Mechanical Stabilisation for Permanent Roads

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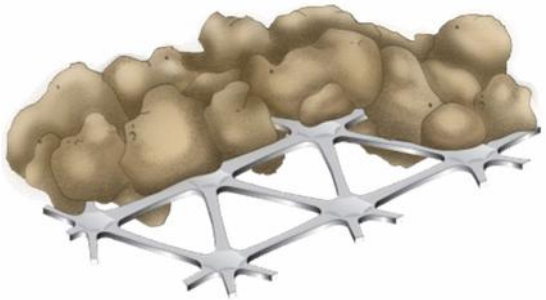
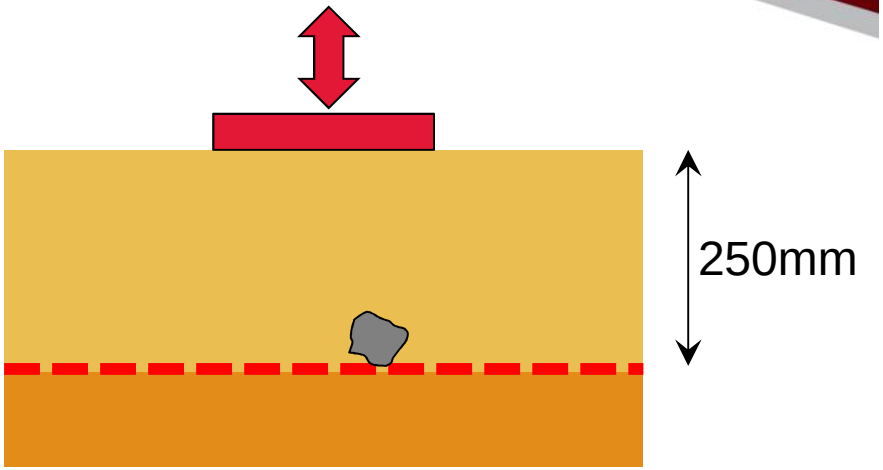
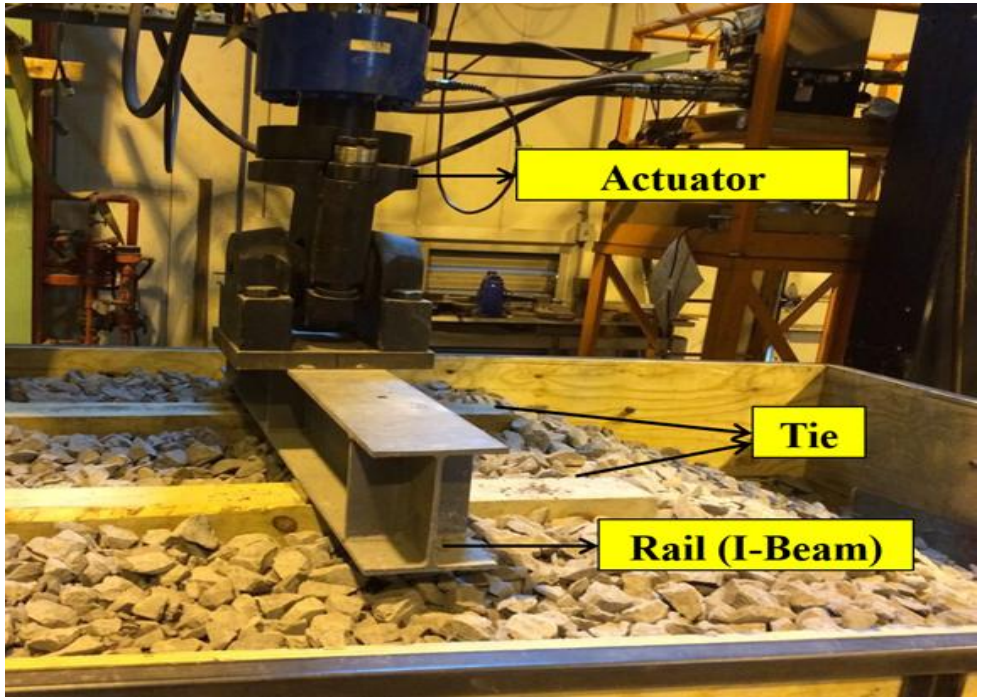
Tensar®

Effect of geogrid on particle movement

Effect of geogrid on particle movement under cyclic loading

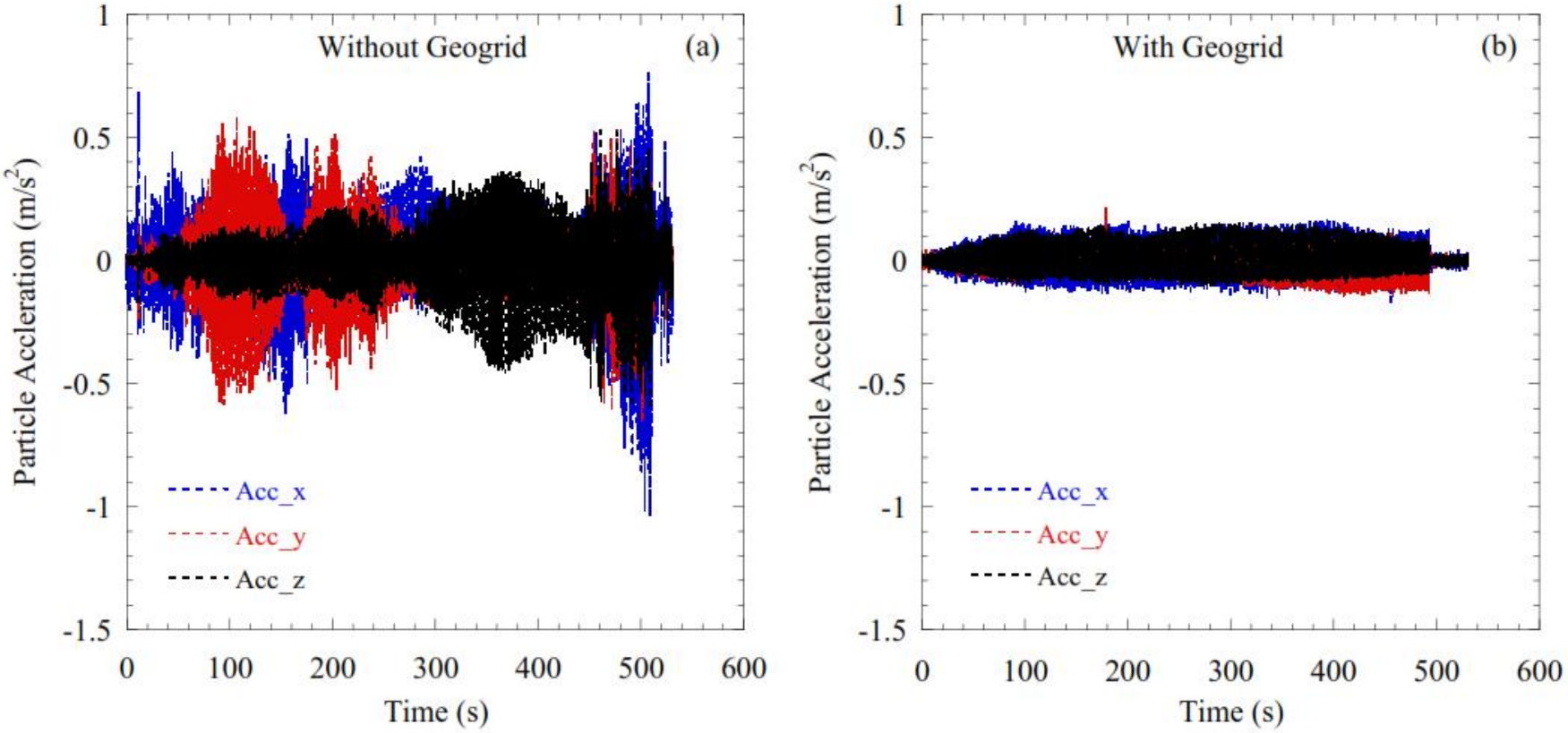






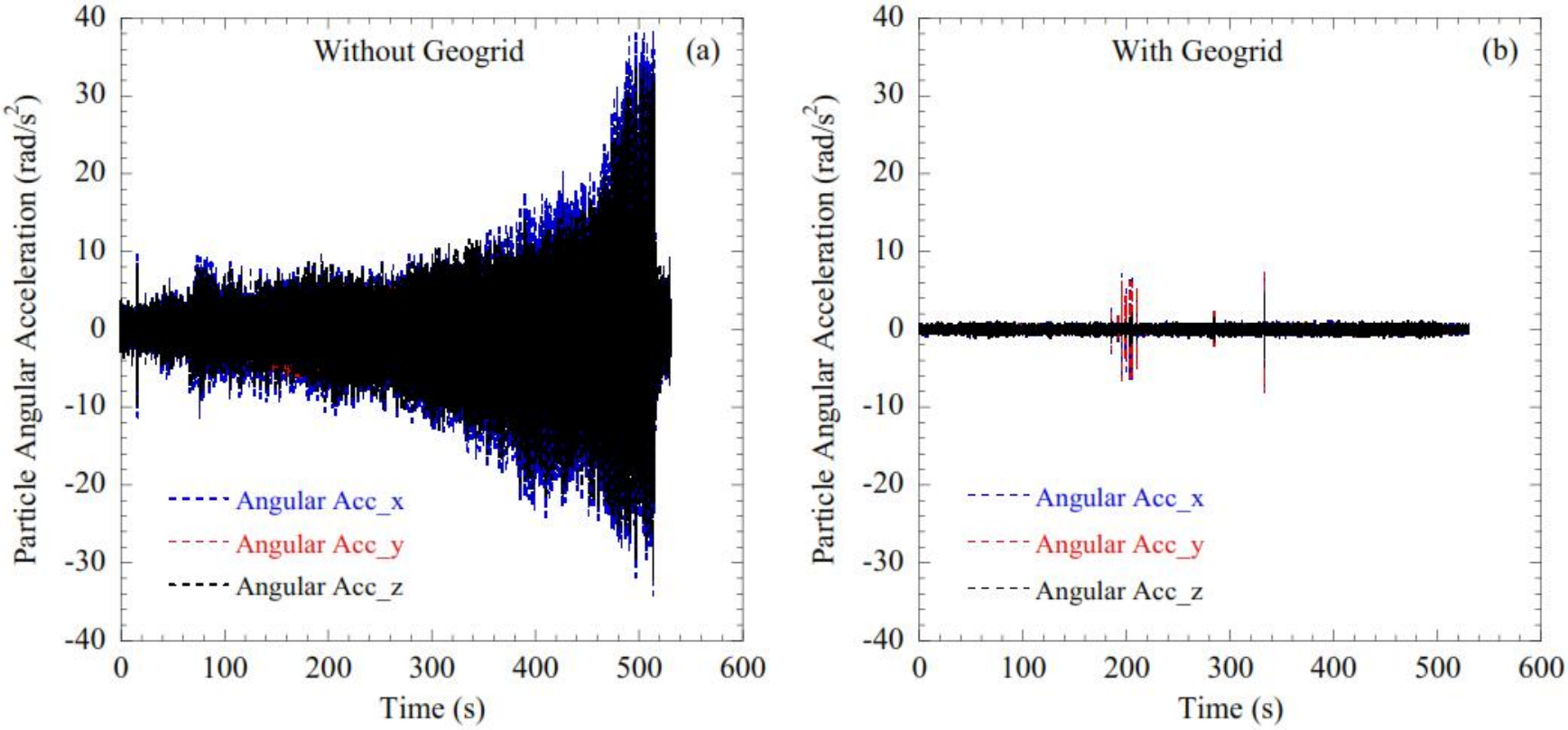
Particle translational acceleration

- PARTICLE TRANSLATIONAL MOVEMENT was significantly reduced with the inclusion of TX190L geogrid.

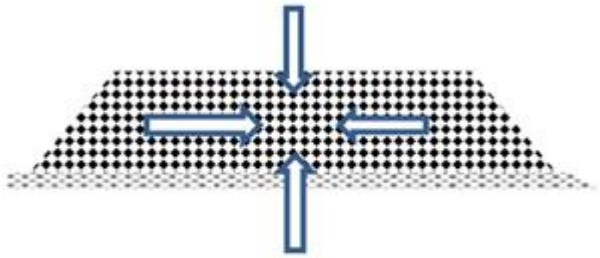


Particle rotational acceleration

- PARTICLE ROTATION was significantly reduced with the inclusion of TX190L geogrid.



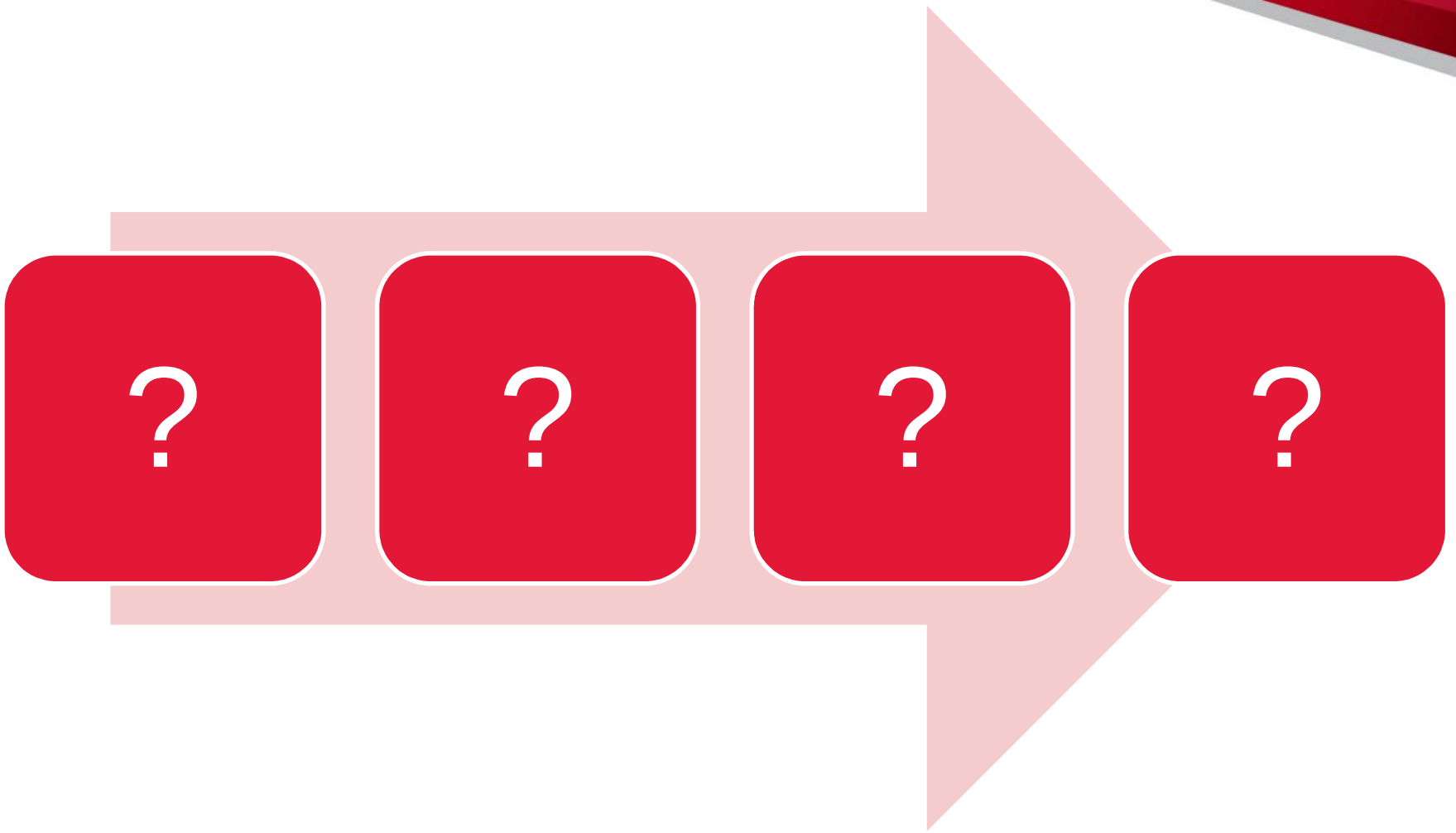
Definition of Stabilisation?



Proposed Definition by ISO TC221 - WG2

- Stabilisation: Improvement of the mechanical behaviour of an unbound granular material by including one or more geosynthetic layers such that the deformation under applied loads is reduced by minimizing soil particle movement.

  - Perhaps Mechanical Stabilisation is a more appropriate description – distinguishes from Chemical Stabilisation, Lime Stabilisation and others



Why do we need a stabilisation function?

There are three perfectly well understood functions of geosynthetics

- Filtration
- Separation
- Reinforcement

Why do we now need a new function?

Is this just a marketing gimmick?

What is the problem?

Challenges

HM Government

Industrial Strategy: government and industry in partnership

Our vision for 2025

Working together, industry and Government have developed a clear and defined set of aspirations for UK construction.

July 2013

Lower costs

33%

reduction in the initial cost of construction and the whole life cost of built assets

Faster delivery

50%

reduction in the overall time, from inception to completion, for newbuild and refurbished assets

Lower emissions

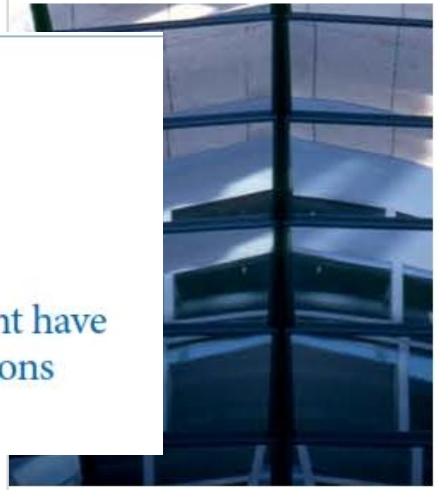
50%

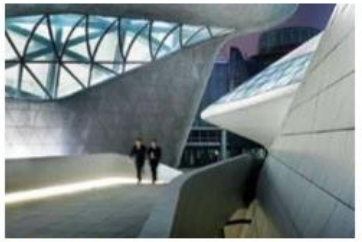
reduction in greenhouse gas emissions in the built environment

Improvement in exports

50%

reduction in the trade gap between total exports and total imports for construction products and materials

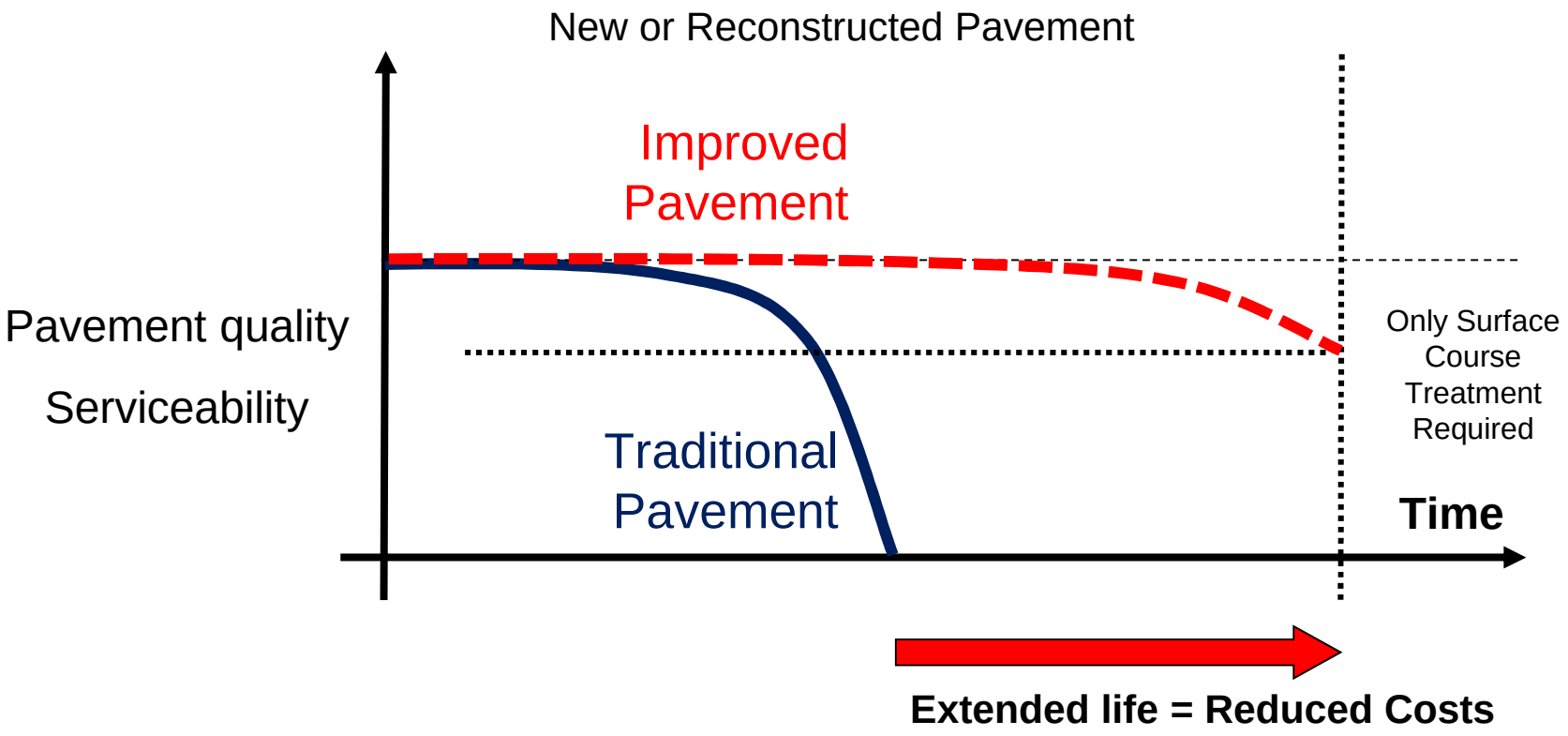




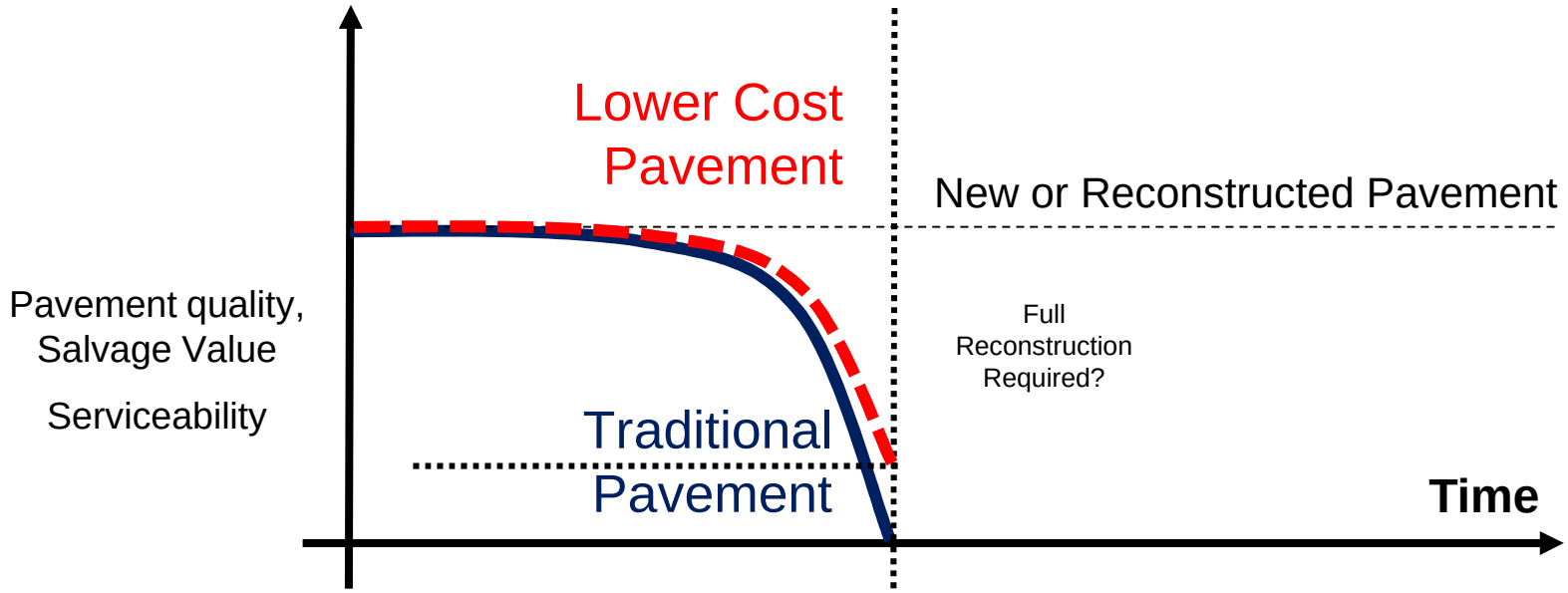
The global construction market is forecast to grow by over 70% by 2025.

