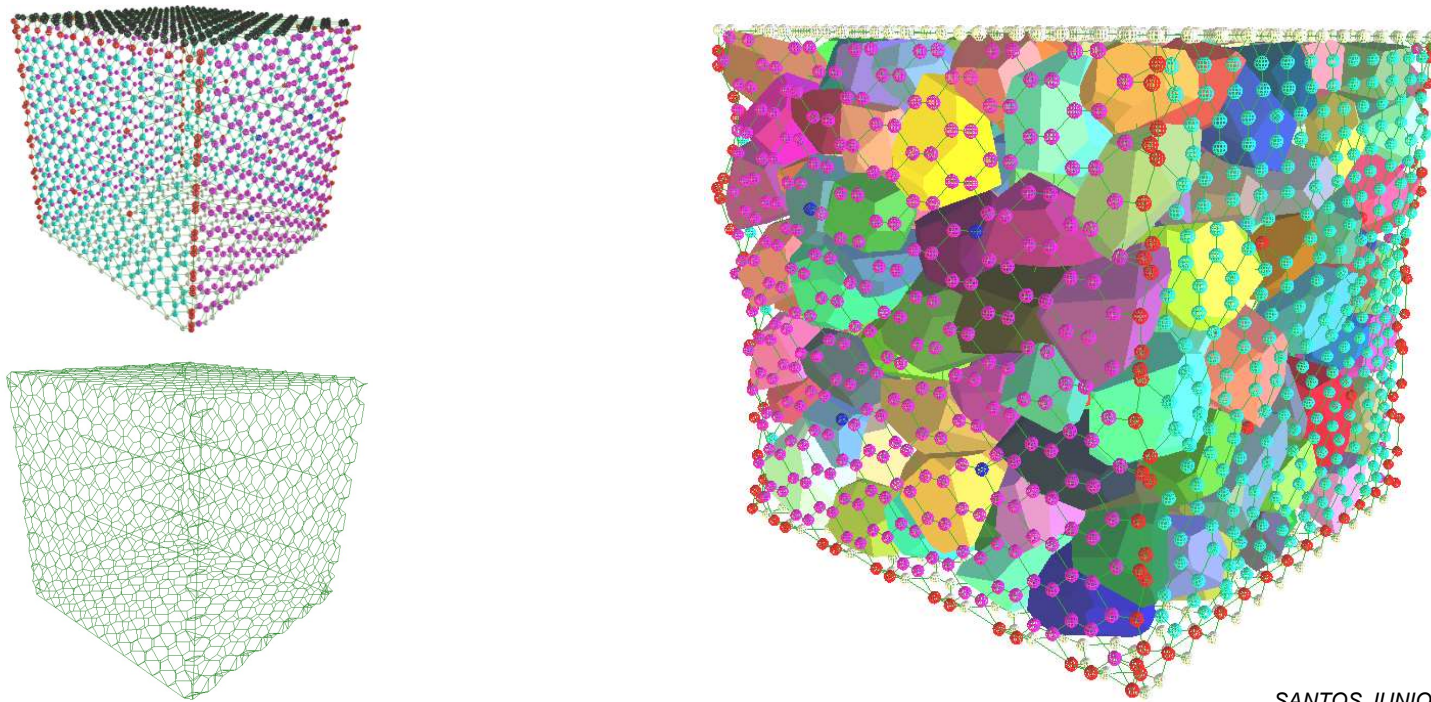


SANTOS JUNIOR, 2018

THE NUMERICAL MODEL - CALIBRATION

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Discrete Element Method (DEM)



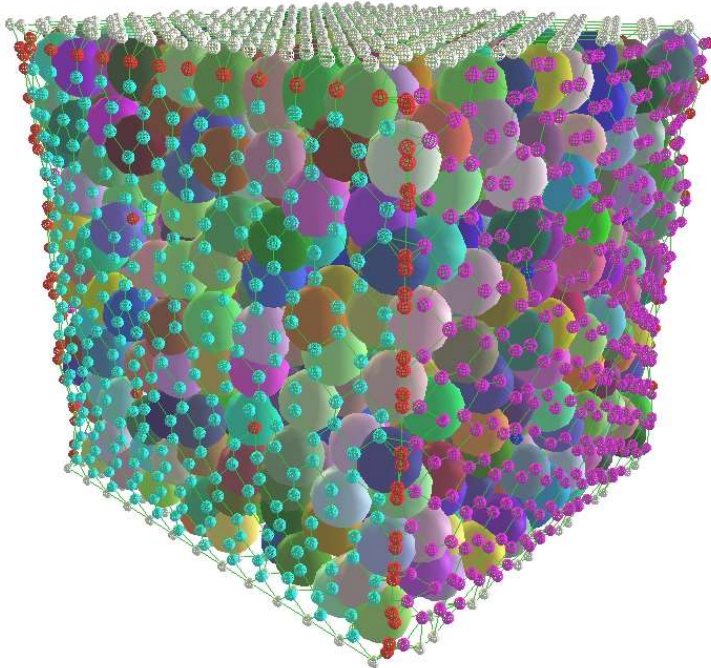
SANTOS JUNIOR, 2018

THE NUMERICAL MODEL - CALIBRATION

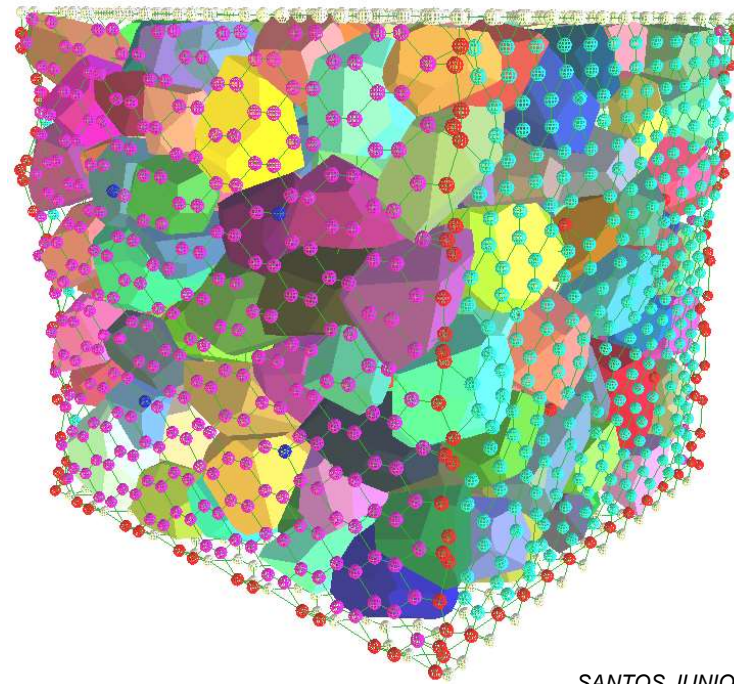
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Discrete Element Method (DEM)

Spherical elements



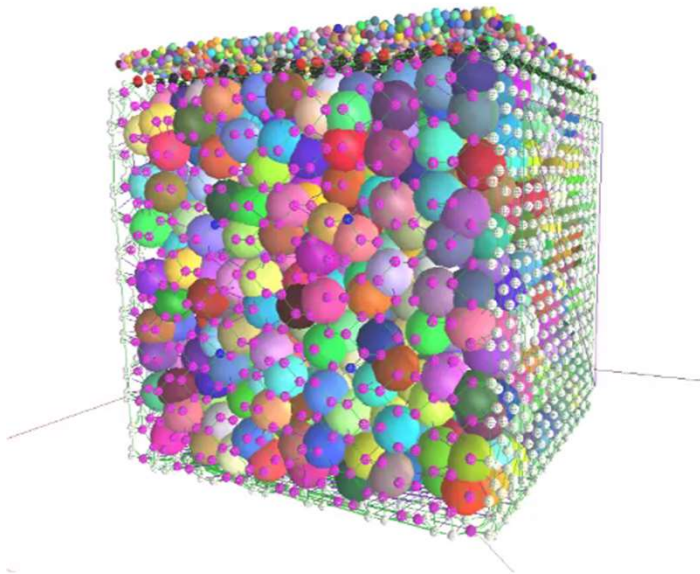
Polyhedral elements



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THE NUMERICAL MODEL - CALIBRATION

Discrete Element Method (DEM)



DEM | Discrete Element Method

SANTOS JUNIOR (2018)



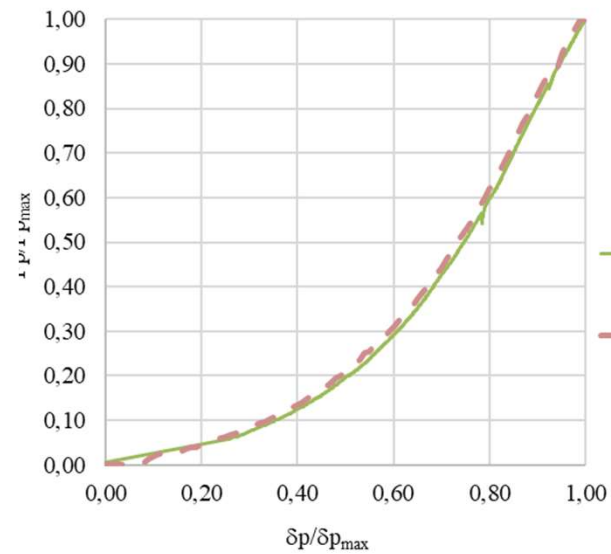
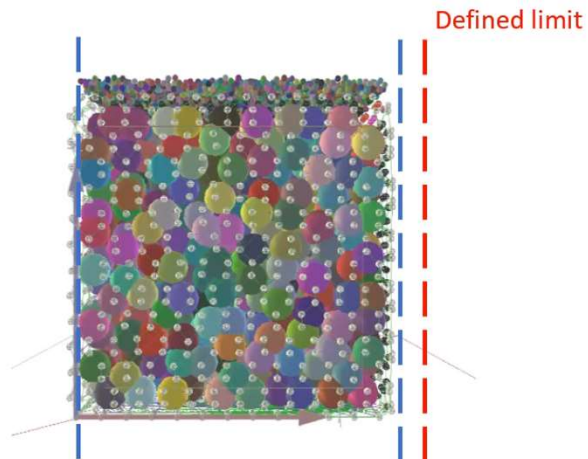
Restricted compression Test
ISM GEO



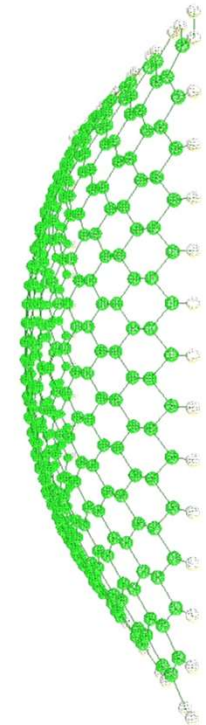
THE RESEARCH

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The maximum deflection in face of the wall can be determined numerically