Global Construction 2025; Global Construction Perspectives and Oxford Economics (July 2013)

Lower Costs
Reducing whole-life cost

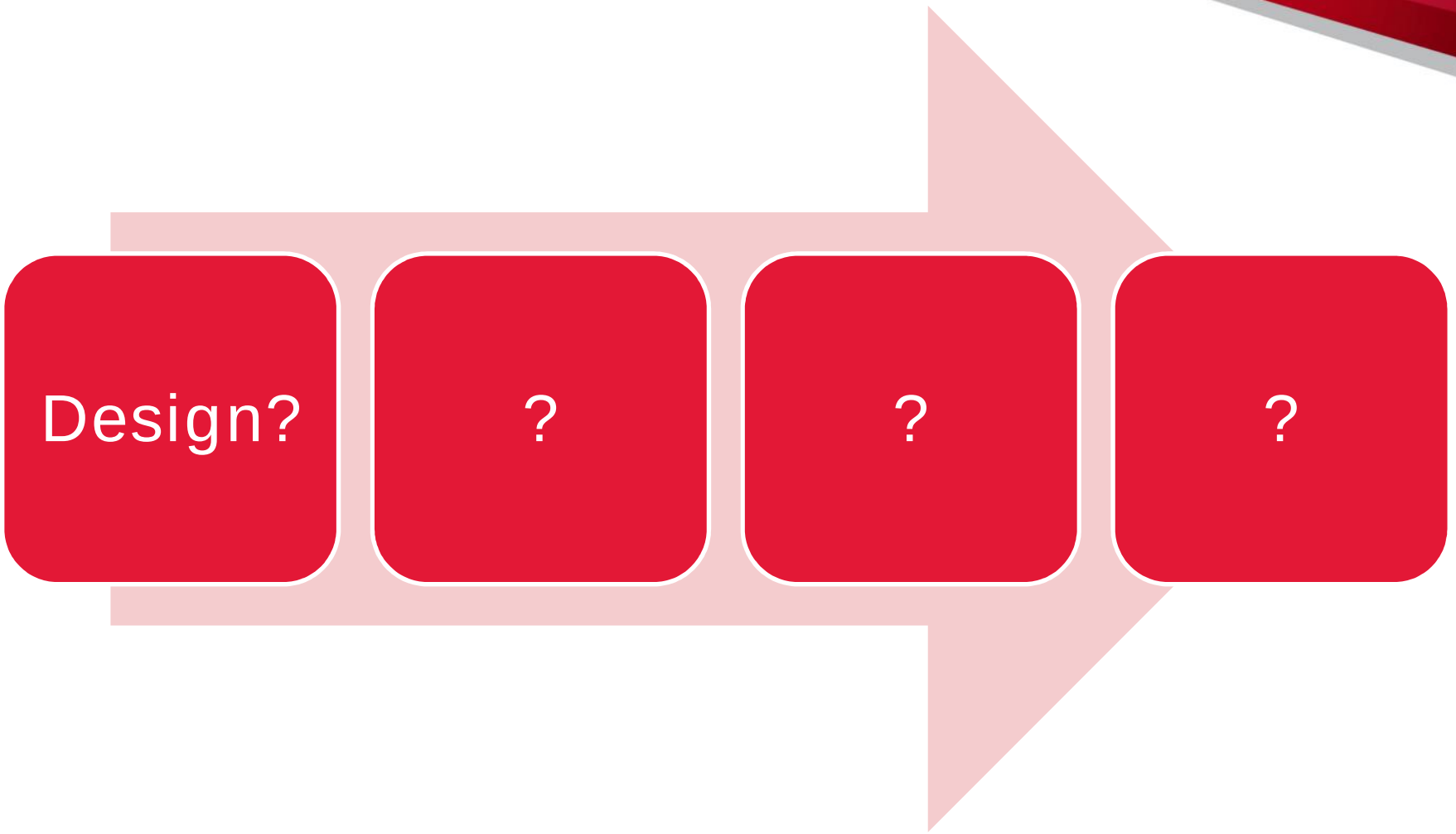


Reduce costs
Lower construction cost for same life



Mechanical Stabilisation

One of the ways in which the performance of permanent roads can be increased



How can we design mechanically stabilised permanent roads?

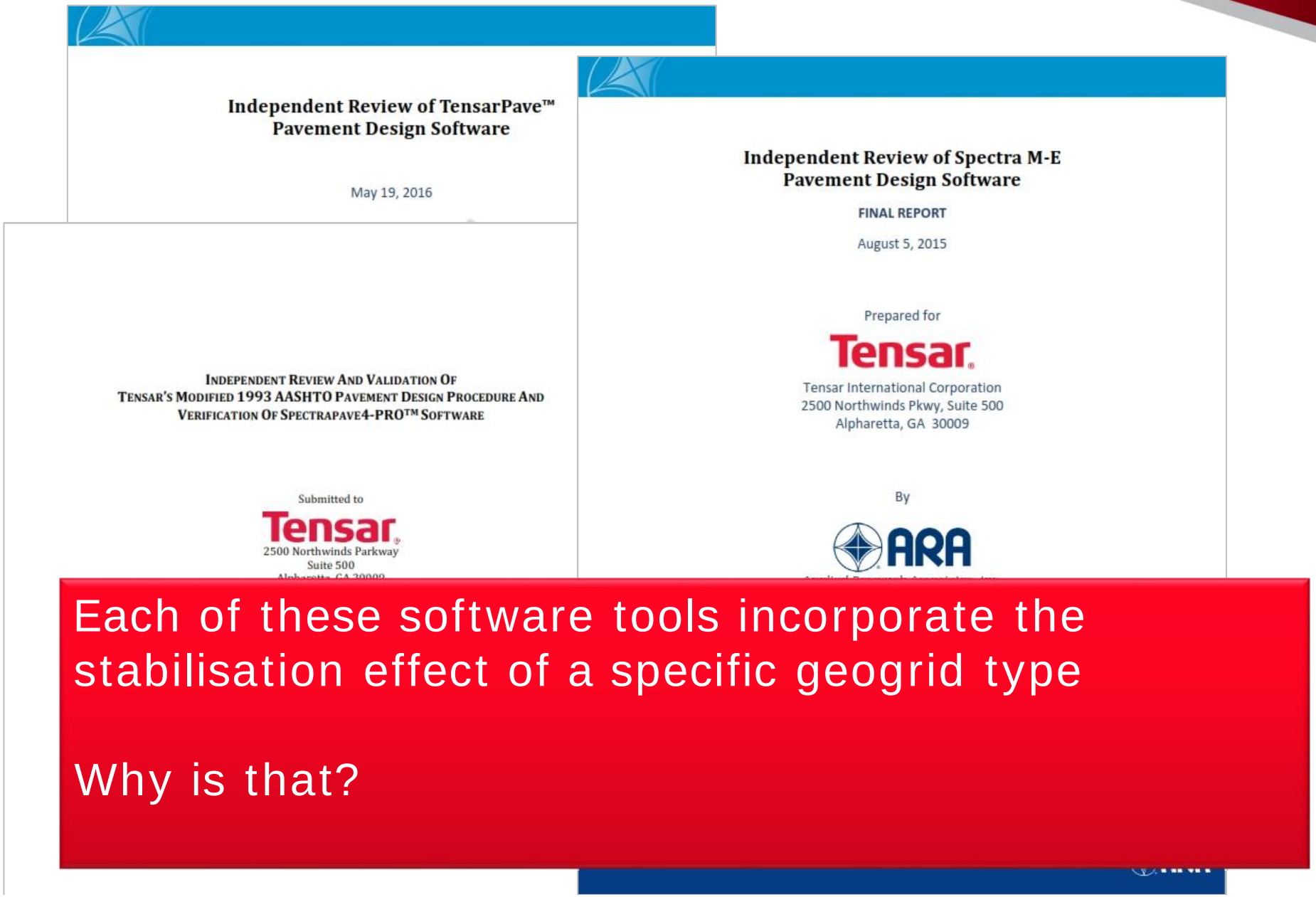
Tools already exist to design for design of mechanically stabilised permanent roads

Tensar has developed three software tools*:

- TensarPave – Spectra
- SpectraPave4-Pro
- Spectra M-E

*other manufacturers may have developed similar software

All of these tools are independently validated

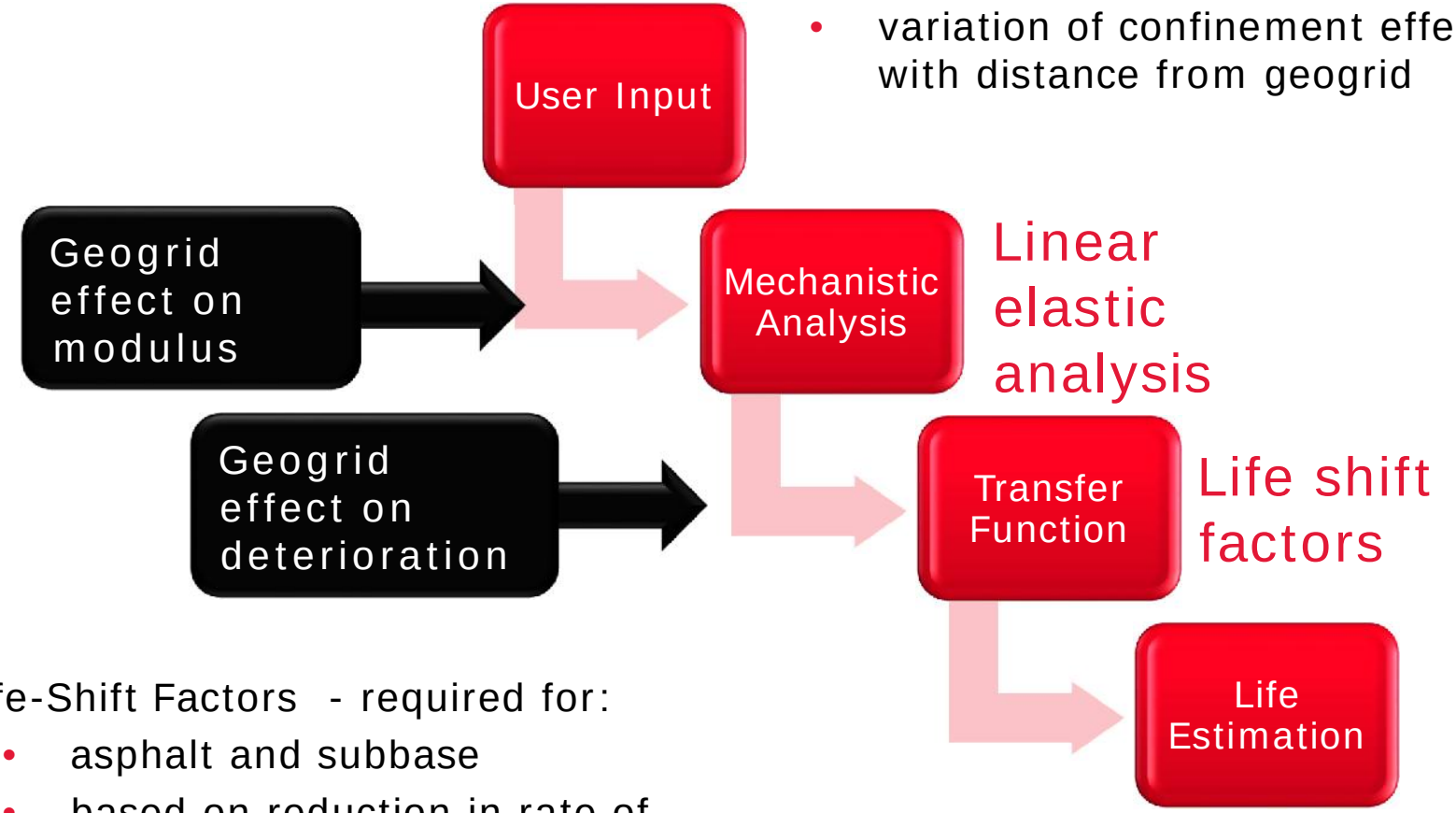


Each of these software tools incorporate the stabilisation effect of a specific geogrid type

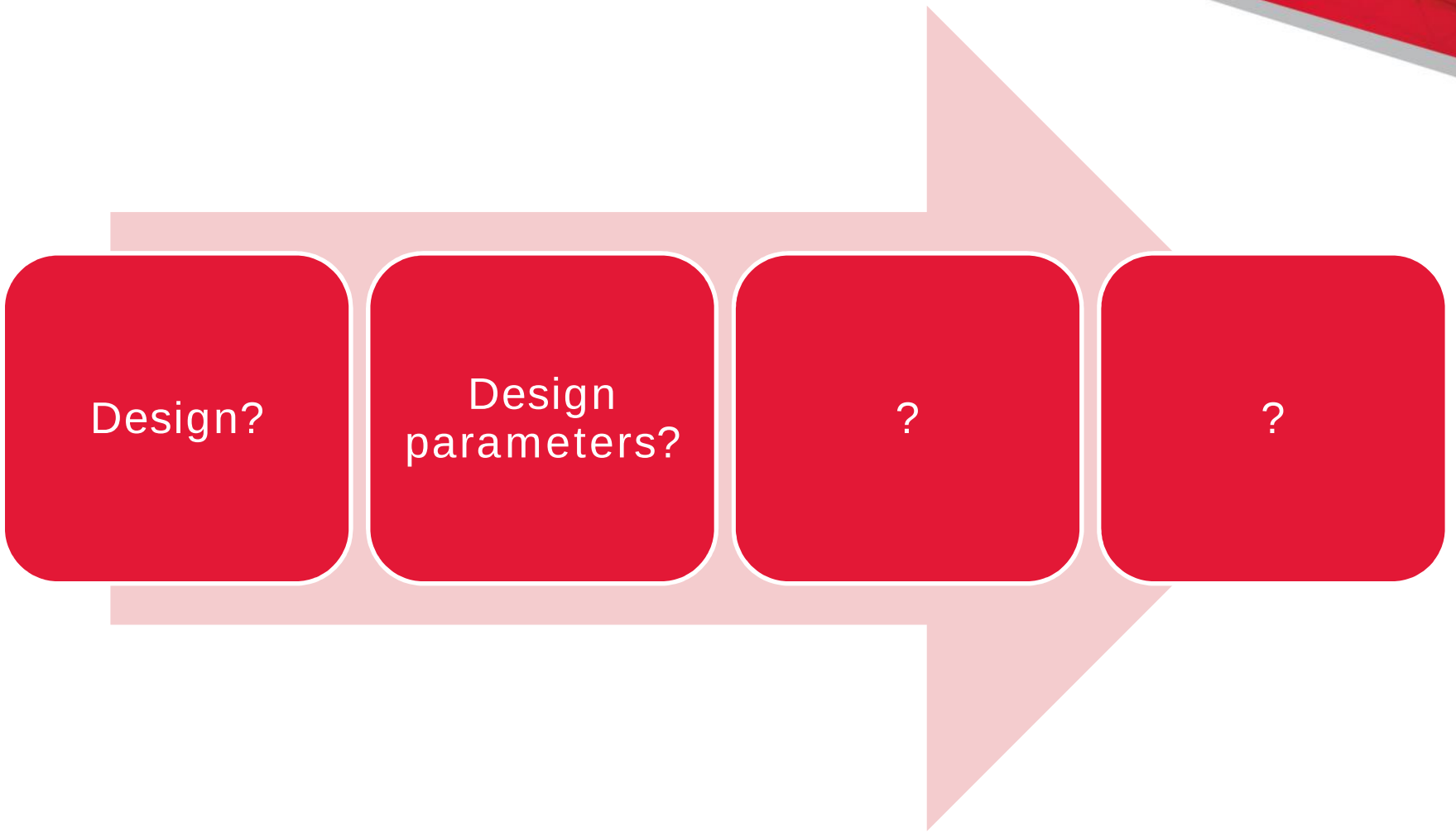
Why is that?

Incorporating the geogrid effect into M-E Design

- Layer modulus - algorithm accounts for:
  - location of geogrid
  - variation of confinement effect with distance from geogrid



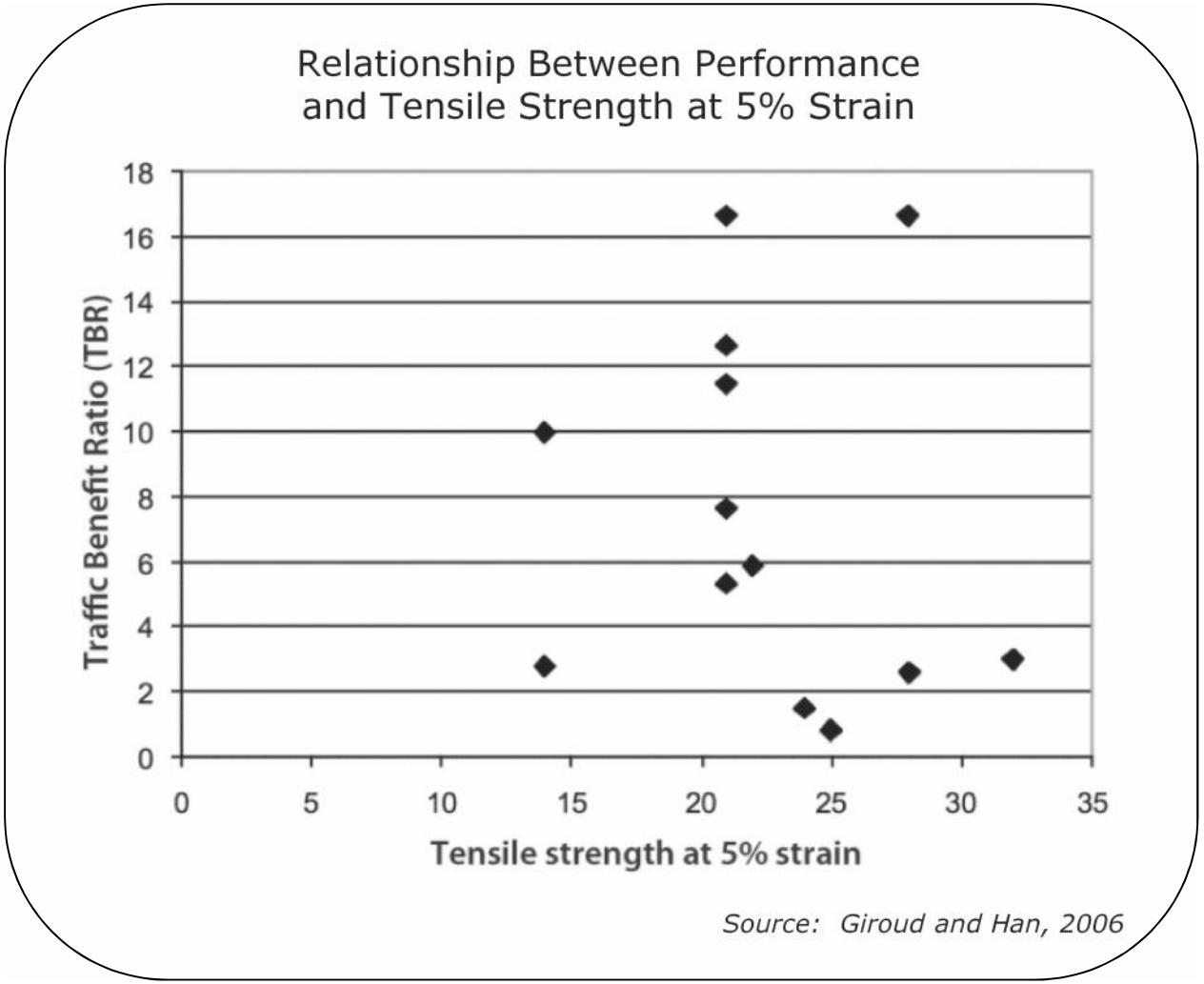
- Life-Shift Factors - required for:
  - asphalt and subbase
  - based on reduction in rate of degradation observed



How can we quantify the geogrid effect and develop design parameters?