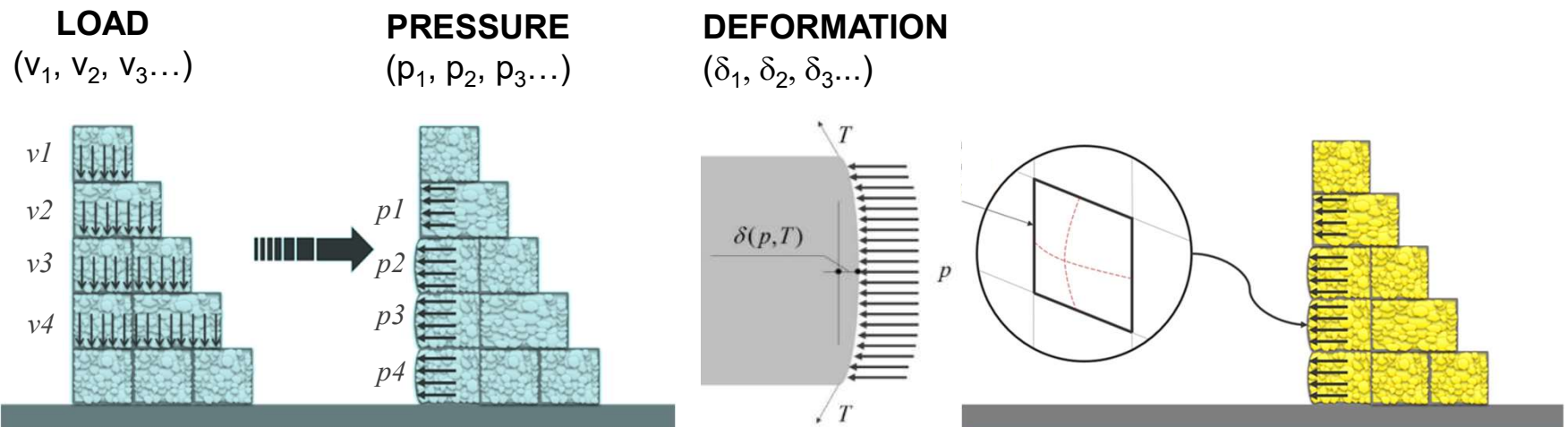
Good agreement between the numerical model and experimental data!



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ANALYSIS OF A GABION STRUCTURE

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ASSUMPTIONS

- M** MESH => ELASTIC MEMBRANE
- M** 2D MATHEMATICAL MODEL POISSON
- M** MAX DISPLACEMENT IN DIRECTION OF PRESSURE APPLIED $\delta(p, T)$
- M** PRESSURE IS A FUNCTION OF VERTICAL STRESS AT EACH LAYER



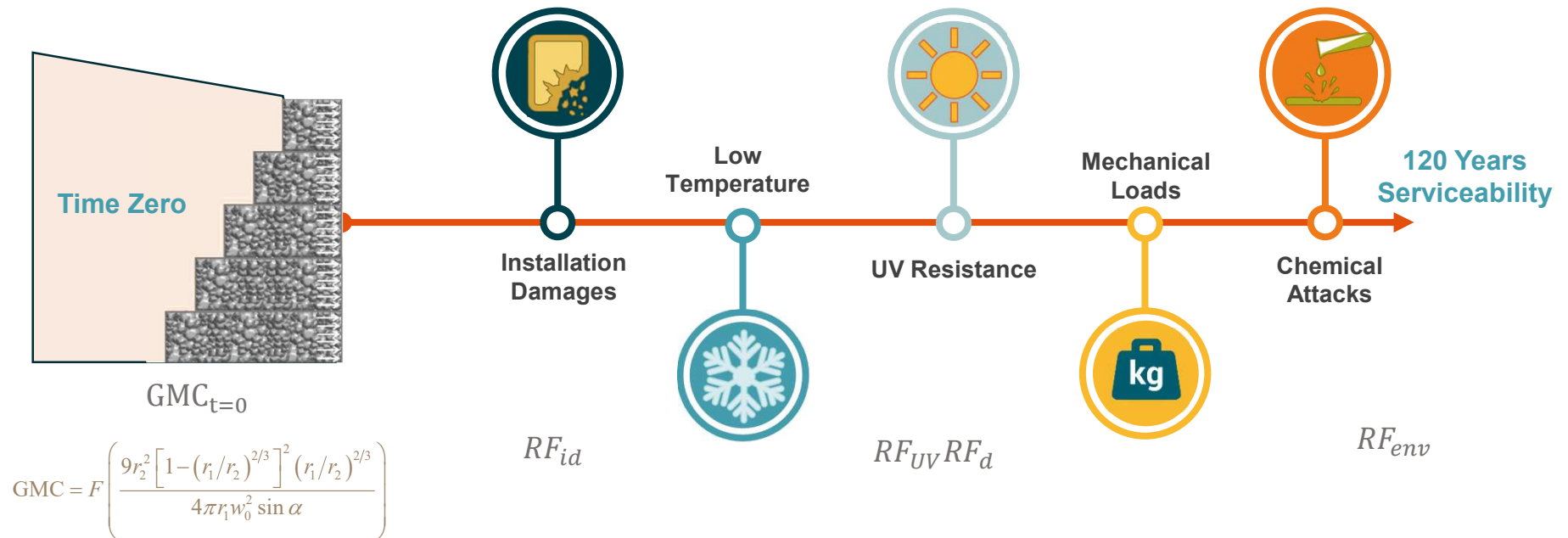
THE RESULT

Turn knowledge into value



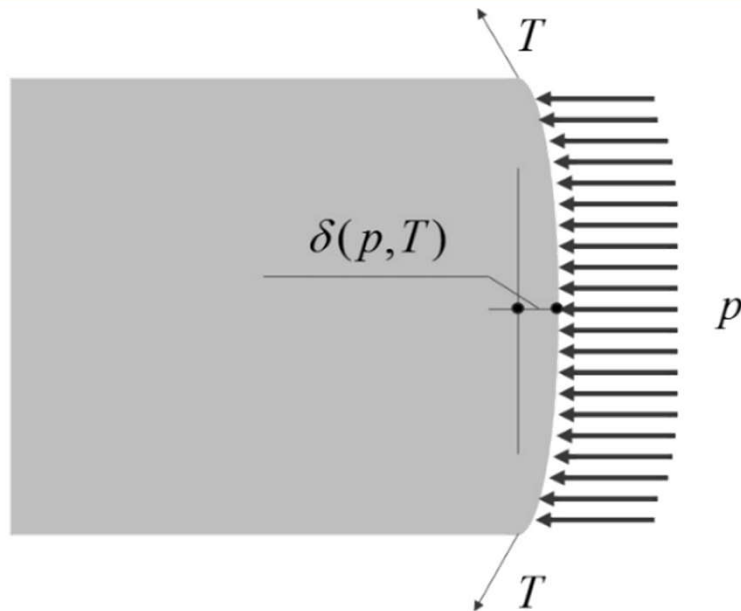
THE RESEARCH - GSC APPROACH

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GABION SERVICEABILITY COEFFICIENT

An **experimental coefficient** that evaluates the gabion **performance over time**, considering mechanical and environmental stresses



- M** Experimentally tested and numerically **verified** method
- M** Increased **cost-effectiveness** of the design
- M** Significant **environmental benefits**

GSC VALUES

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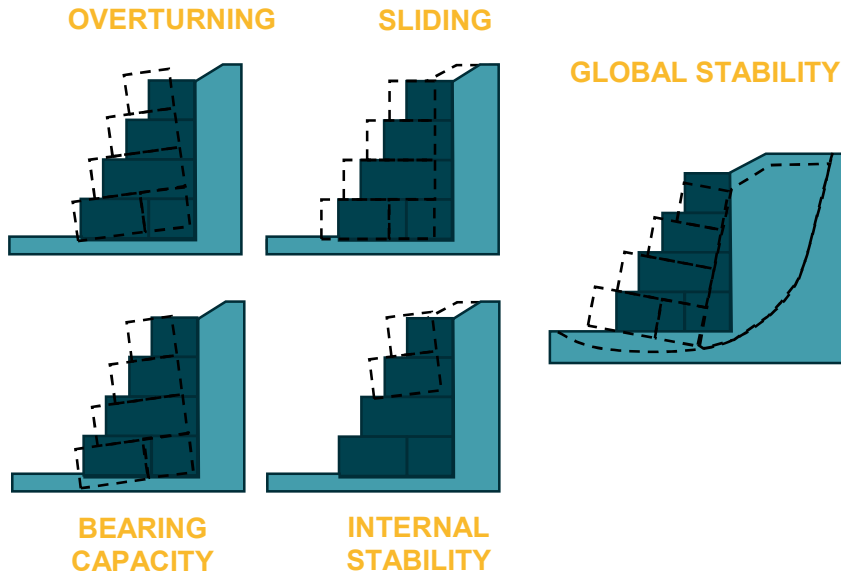
MESH TYPE	WIRE (mm)	POLIMAC	PVC	GALMAC 4R (Zn90Al10)	GALMAC 95 (Zn95Al5)	ZINC
8x10	3.9	NA	NA	504	252	84
8x10	3.4	678	NA	387	194	65
8x10	3.0	623	NA	356	178	59
8x10	2.7	489	342	279	140	47
8x10	2.4	410	287	234	117	39
6x8	2.7	638	NA	365	182	61
6x8	2.4	528	370	302	151	50
10x12	3.4	NA	NA	315	157	NA
10x12	3.0	481	337	275	137	46
10x12	2.7	418	293	239	119	40
10x12	2.4	378	265	216	108	36

THE GSC EFFECTIVENESS : LONG TERM PERFORMANCE

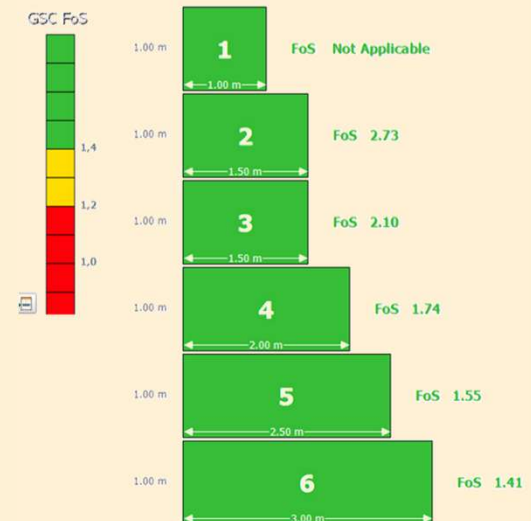
Classic Design Calculation



Design based on Gabion PERFORMANCE



SLS Serviceability Limit State Gabion Serviceability Coefficient





**DESIGN WITH
SERVICEABILITY**
*GAWAC 3.0 & GABION
STRONG FACE*





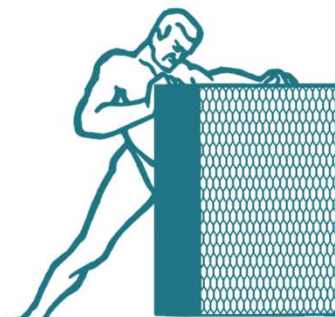
NEW DESIGN APPROACH

GAWAC 3.0 is the new software developed for the design and optimisation of Gabion Walls.