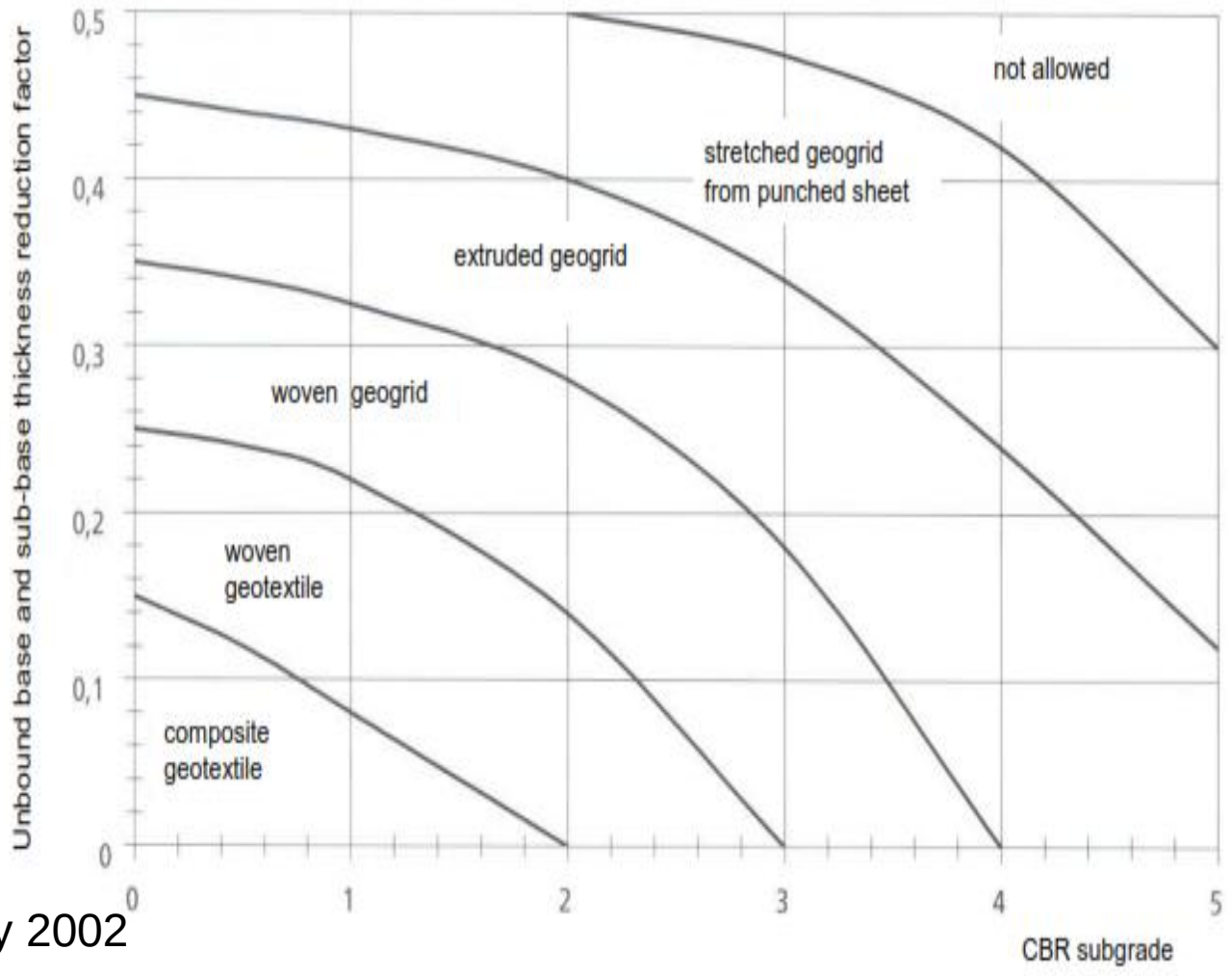
What influences the geosynthetic effect?

Tensile strength has no relation to trafficking performance



What influences the geosynthetic effect?

Geosynthetic form has an influence on performance



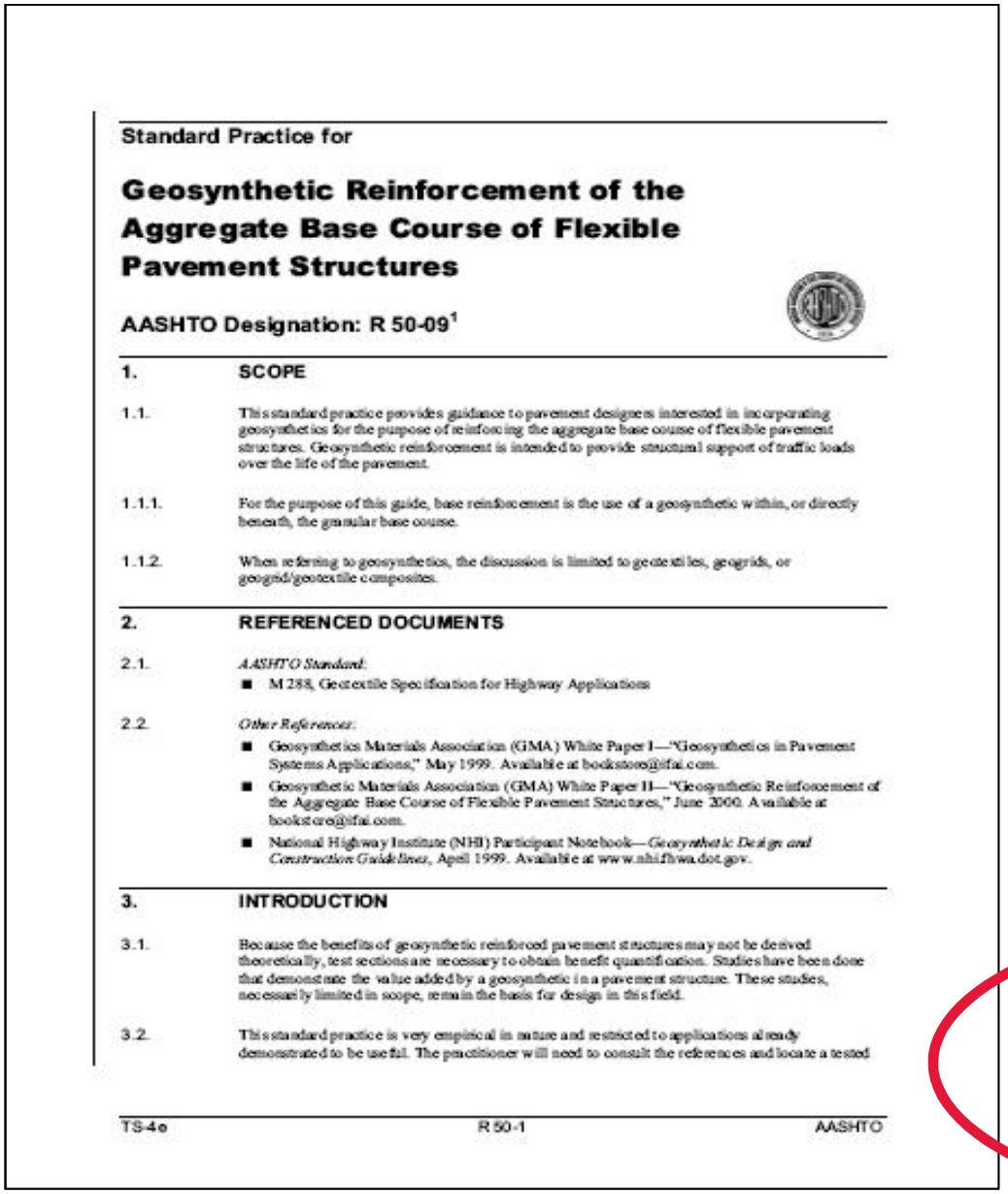
CROW Publication - January 2002

What do we know?

After 30+ years of research on geogrid performance in roadway applications:

- No single index property positively correlates to performance
- A combination of several important features influences performance
- Designs need to be based upon performance of the stabilised layer – not geogrid properties

Guidance available: AASHTO: R50-09



Standard Practice for

Geosynthetic Reinforcement of the Aggregate Base Course of Flexible Pavement Structures

AASHTO Designation: R 50-09[1]

1. SCOPE

1.1. This standard practice provides guidance to pavement designers interested in incorporating geosynthetics for the purpose of reinforcing the aggregate base course of flexible pavement structures. Geosynthetic reinforcement is intended to provide structural support of traffic loads over the life of the pavement.

1.1.1. For the purpose of this guide, base reinforcement is the use of a geosynthetic within, or directly beneath, the granular base course.

1.1.2. When referring to geosynthetics, the discussion is limited to geotextiles, geogrids, or geogrid/geotextile composites.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standard:*
- M 288, Geotextile Specification for Highway Applications

2.2. *Other References:*
- Geosynthetics Materials Association (GMA) White Paper I—"Geosynthetics in Pavement Systems Applications," May 1999. Available at bookstore@ifai.com.
- Geosynthetic Materials Association (GMA) White Paper II—"Geosynthetic Reinforcement of the Aggregate Base Course of Flexible Pavement Structures," June 2000. Available at bookstore@ifai.com.
- National Highway Institute (NHI) Participant Notebook—*Geosynthetic Design and Construction Guidelines*, April 1999. Available at www.nhi.fhwa.dot.gov.

3. INTRODUCTION

3.1. Because the benefits of geosynthetic reinforced pavement structures may not be derived theoretically, test sections are necessary to obtain benefit quantification. Studies have been done that demonstrate the value added by a geosynthetic in a pavement structure. These studies, necessarily limited in scope, remain the basis for design in this field.

3.2. This standard practice is very empirical in nature and restricted to applications already demonstrated to be useful. The practitioner will need to consult the references and locate a tested

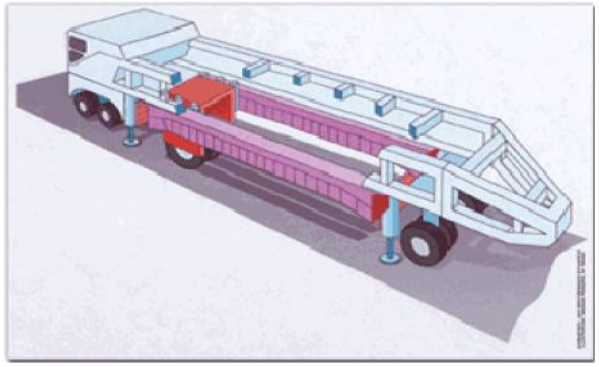
TS-4e R 50-1 AASHTO

- Benefit of including geosynthetics in pavement is recognised to:
  - Improved life
  - Reduced thickness
- Benefits of a specific geosynthetic cannot be derived theoretically
- Designs not easily translated to other geosynthetics
- Test sections are necessary to obtain benefit quantification

Extensive research and APT testing

…to characterise the MSL properties

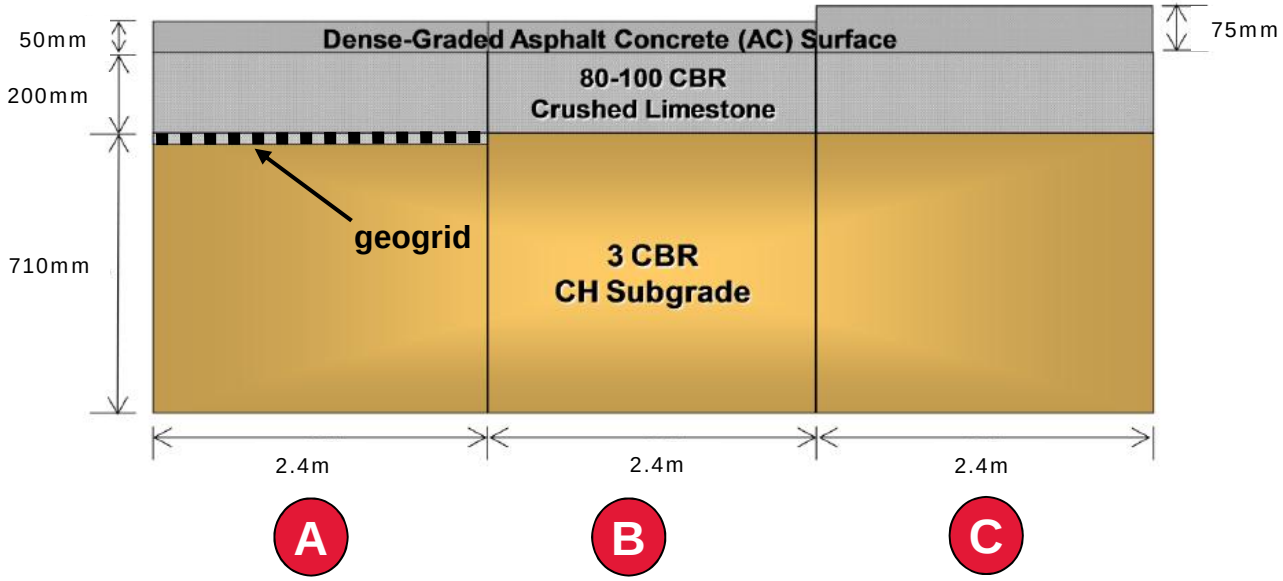
US Corps of Engineers - Full scale APT studies



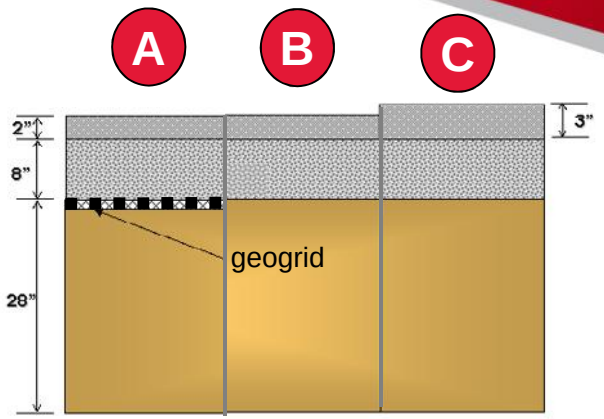
- Project in 3 Phases phases
- Set up for Phase 1:
  - CBR=3%
  - Dual wheel. 2.08 ESAL
  - 0.8m wander pattern
  - Constant temperature

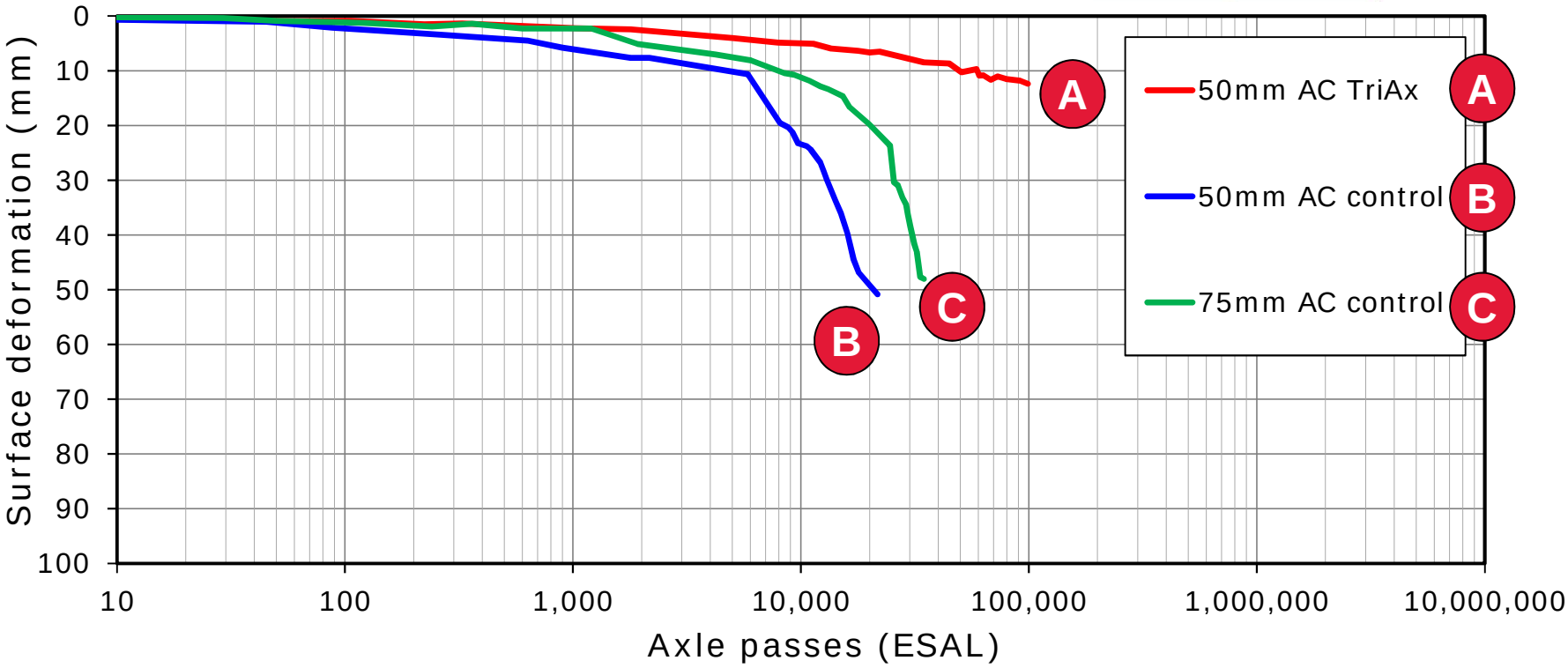
Full Scale Evaluation with APT
Phase 1

A	B	C
geogrid stabilised base 50mm asphalt	non - stabilised 50mm asphalt	non - stabilised 75mm asphalt

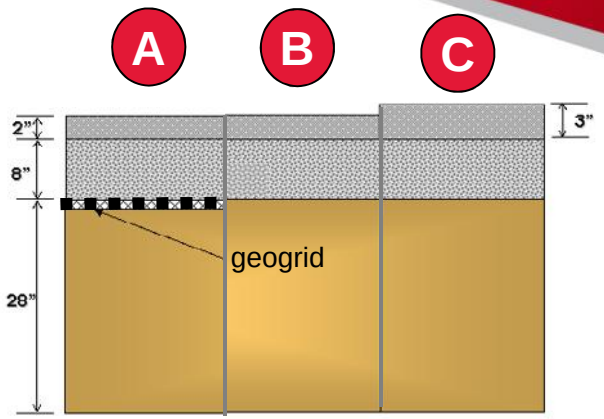


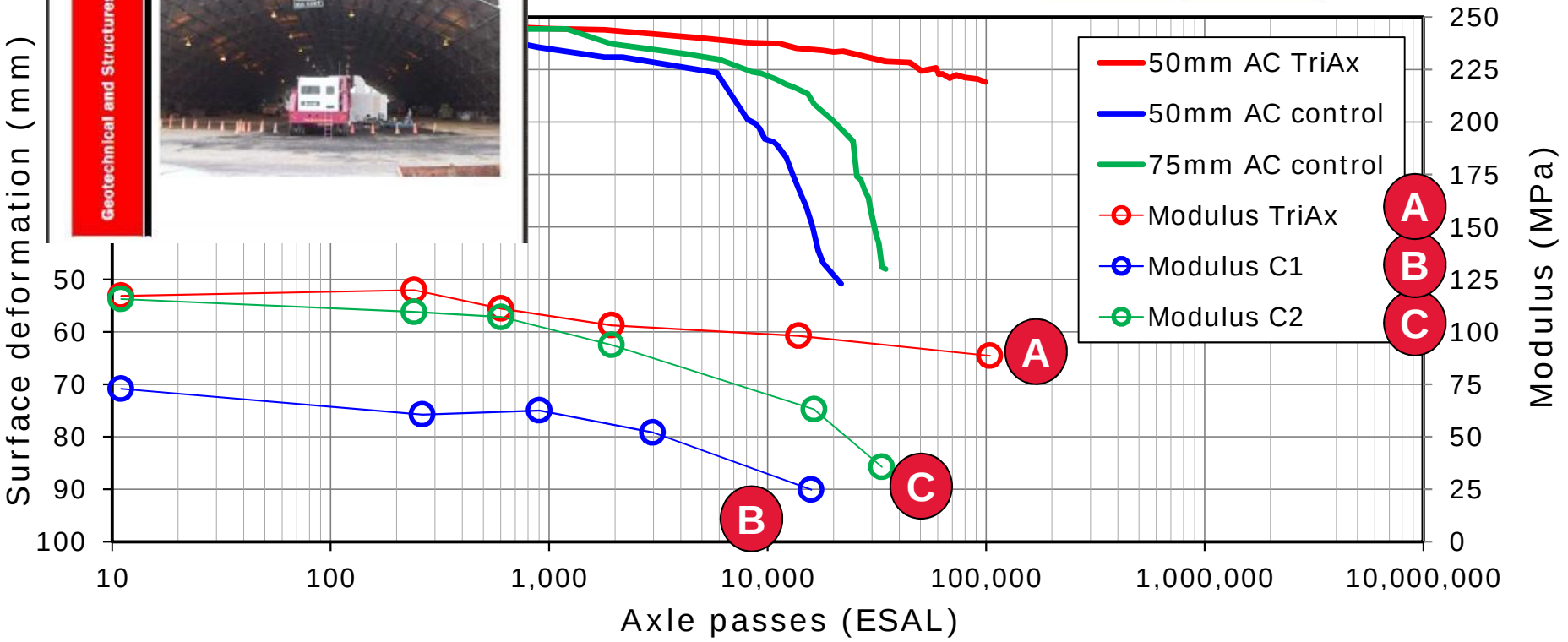
USCoE trials, Phase 1 – Trafficking Results