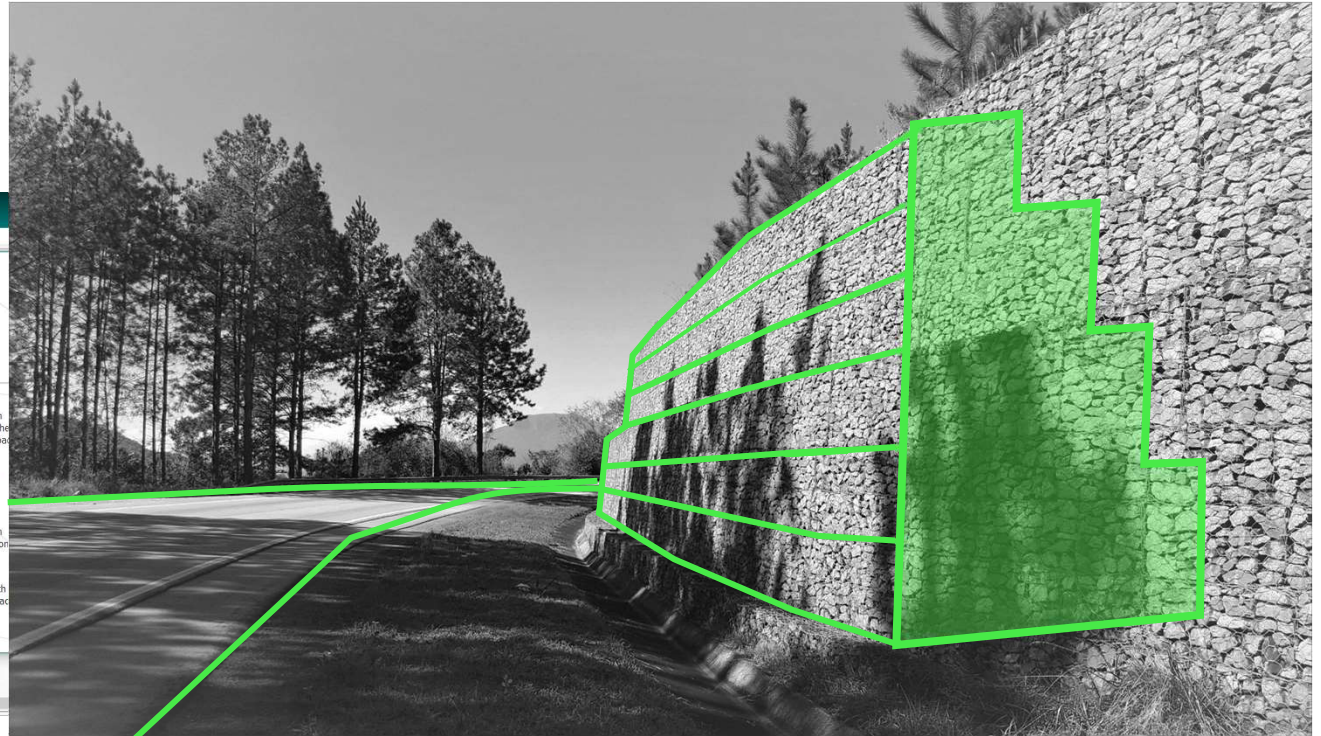
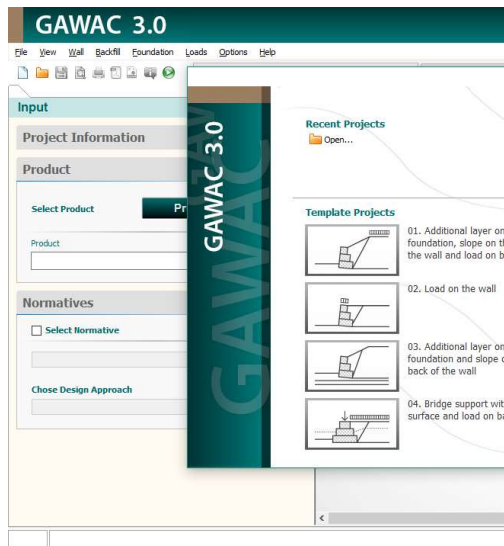


INNOVATIVE SOLUTIONS

Gabion Strong Face with **PoliMac** is the innovative solution that minimizes structure long-term cost



**GABION
STRONG
FACE**



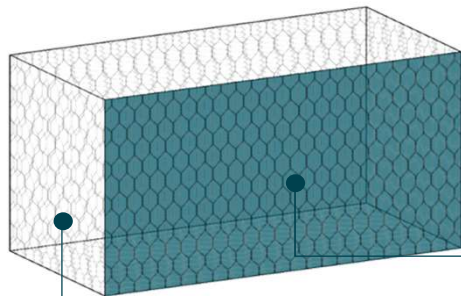
GABION STRONG FACE

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Gabion Strong Face

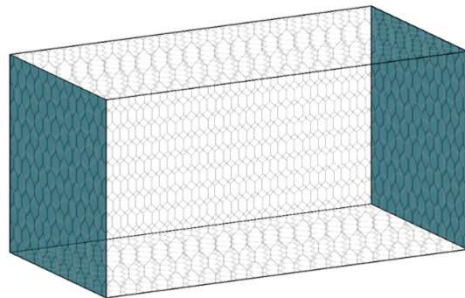
more resistance where required



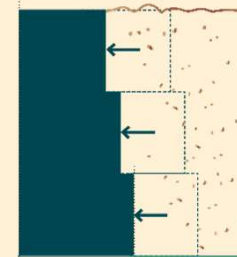
2 different wire diameters

Thick wire diameter on the front exposed faces

Light wire diameter on the rear confined faces



Available in different configurations and wire diameters



Strong Face Gabions enable the **optimization of the wall cross section**



Less Gabions



Less Stones



Faster installation



Lower environmental impacts





THE BENEFITS OF THE NEW APPROACH

Turn knowledge into value



WHAT ARE THE BENEFITS OF THE NEW APPROACH?