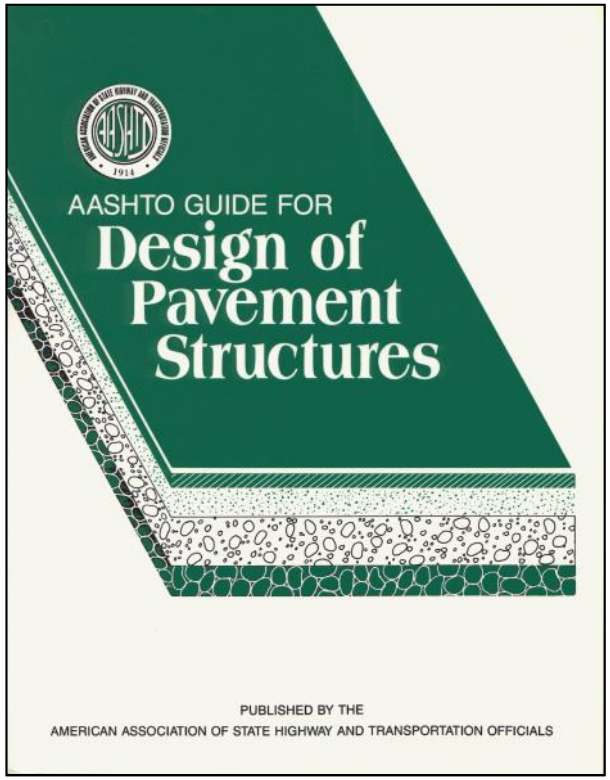
USCoE trials, Phase 1 – Surface Modulus





Incorporating the stabilization effect into design tools

- We need to develop a deign tool that can incorporate the stabilisation benefit
- One approach is to modify a proven Empirical method (e.g. AASHTO '93)



AASHTO Method:

- Empirical methodology
- Based on AASHTO Road Test

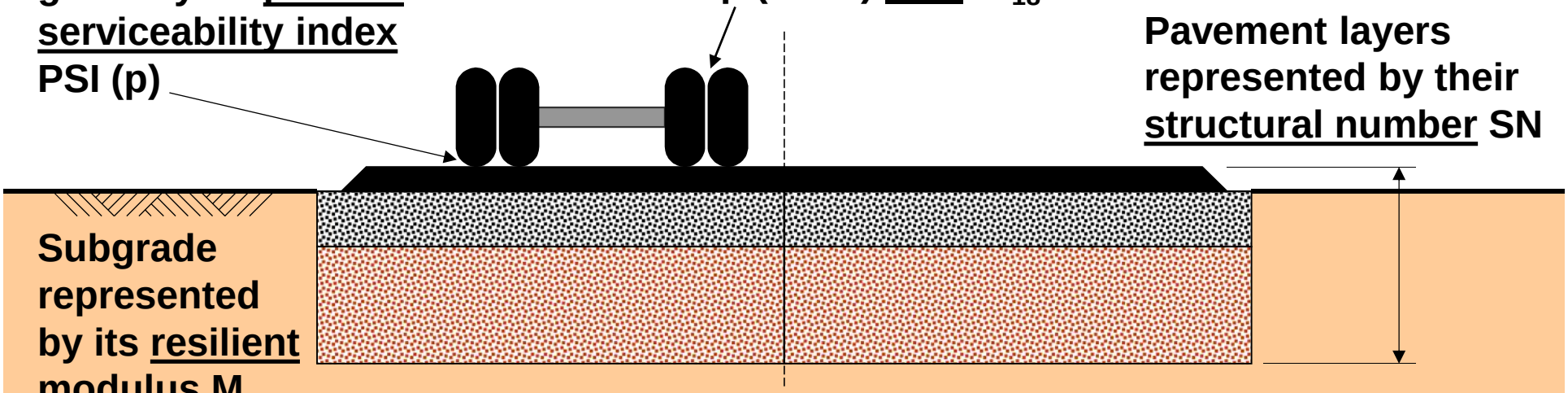
Developing an Empirical Design Method
Modified AASHTO '93

- Incorporating the geogrid effect
- $SN = a_1 d_1 + a_2 d_2 m_2 + a_3 d_3 m_3$ d = layer thickness, m = drainage coefficient
- Mechanical stabilisation effect is included as an enhanced "a" value for the base layer. Where 'a' is a variable

Pavement condition given by its present serviceability index PSI (p)

Traffic given by number of 18 kip (80kN) ESA W_{18}

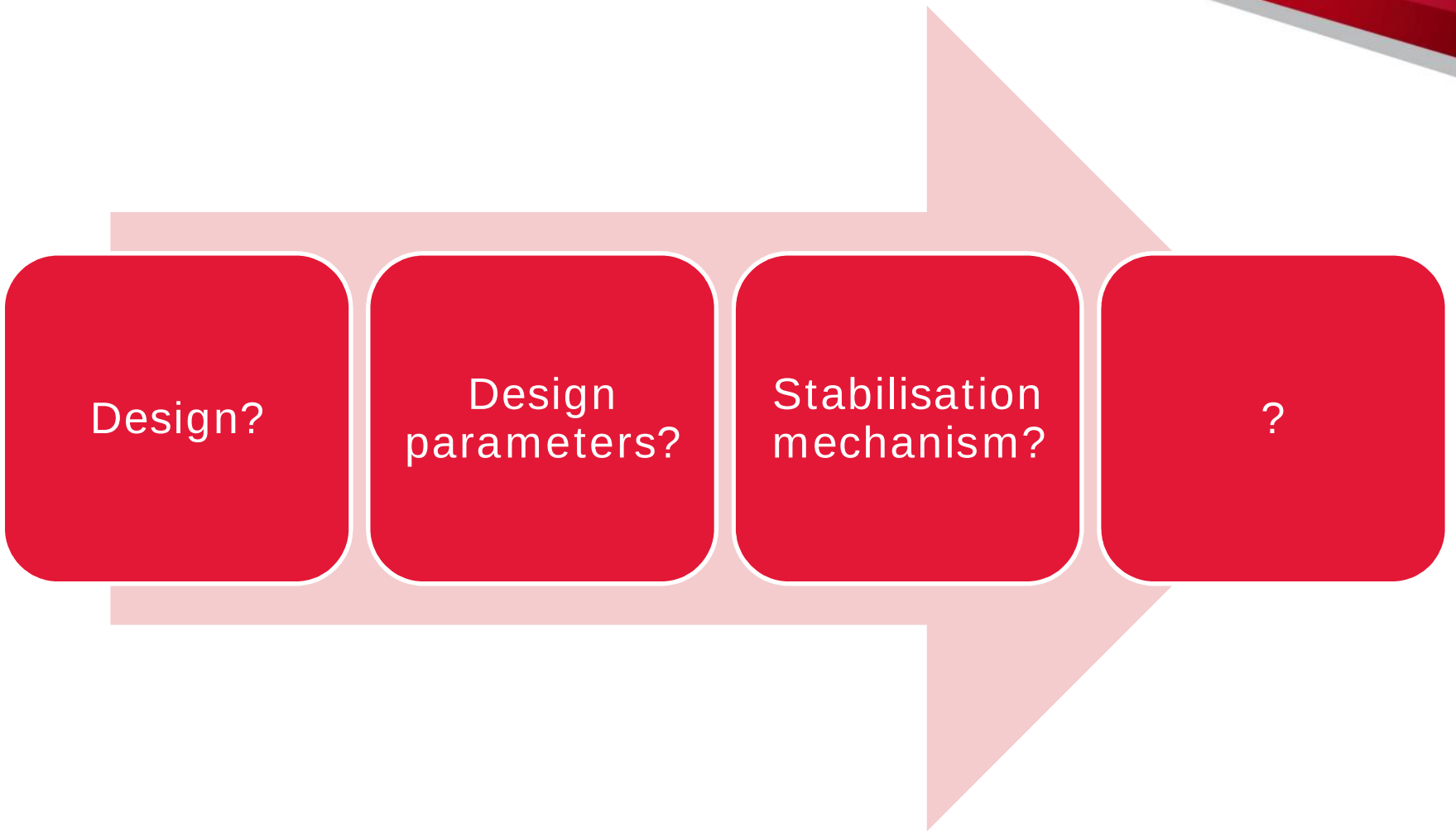
Pavement layers represented by their structural number SN



Subgrade represented by its resilient modulus M_R

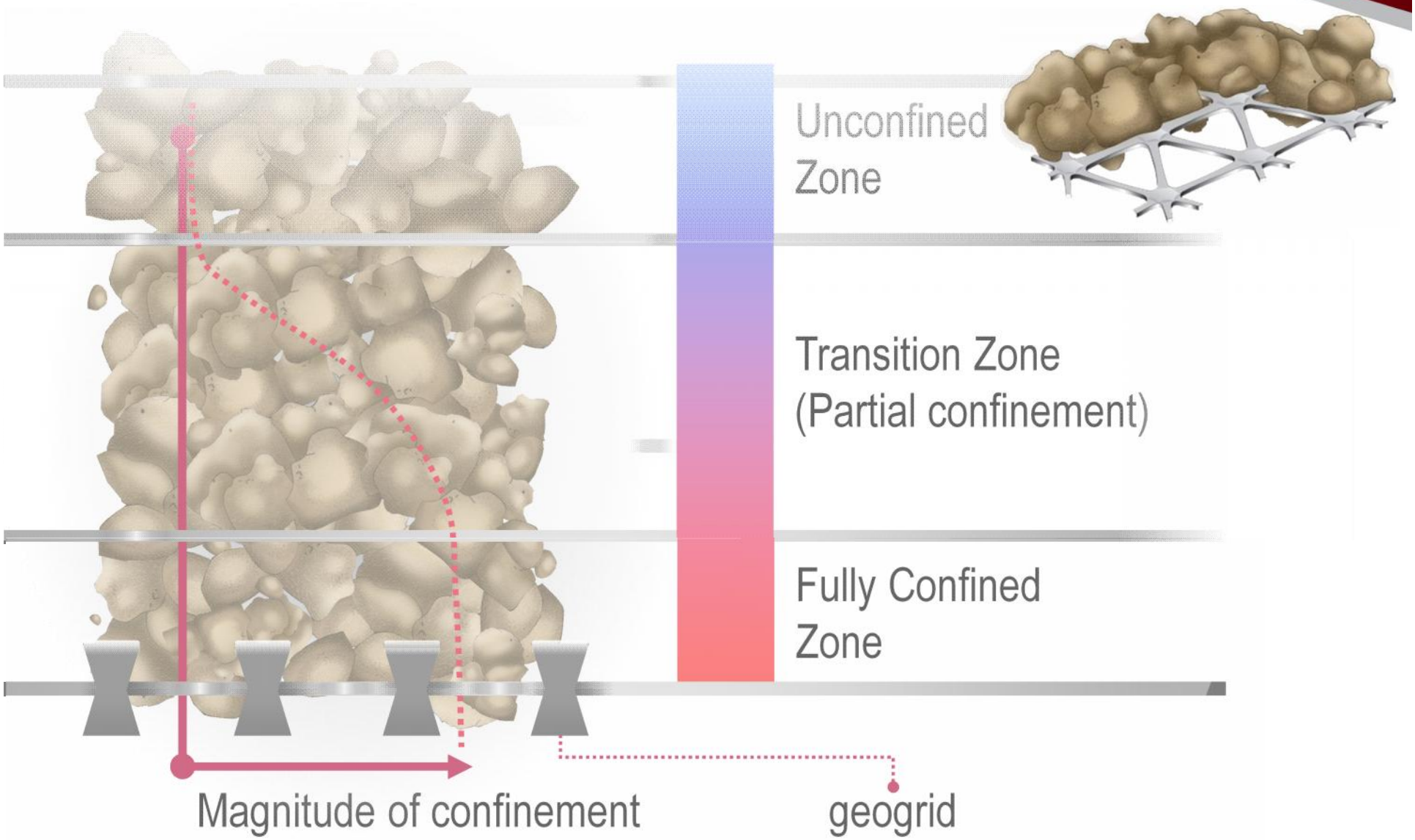
$$\log_{10} W_{18} = Z_R S_0 + 9.36 \log_{10}(SN+1) - 0.2 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.4 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \log_{10} M_R - 8.07$$

AASHTO '93 Controlling equation

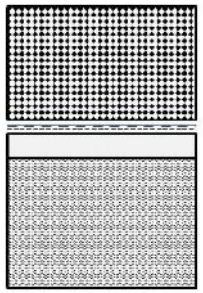


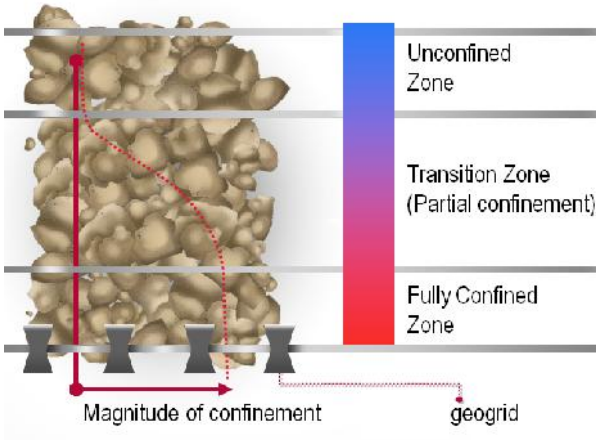
What is the mechanism for stabilisation?
How does a geogrid stabilise?

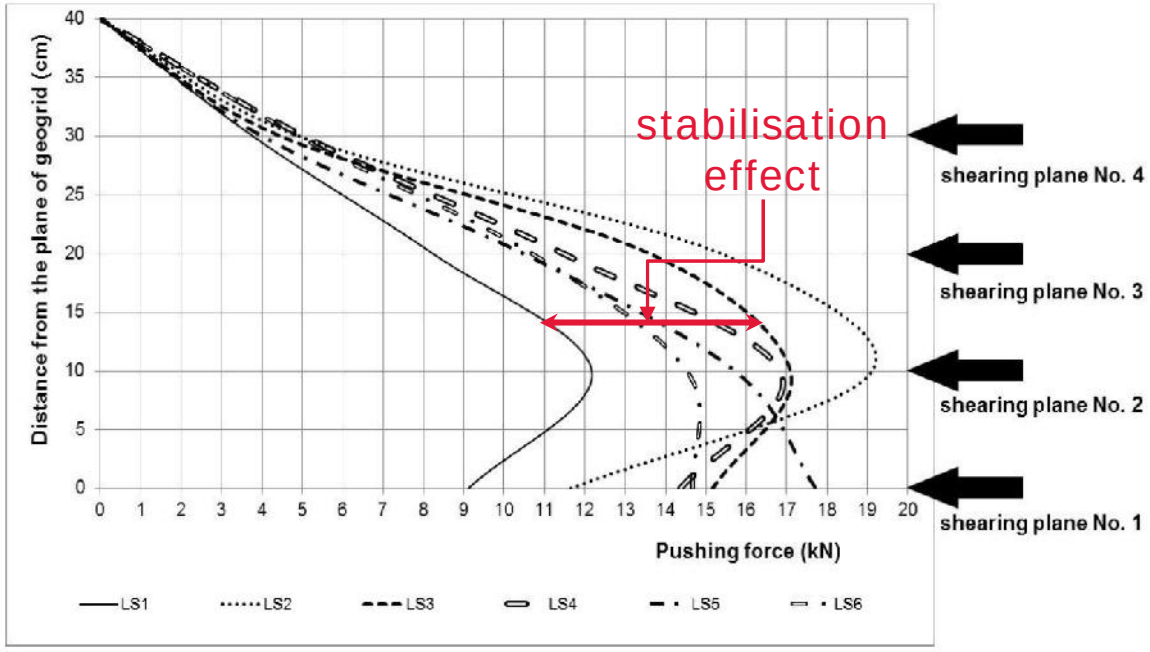
How does a geogrid provide mechanical stabilisation?



Evidence of the Zone of Confinement



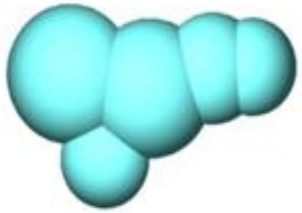


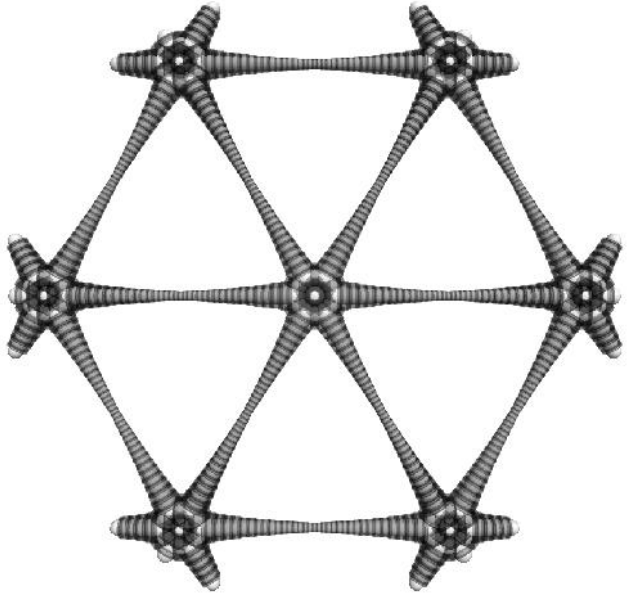


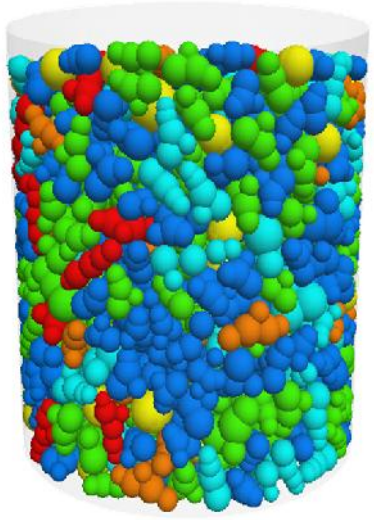
(Horvat, Klompmaker :2014)

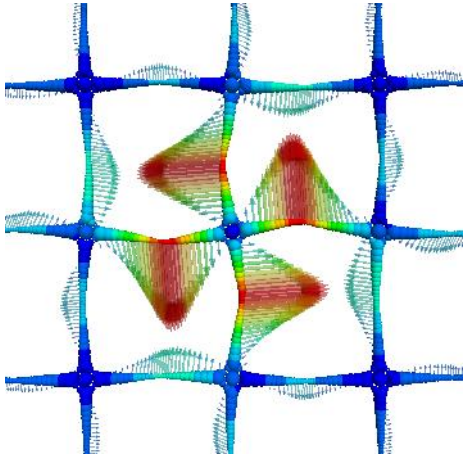
Multi-Level Shear Box Testing – with Geogrid

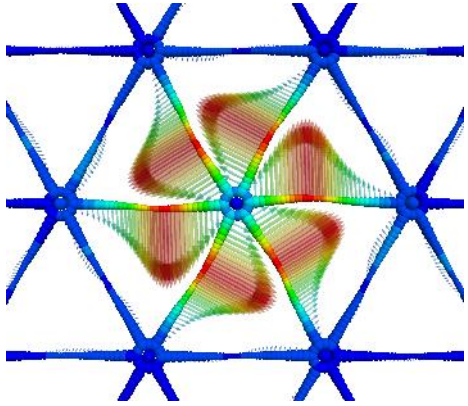
DEM Modelling to demonstrate the effect of particle confinement and lateral restraint