HOW MUCH
DOES GABION
WALL COST?



The purchase price is only part of what you actually end up spending when you purchase something it.

Total Cost of Ownership includes the purchase price as well as all the costs associated with the owning of the item.



LESS MATERIALS

Less stone means savings! Thanks to the GSC concept, the amount of material needed to build a gabion wall is drastically reduced.



BETTER PERFORMANCE

PoliMac coating means outstanding performance in aggressive environments. It will preserve the structure serviceability reducing maintenance costs.



QUICKER INSTALLATION

Material reduction means easier and faster installation. An optimised design increases the production rate.



LOWER ENVIRONMENTAL IMPACTS

Reduction of quarry stones means cutting the environmental burden. Take advantage of the new design approach for reducing the environmental impact of the structure.

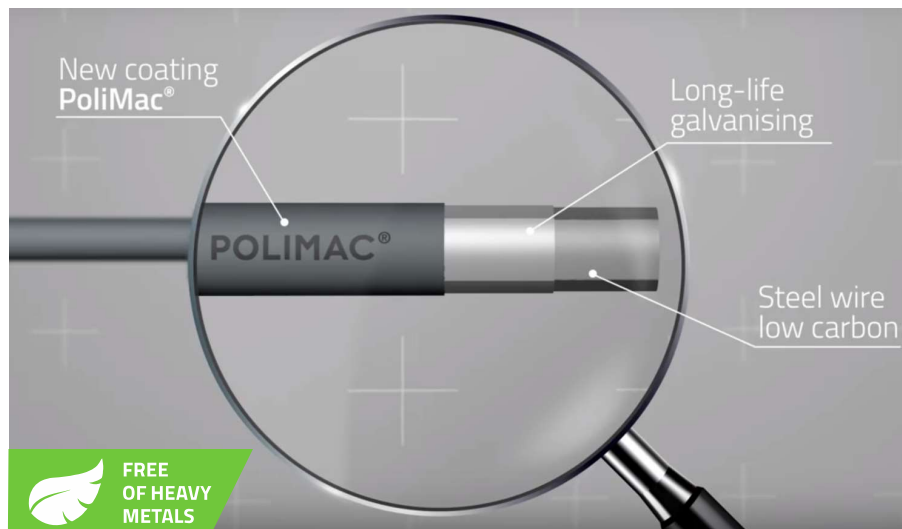




POLIMAC COATING – GREEN REVOLUTION

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Gabion Strong Face is coated with **PoliMac®**, the revolutionary coating that can withstand the most aggressive environmental conditions.



PoliMac®
WIRE PROTECTION FOR A CHANGING WORLD

10x Better resistance to **abrasion**, including installation damages



2x More resistance to **chemical aggressions***



4x More performance in **cold weather**



4x More resistance to **UV rays****



* In terms of resistance to sulphuric, nitric, formic, acetic acids

** In terms of elongation after 2500 hrs of exposure





A NEW ERA FOR RETAINING WALLS

*GAWAC 3.0 - LIVE
TRAINING*



LIVE EXAMPLE WITH GAWAC 3.0

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CASE STUDY

WALL SET UP

Wall Batter (°)	6
Rockfill unit weight [kN/m^3]	24.5
Gabion Porosity (%)	30

SOIL PROPERTIES

BACKFILL SET UP

Unit weight [kN/m^3]	18
Friction angle (°)	30
Cohesion [kN/m^2]	0

FOUNDATION SET UP

Unit weight [kN/m^3]	19
Friction angle (°)	32
Cohesion [kN/m^2]	10

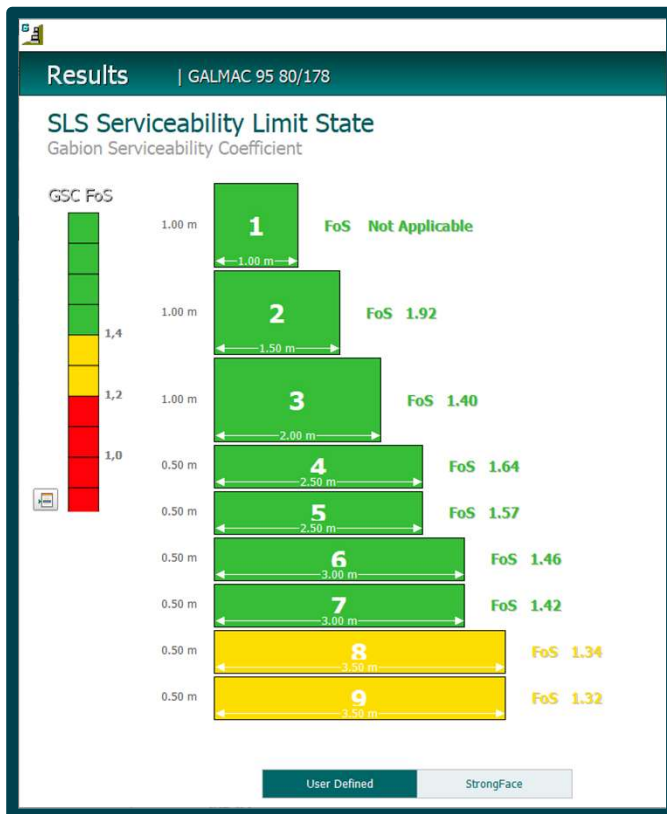


TRAINING

LIVE EXAMPLE - RESULTS ANALYSIS

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Galmac 3.0



Stone
consumption of
13,5 m³/m

Gabion 0.5 m

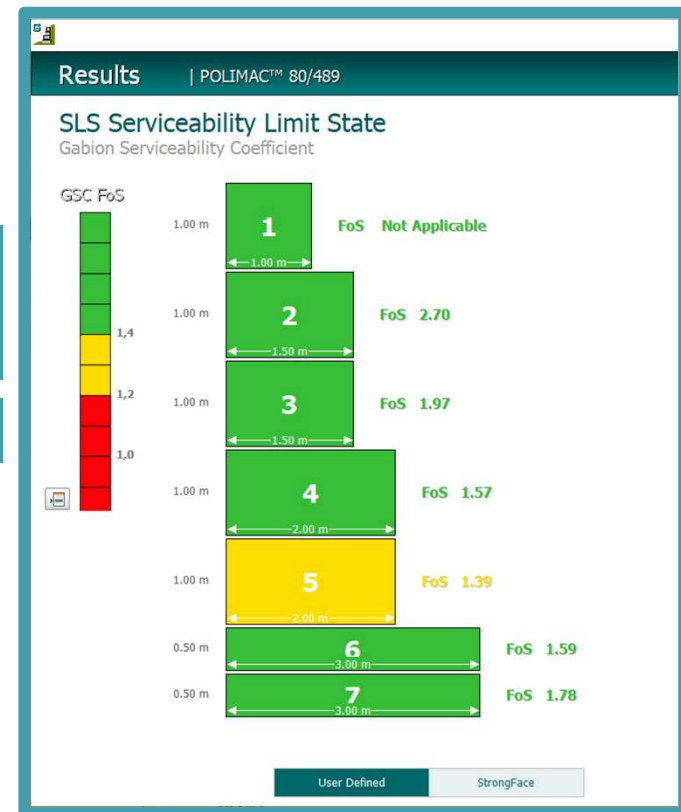
LIVE EXAMPLE - RESULTS ANALYSIS

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PMC 2.7

Stone
consumption of
11 m³/m

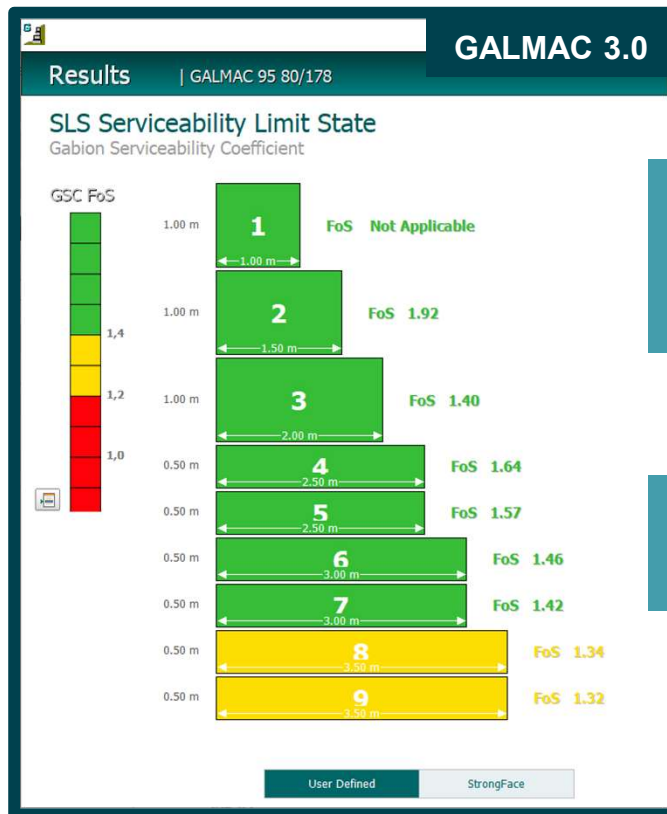
Gabion 1 m



LIVE EXAMPLE - RESULTS ANALYSIS

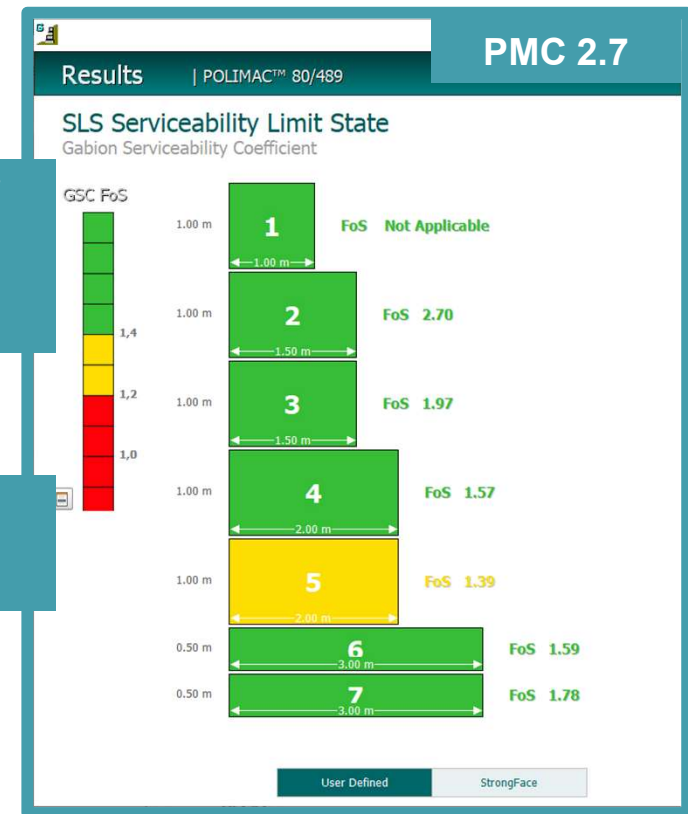
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Gawac 3.0 vs PMC 2.7