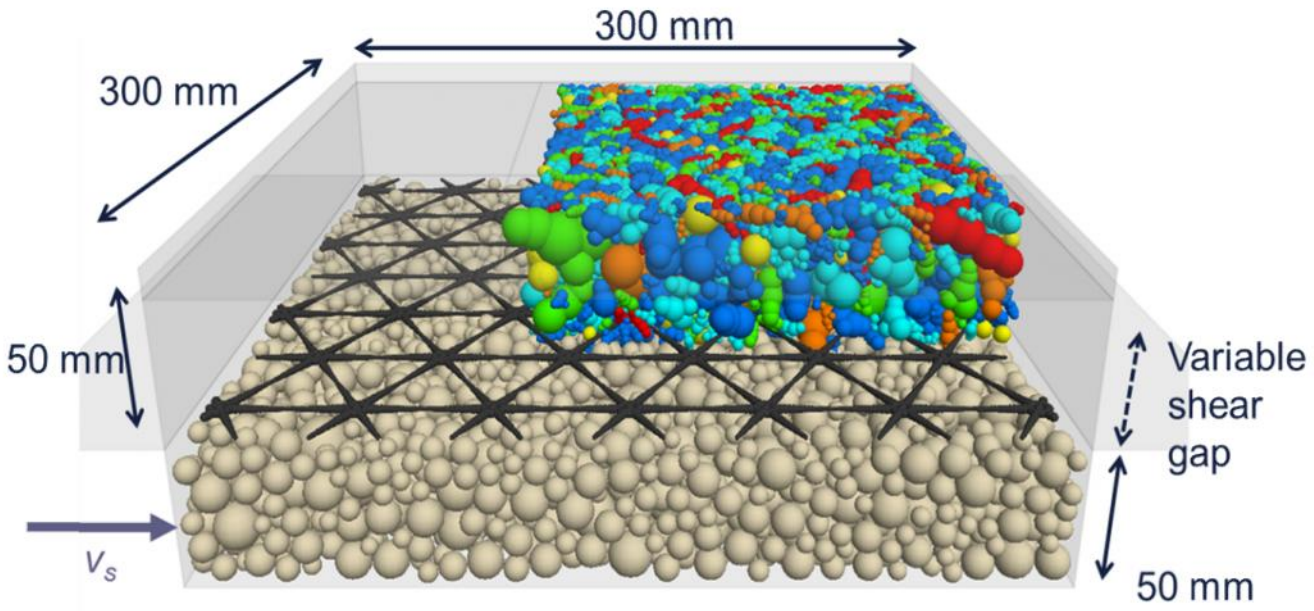


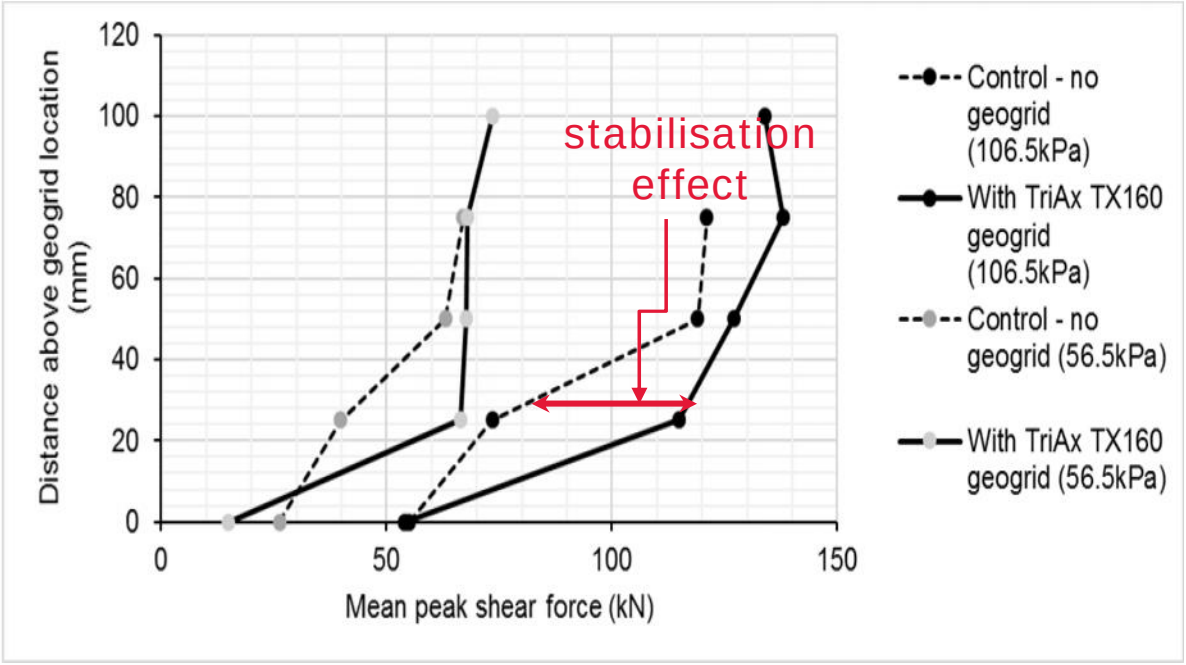




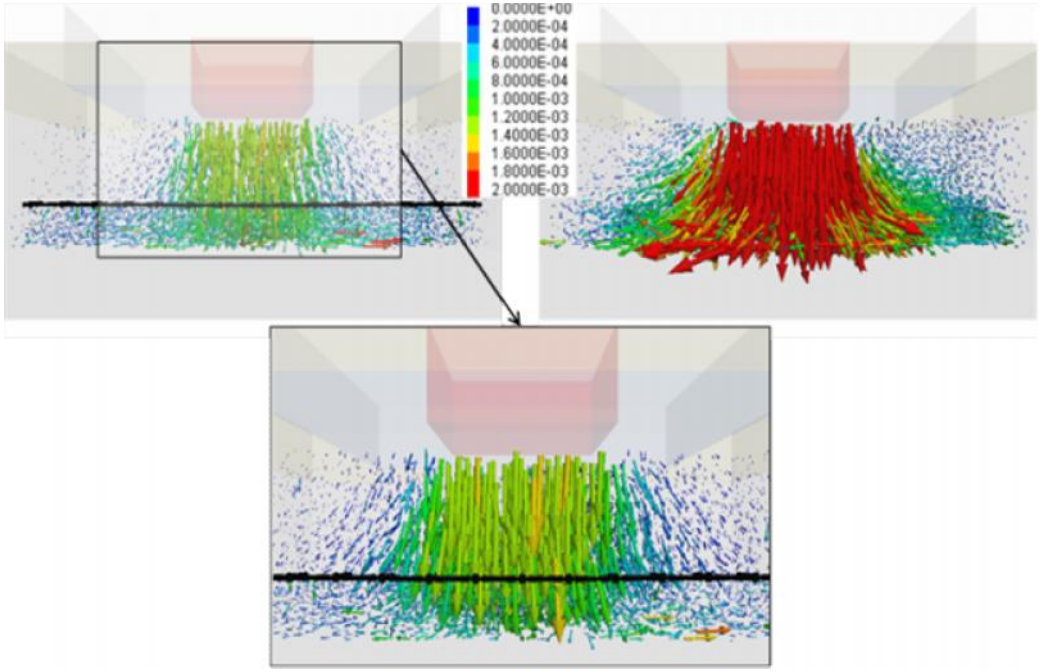


DEM Multi-layer shear model



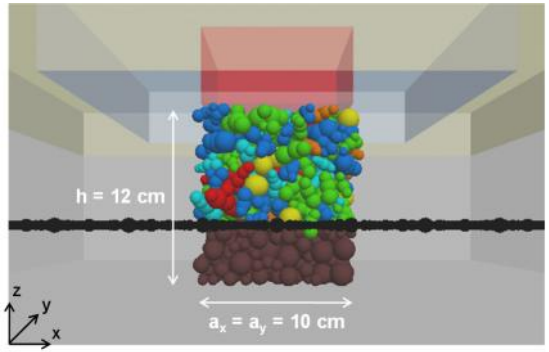


DEM - Confinement effect in a plate-load test

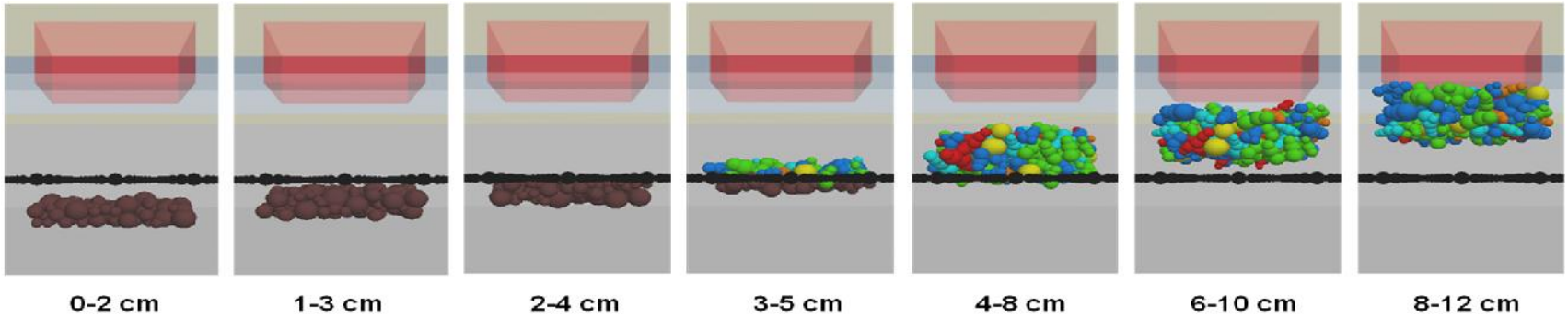


DEM - Confinement effect in a plate-load test

Biaxial geogrid model

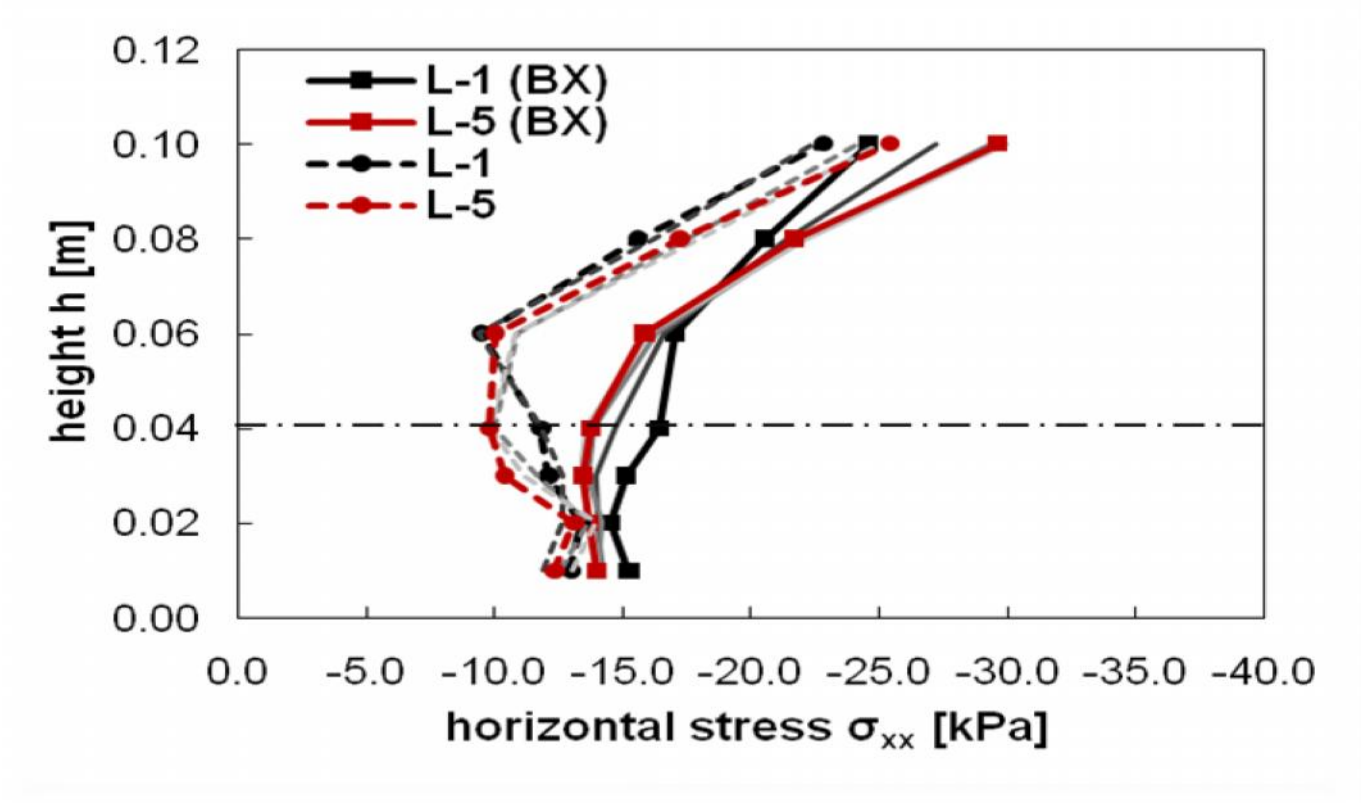


Rectangular Plate
Load cycled five times
L1 to L5



Stress condition examined within seven separate layers

Confinement effect in a plate-load test



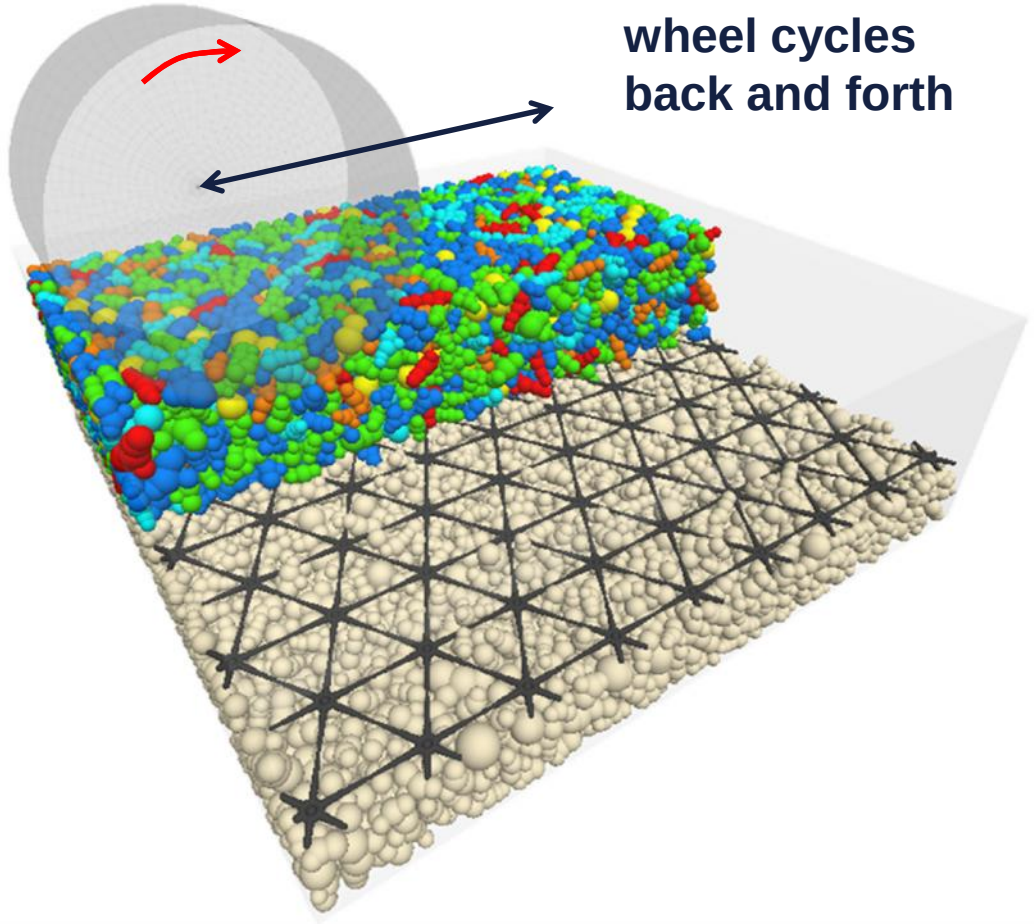
Stress state* (σ_{xx})

Loaded condition (L1 and L5)

*directly below plate

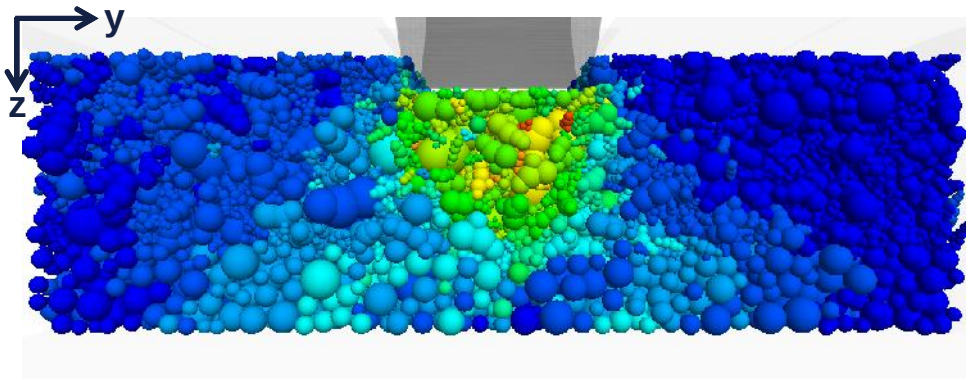
Moving wheel load simulation

- 10 wheel crossings (500 N, 0.5 m/s)
  - 5 kPa normal stress is applied on load walls during the test

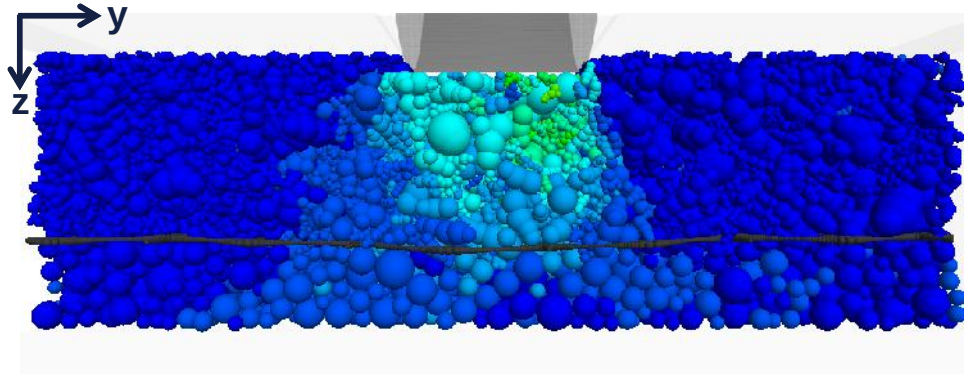


Y-Z displacements - cross section

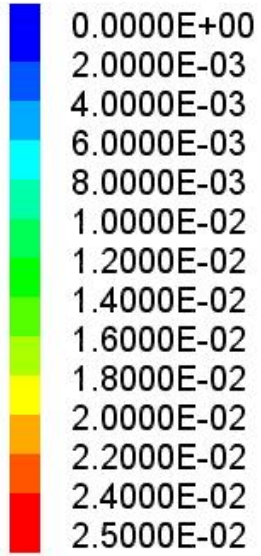
Comparing stabilised with non-stabilised section



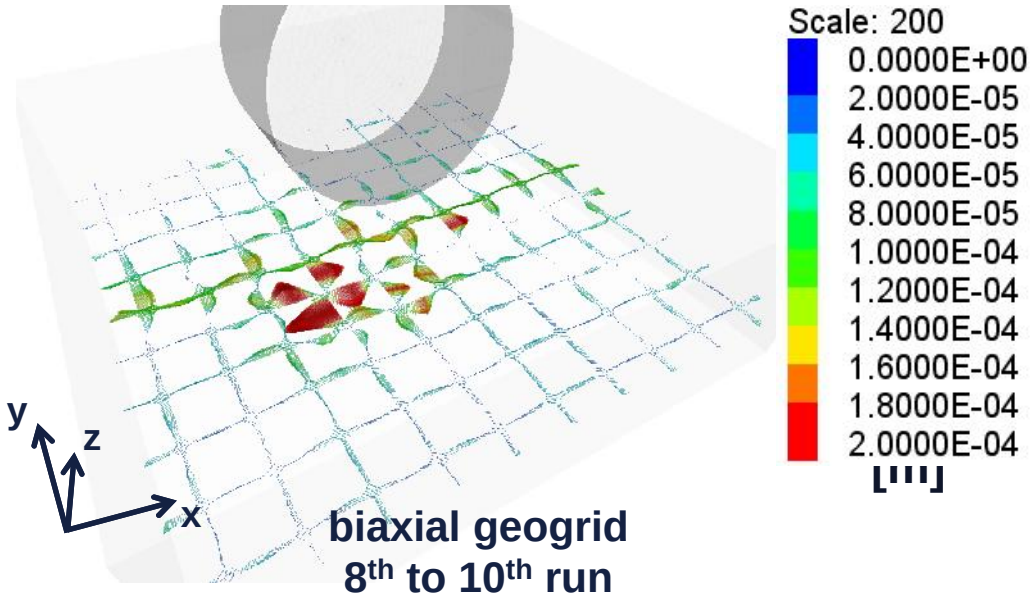
No grid - 9th run



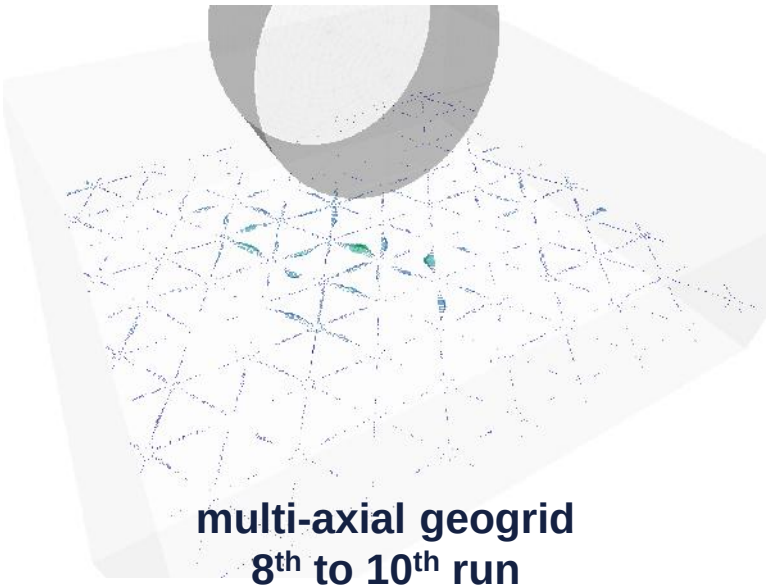
TX160 - 9th run



In-plane (XY) Displacement of The Geogrid

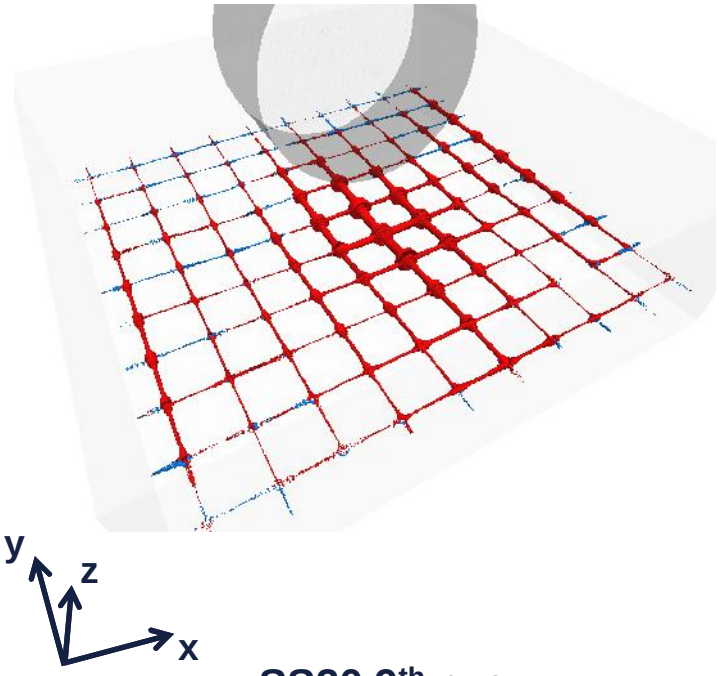


biaxial geogrid
8th to 10th run



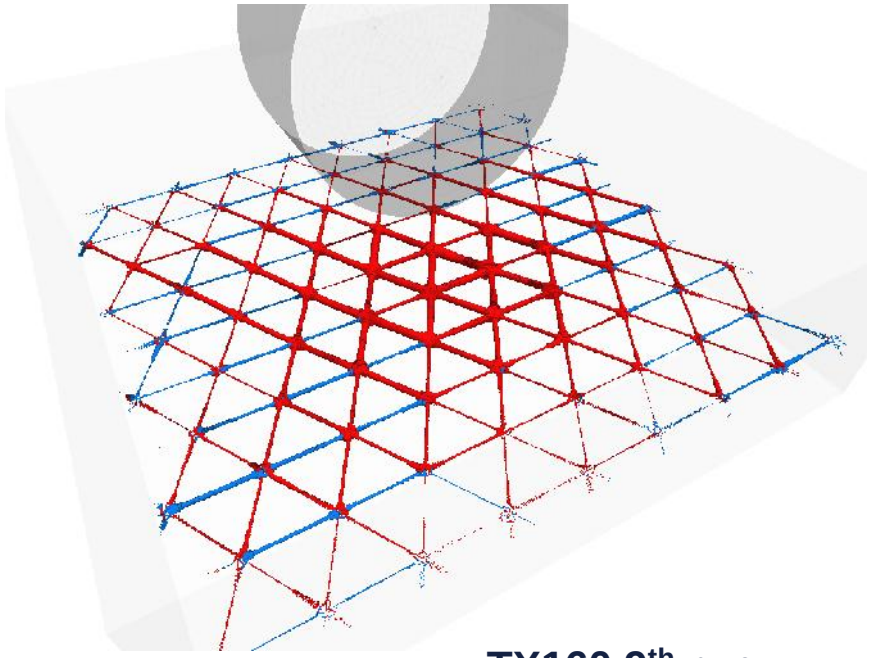
multi-axial geogrid
8th to 10th run

Forces in the Geogrid Under a Wheel Loading



SS20 9th run

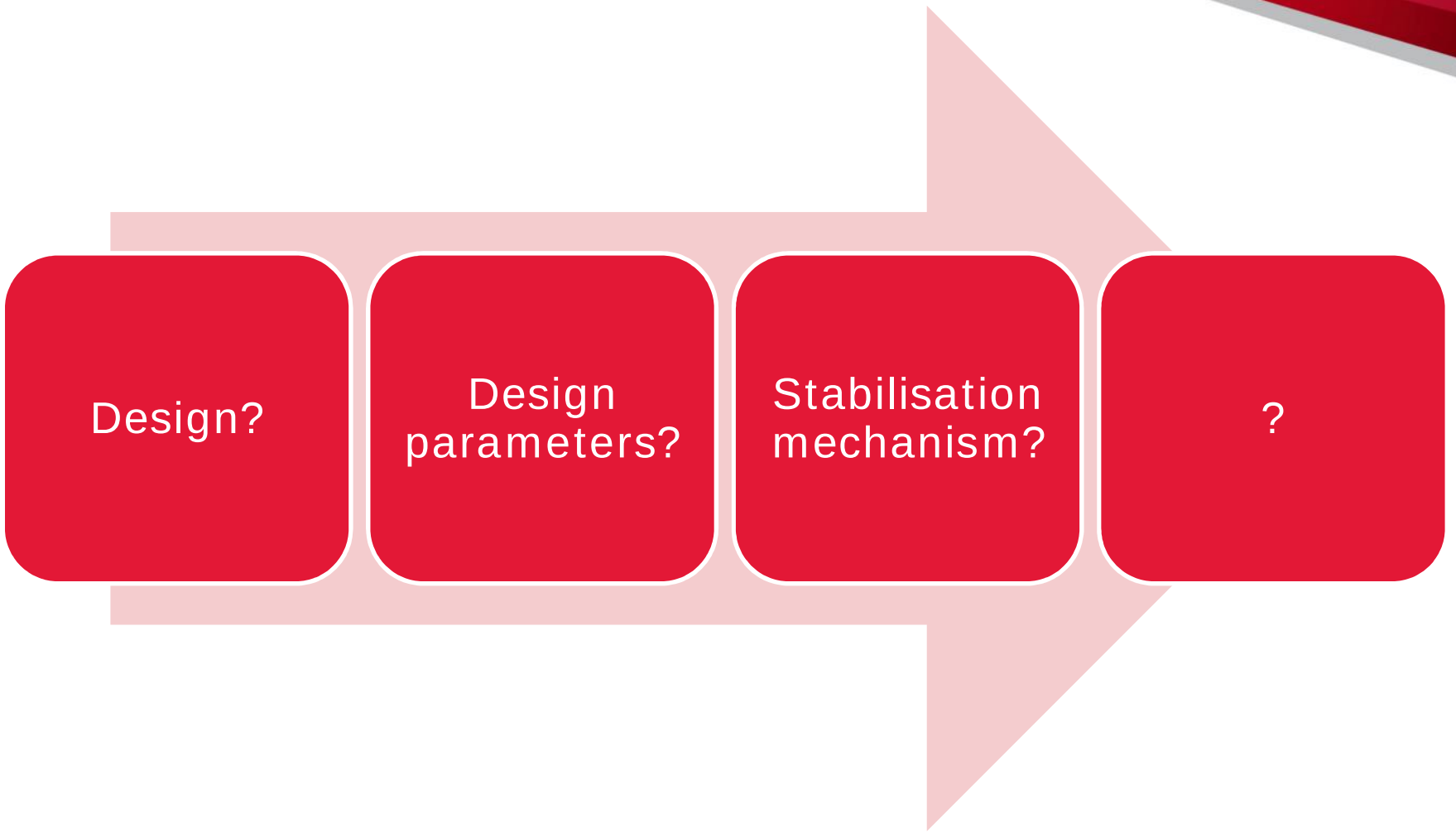
F_{max} = 0,49 kN/m



TX160 9th run

F_{max} = 0,27 kN/m

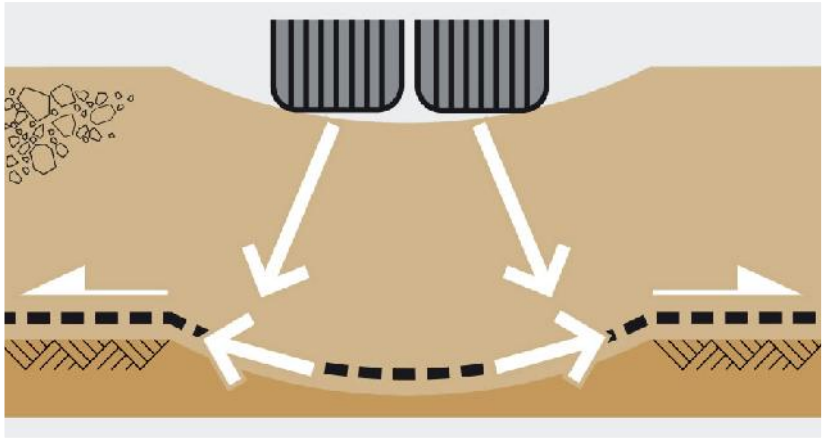
Compression
Tension



So how does stabilisation differ from reinforcement?

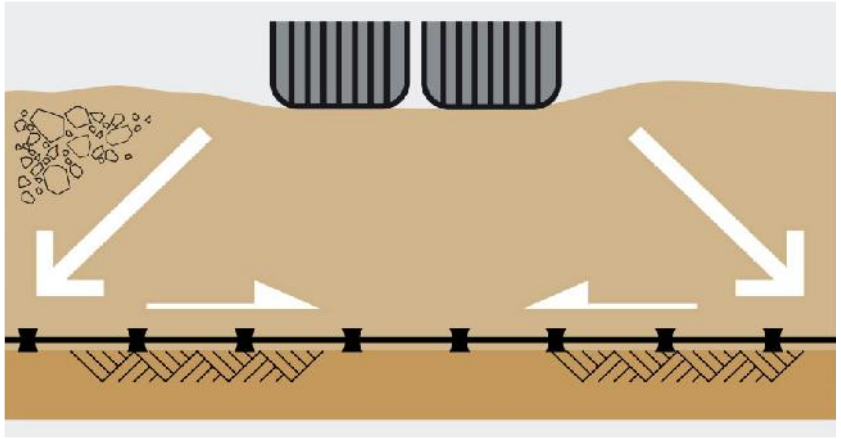
Stabilisation and Reinforcement Functions in Roadways

Reinforcement



Particle confinement not developed – geosynthetic acts as tensioned membrane

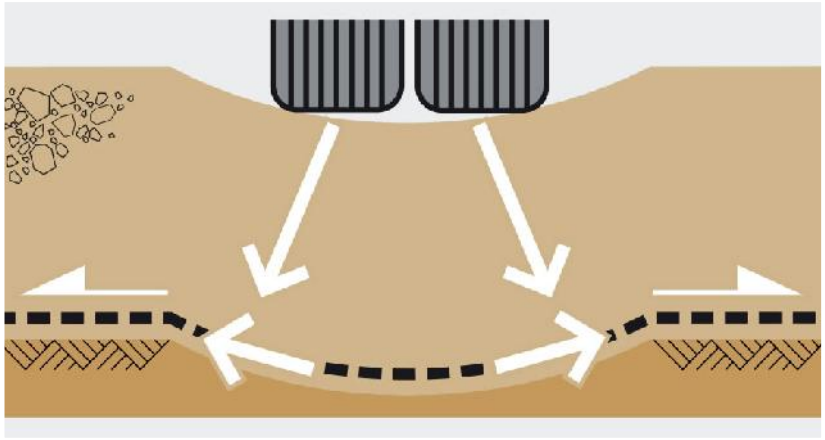
Stabilisation



Efficient particle confinement results in stabilisation

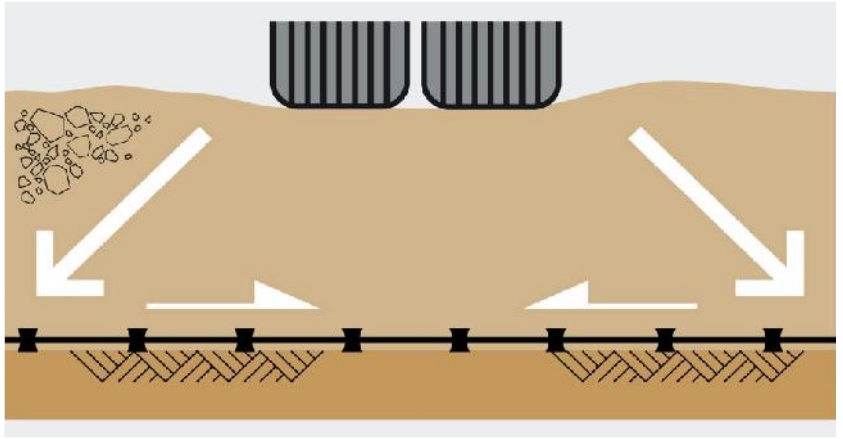
Stabilisation and Reinforcement Functions in Roadways

Reinforcement function



Incorporates a tensile element as a separate component in the system

Stabilisation function

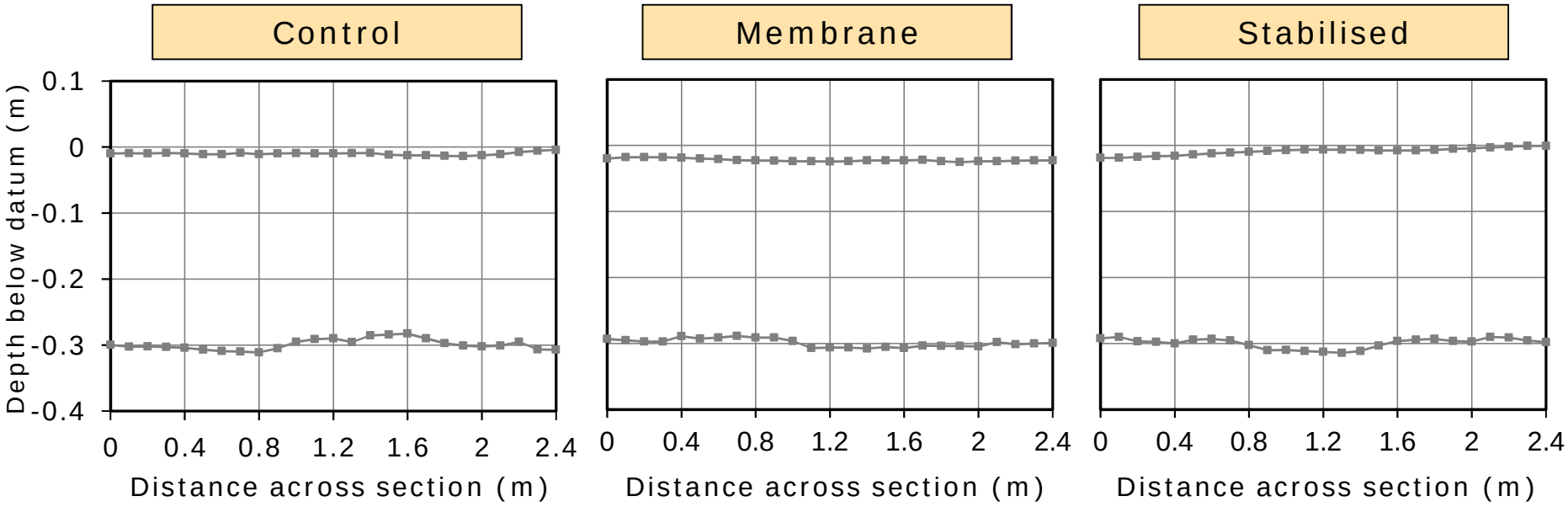


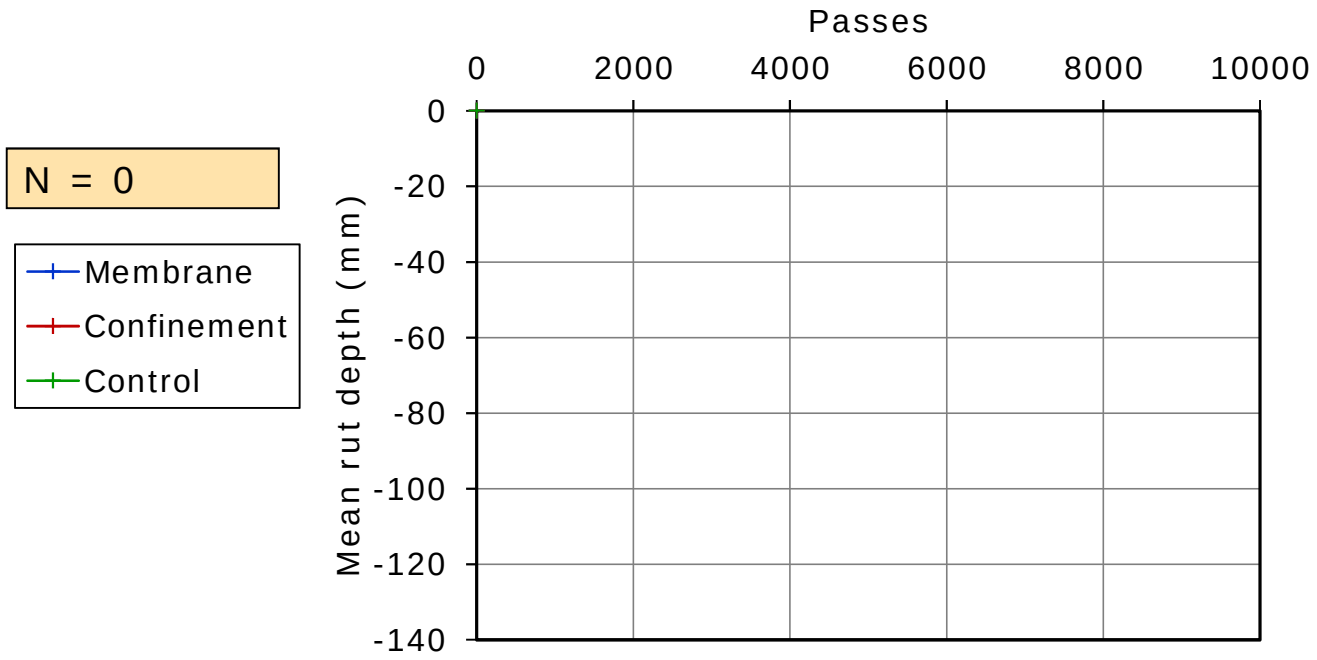
Changes behaviour of the granular layer to create a composite material

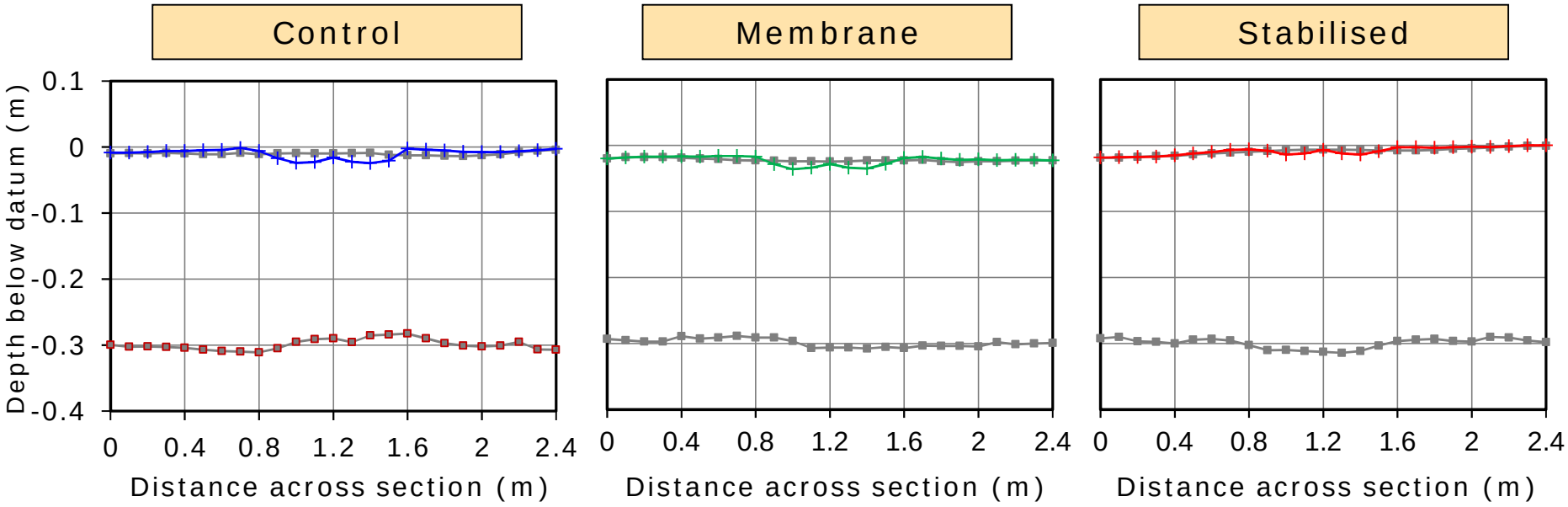
Trafficking Trials - UK Transport Research Laboratory

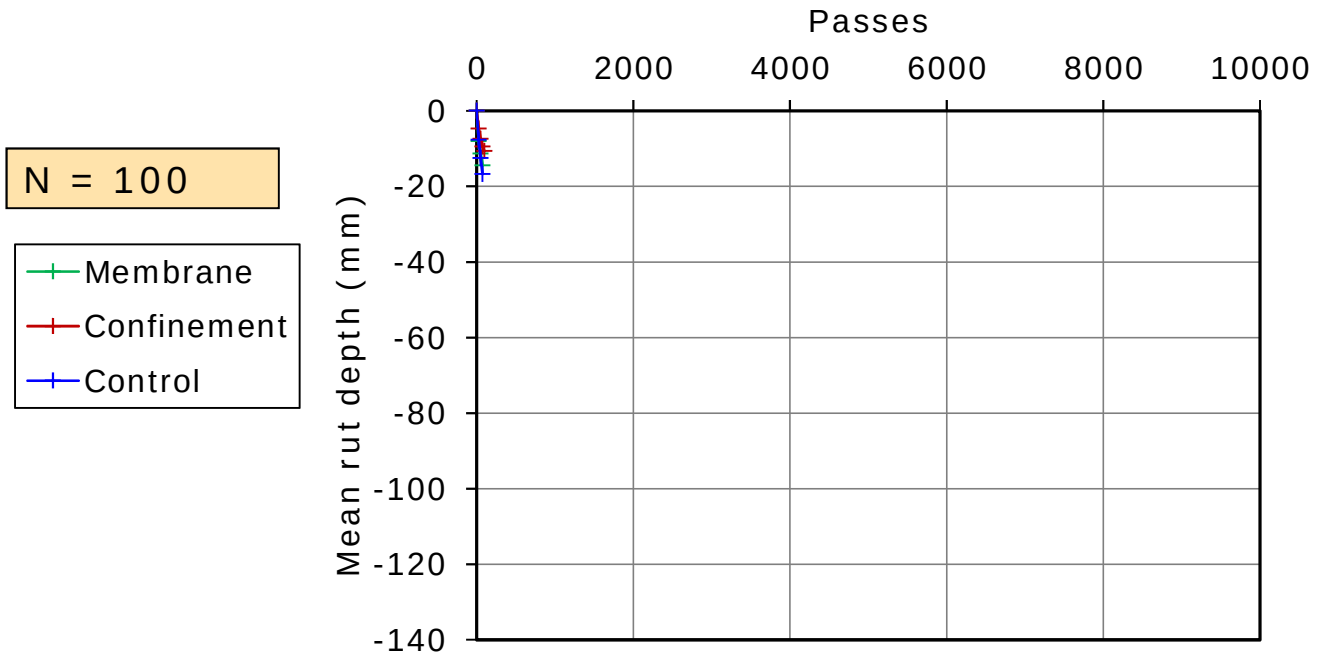
- Soft subgrade approx. 2% CBR
- 40kN wheel (equal to 1 ESAL)