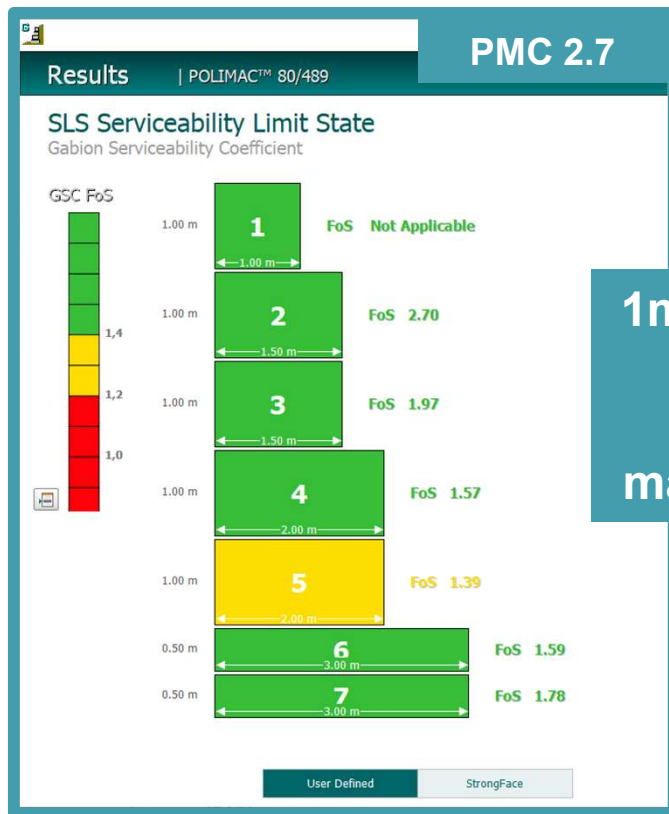
**Saving 20% of
rock
consumption**

**Faster
installation**

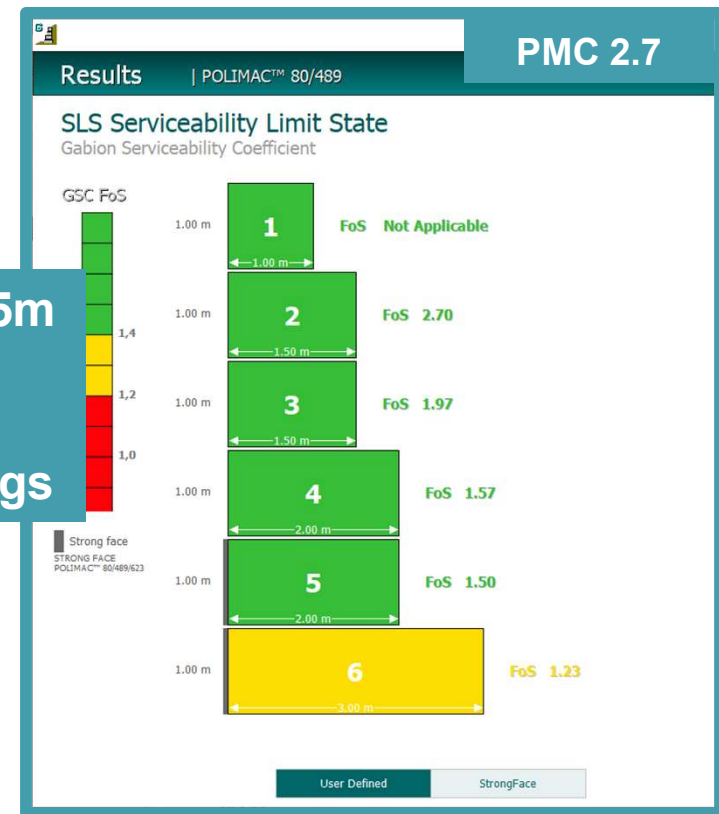


LIVE EXAMPLE - RESULTS ANALYSIS

PMC 2.7 vs PMC 2.7 with two base layers SF PMC 2.7 / 3.0



1m and not 0.5m
gabions
> time and
material savings



**DESIGN
THE
CHANGE**

A NEW ERA FOR
**RETAINING
GABION WALLS**





Not only **performance** certification but also to **environmental** and **digital** ones.



We provide reliable and comparable information on the environmental impacts of the product life cycle **reducing energy** and **material consumption**

visit maccaferri.com/EPD



Our products are also available as BIM. Our BIM Object have been validated by the British Board Agreement (BBA) as being a true and fair representation of the physical product/system. BIM system **reduces design time and cost** and facilitates cooperation between project stakeholders

visit maccaferri.com/BIM

WE ARE PART OF A WIDER FRAMEWORK

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The UN set the SDG

We took on the challenge of achieving a better and more sustainable future for all.



DESIGN THE CHANGE - CONCLUSIONS

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- M** New calculation model that allows analyzing the gabion wall under **serviceability condition**
- M** Optimization of Gabion Walls in compliance with the main **international standards**
- M** Enhanced **long-term performance** and **reduction in environmental burden**

GABION
SERVICEABILITY
COEFFICIENT

GAWAC 3.0
Gabion Wall Design
2020



PoliMac®
WIRE PROTECTION FOR A CHANGING WORLD



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**DESIGN
THE
CHANGE**



*United Arab Emirates,
32-m high Retaining Wall*



A dark teal background featuring a faint, light-colored world map. The map shows the outlines of continents and major landmasses, including North America, South America, Europe, Africa, Asia, and Australia. The text is overlaid on this map.

New worldwide
tests

to develop

A NEW WAY TO DESIGN GABIONS



Q&A