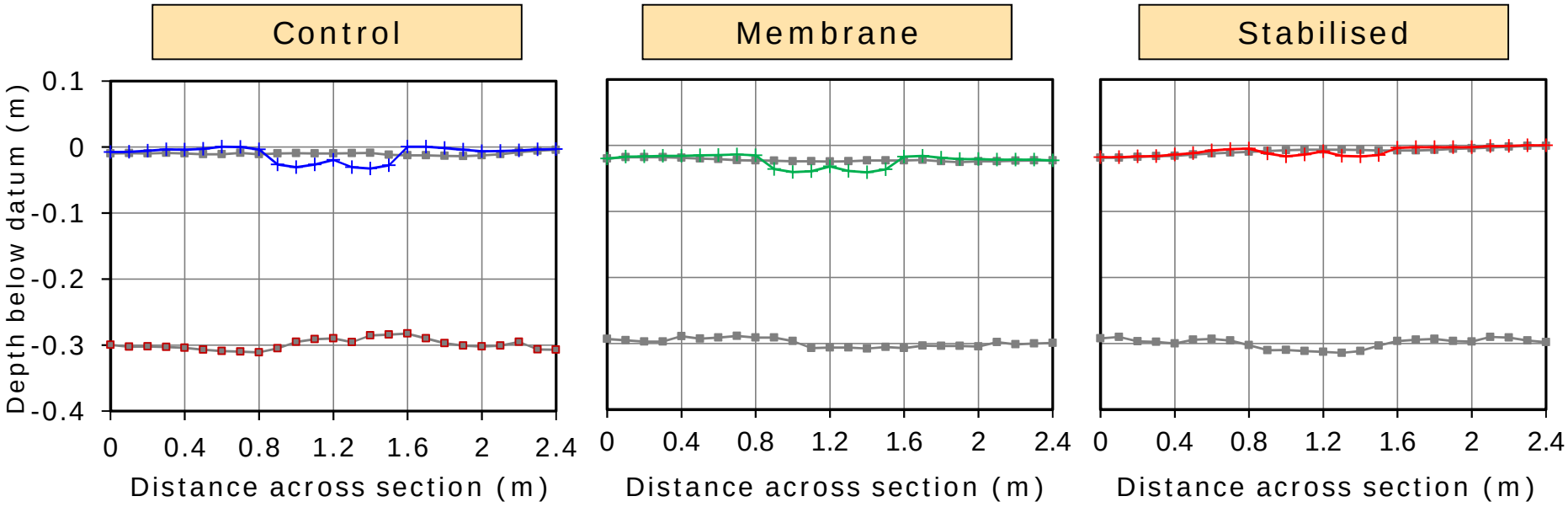
Jenner, Watts & Blackman (2002)

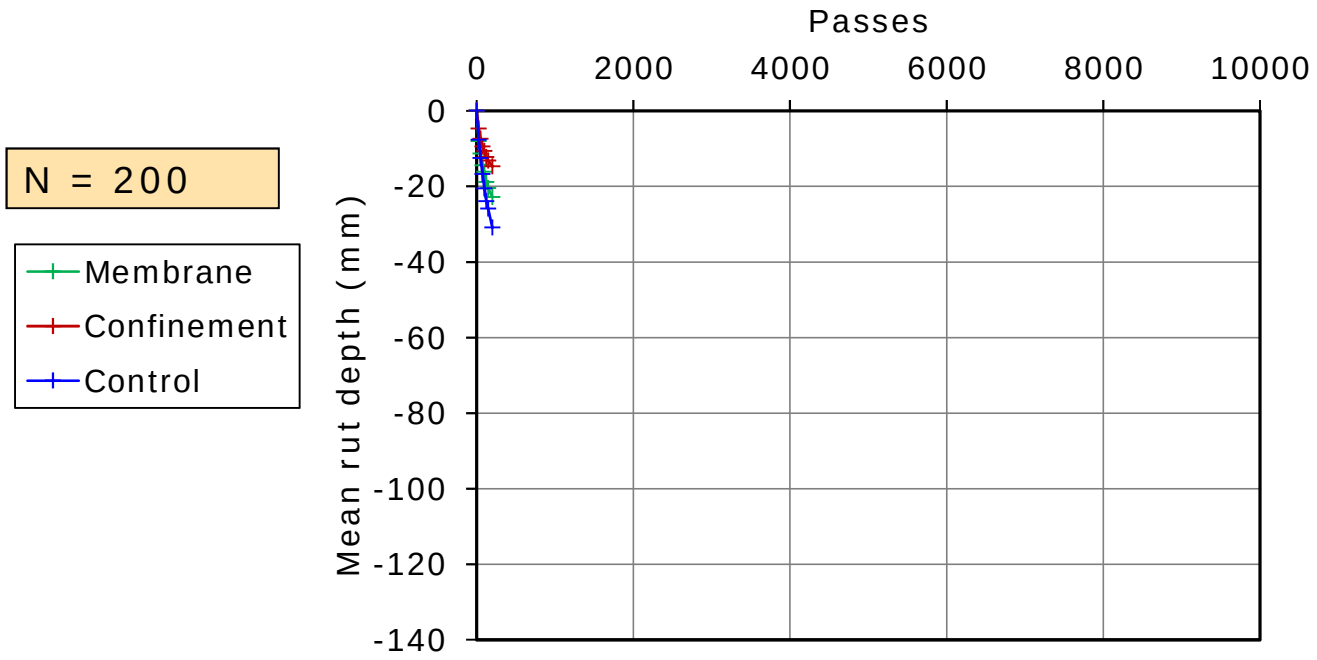


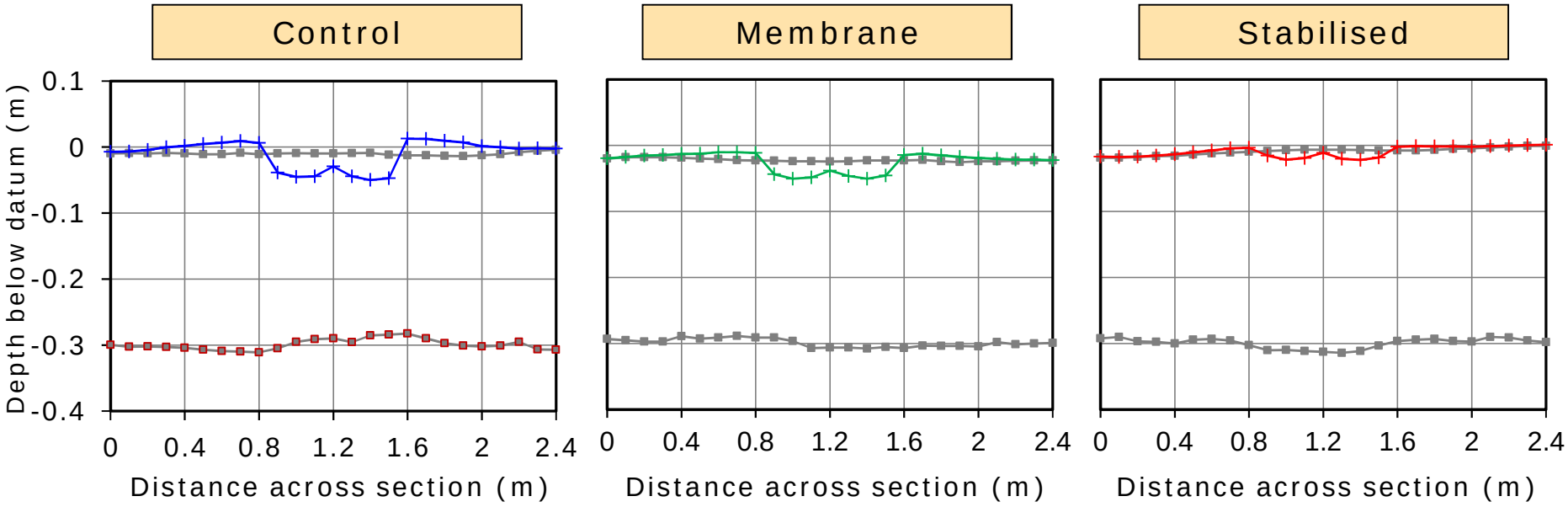


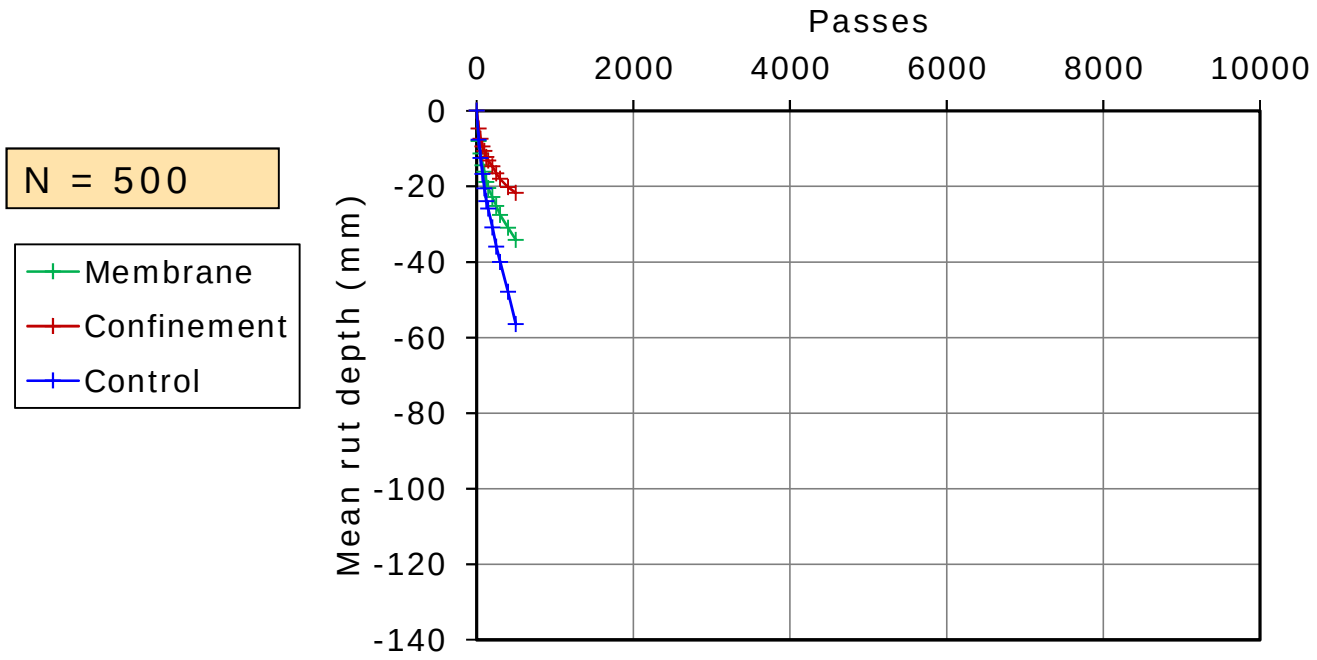


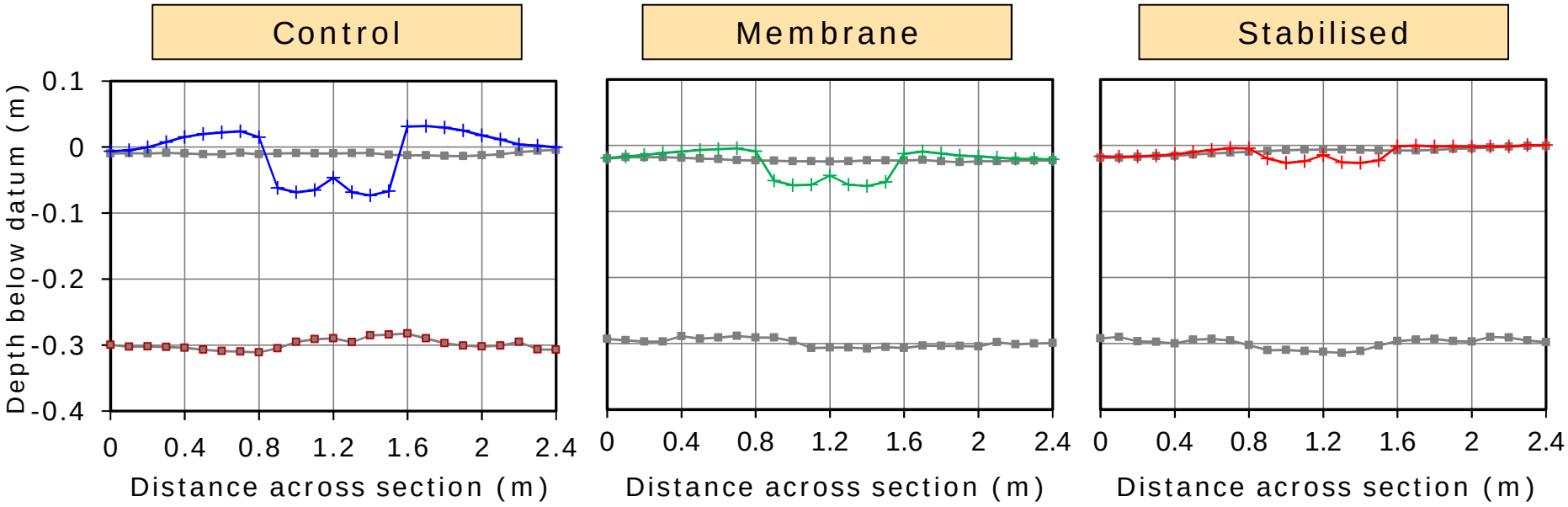


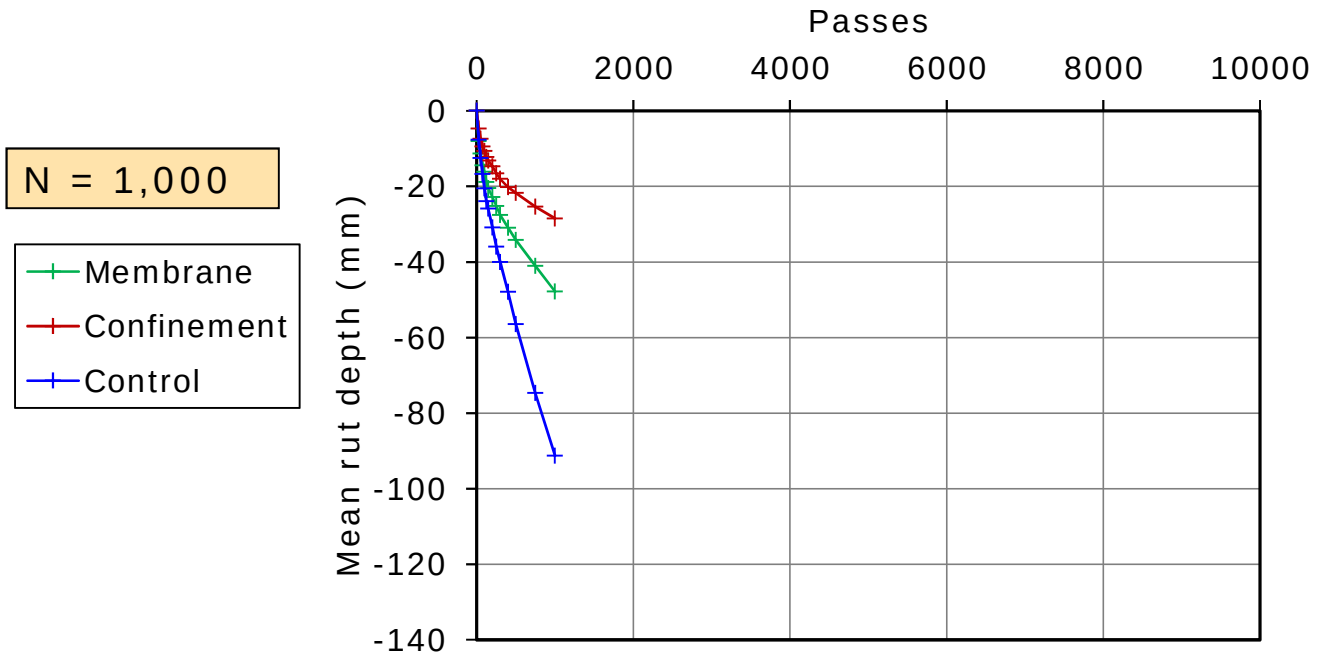


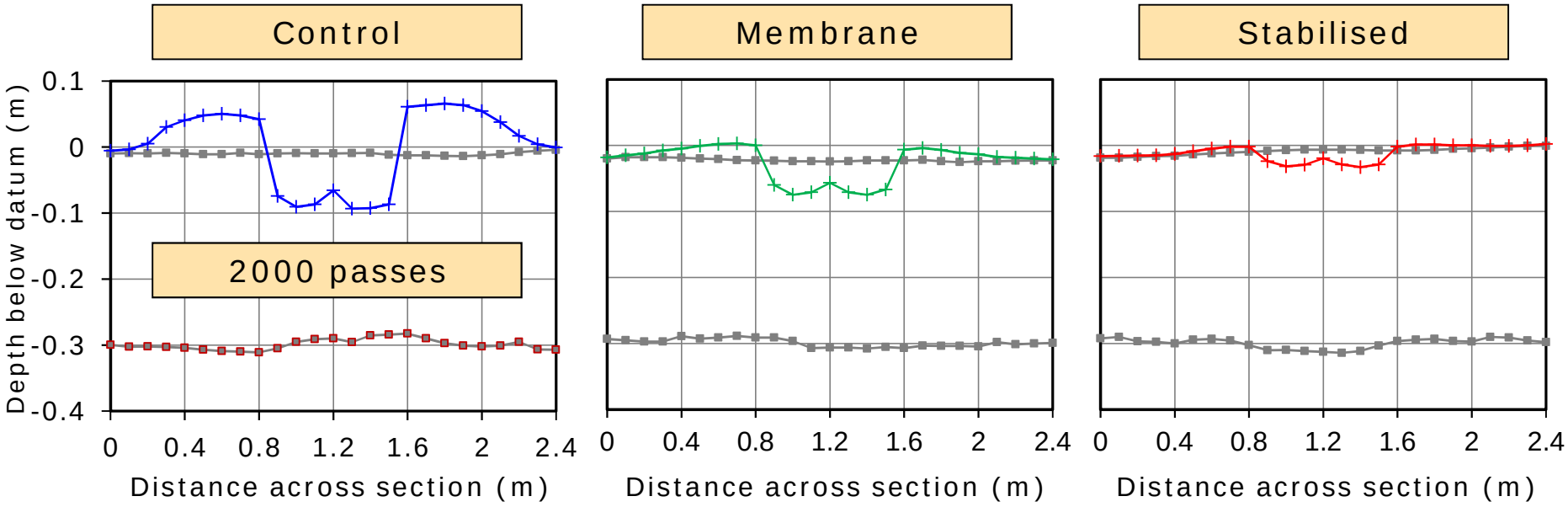


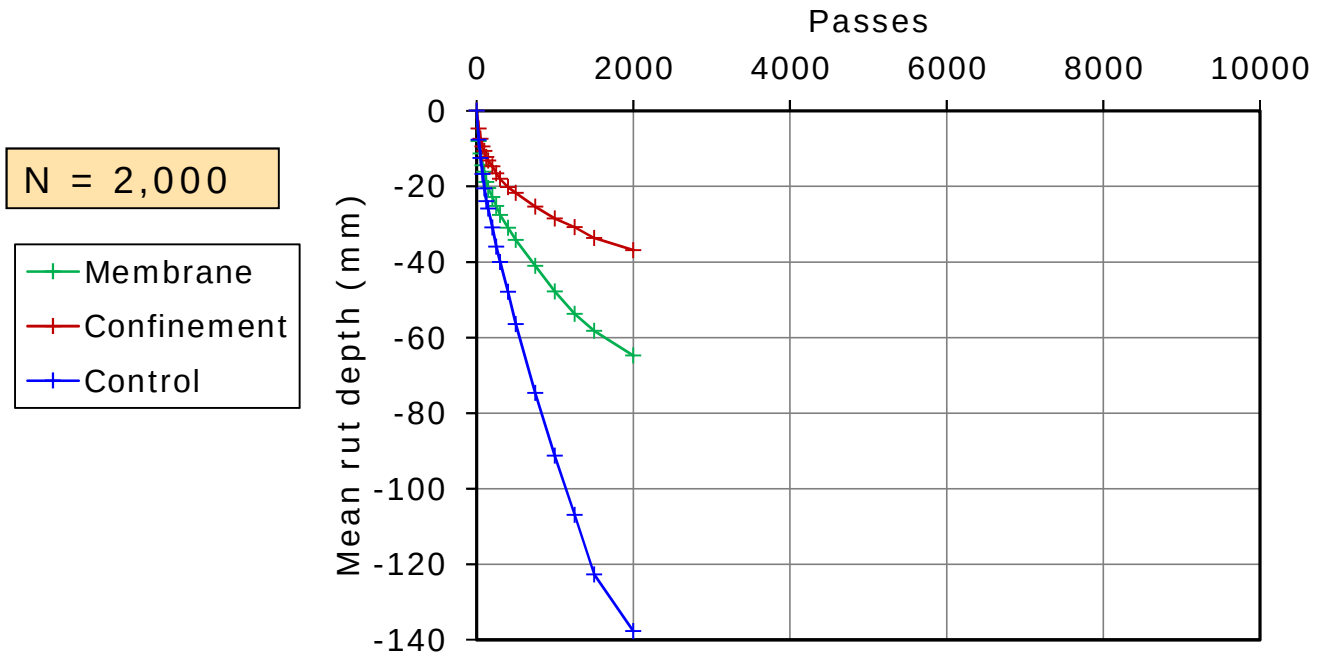


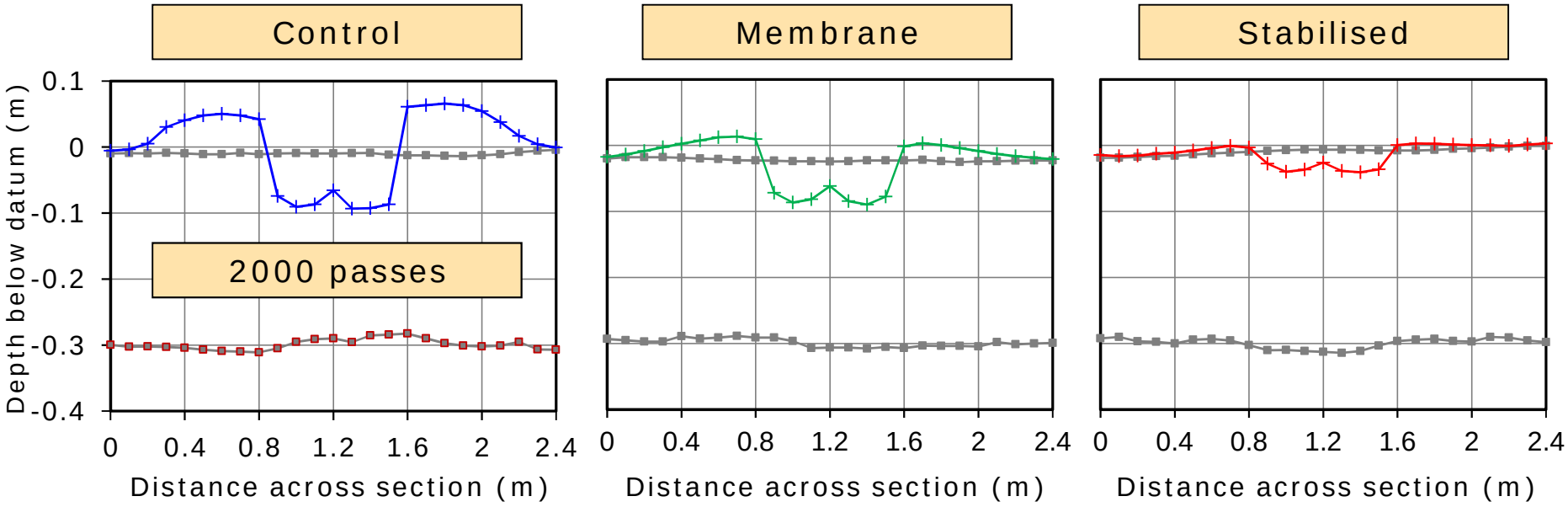


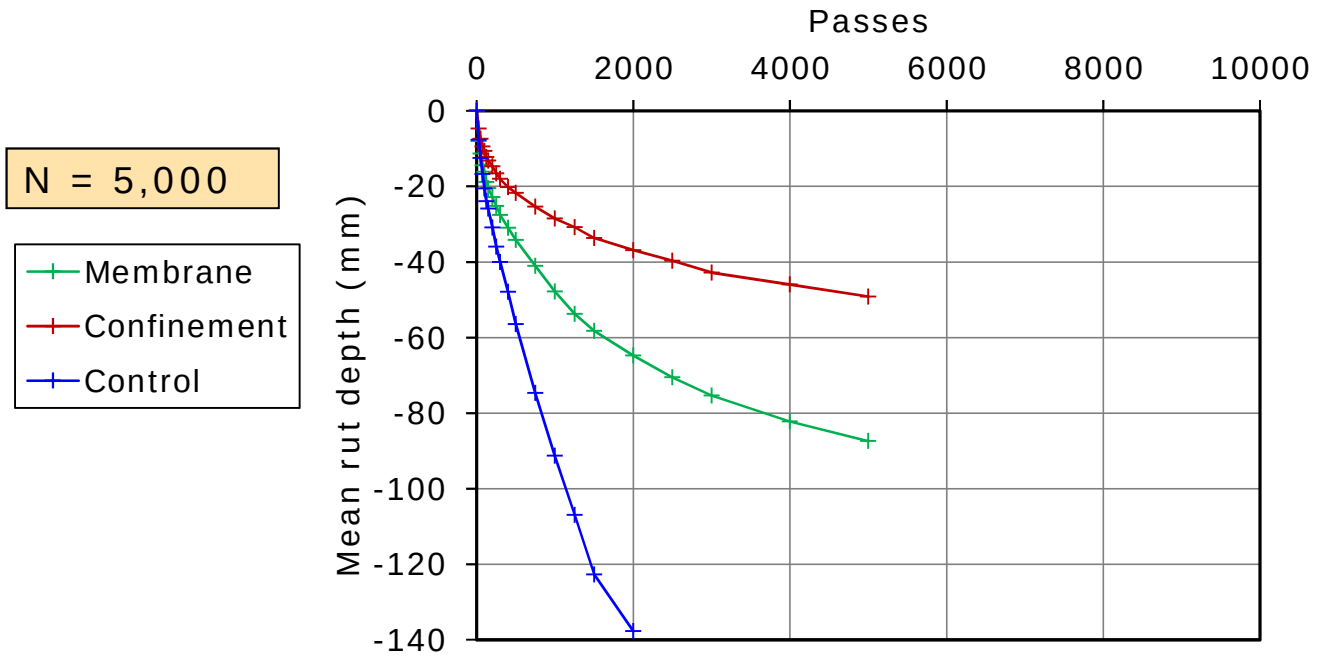


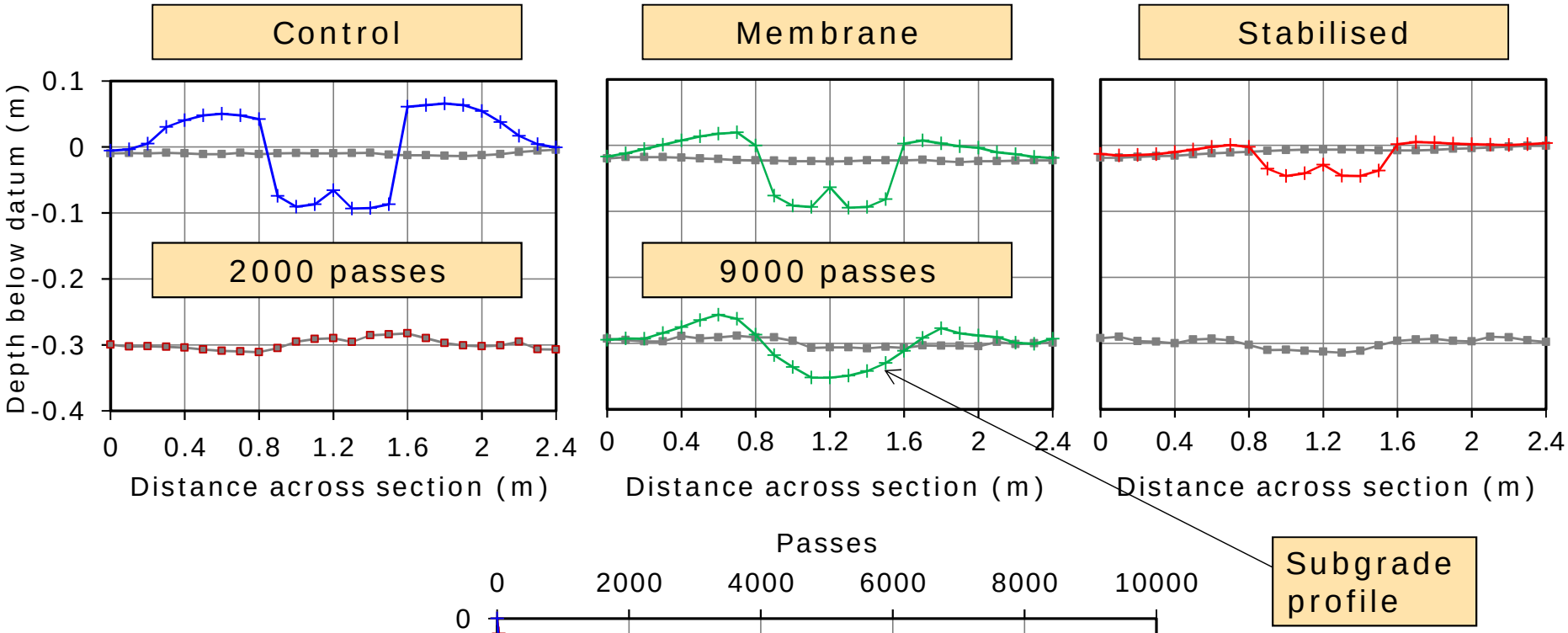


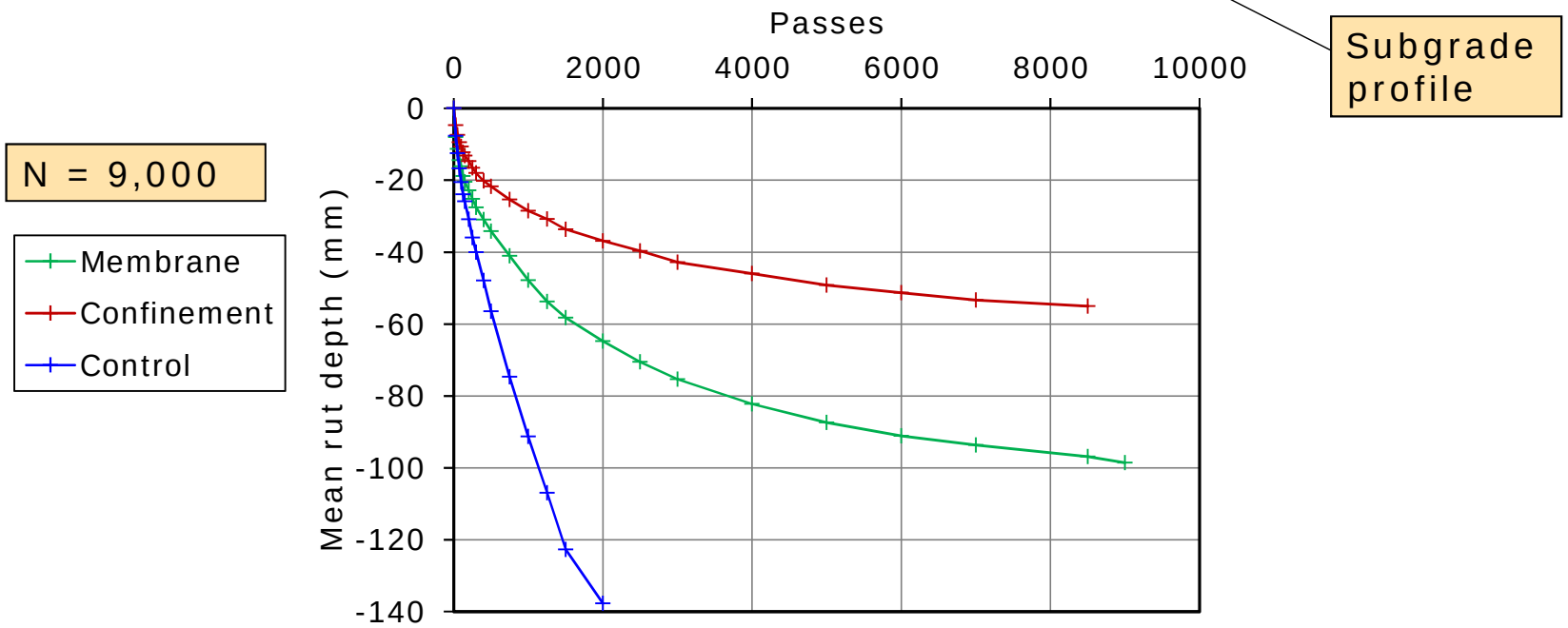


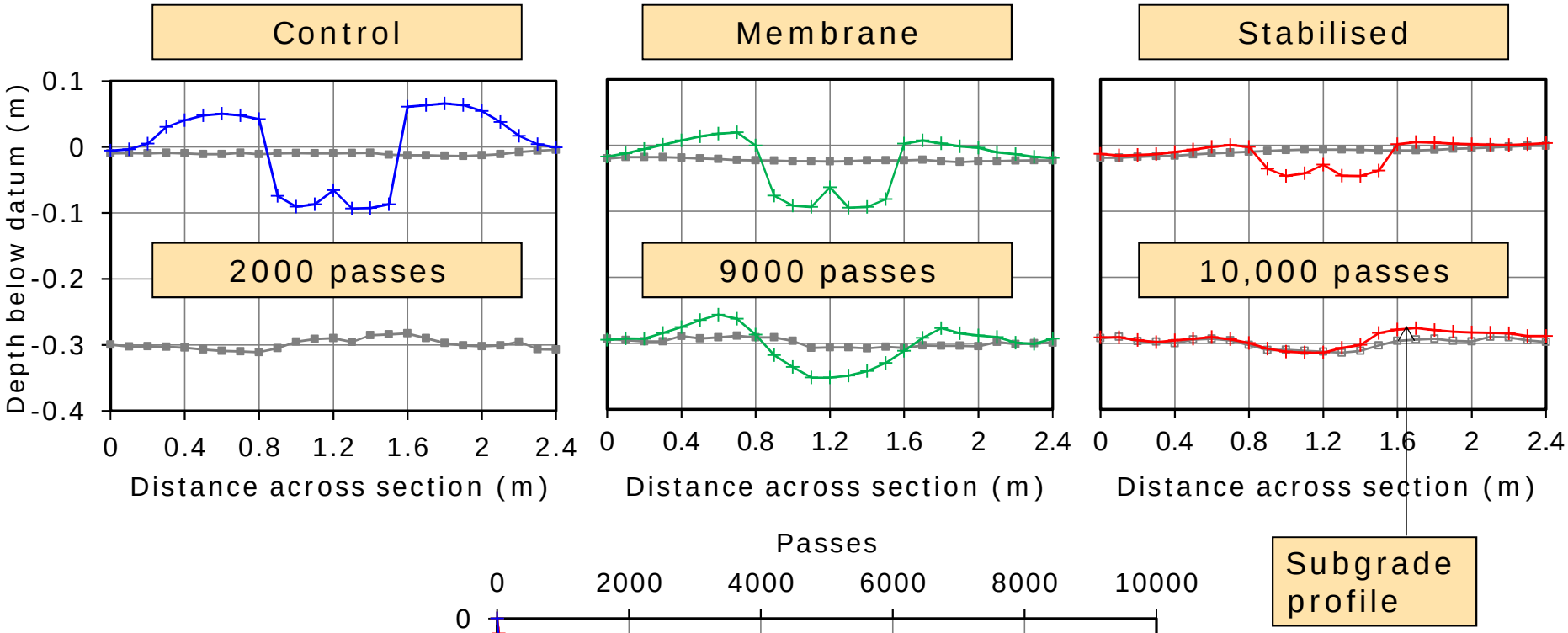


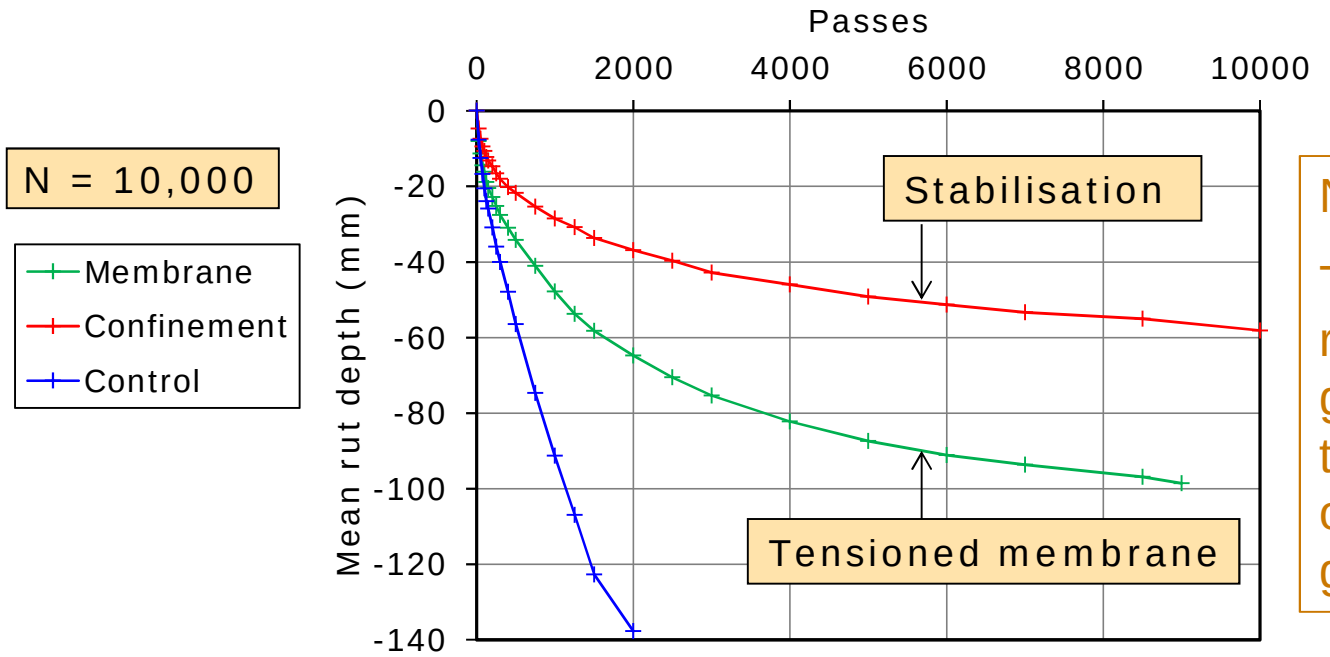








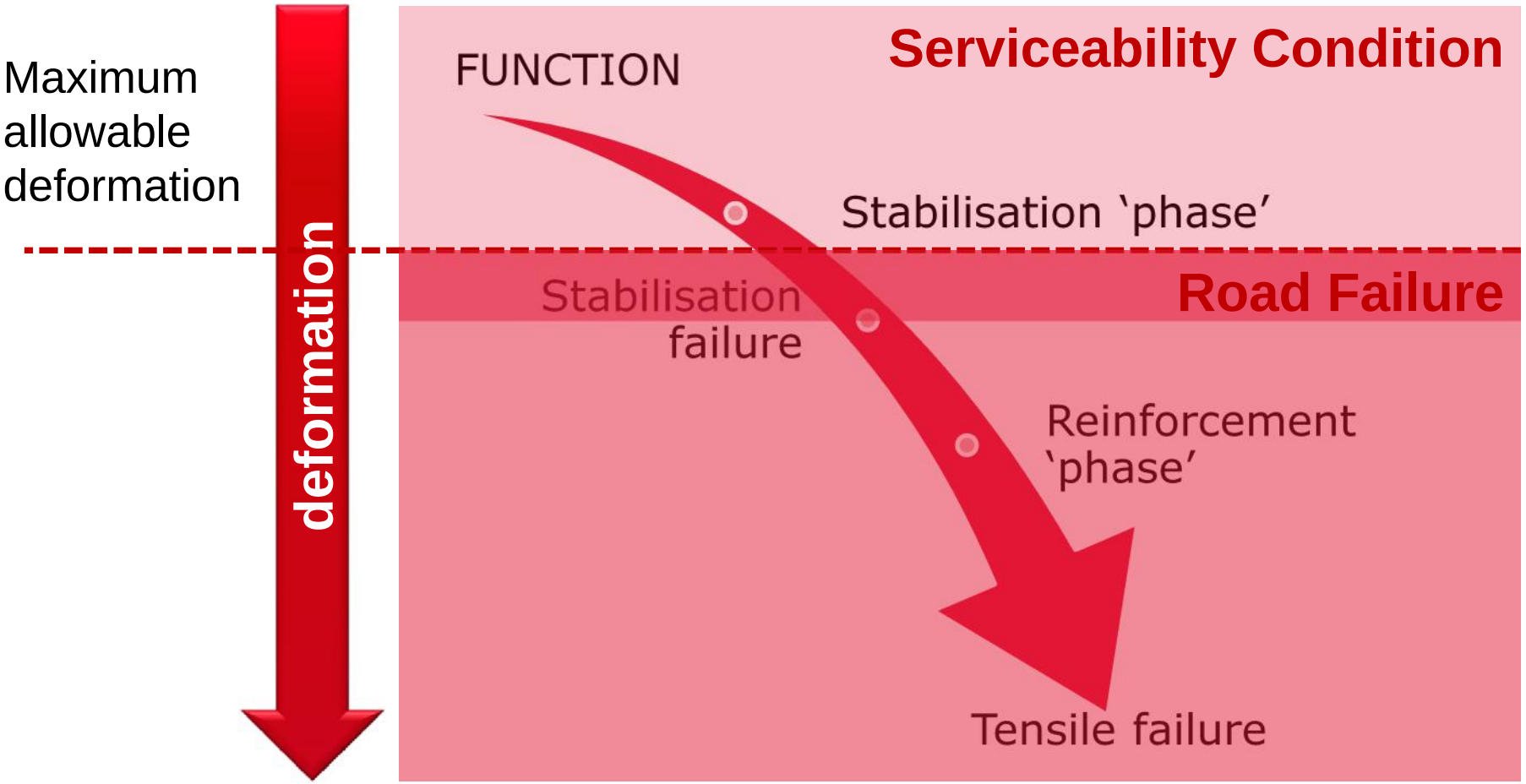


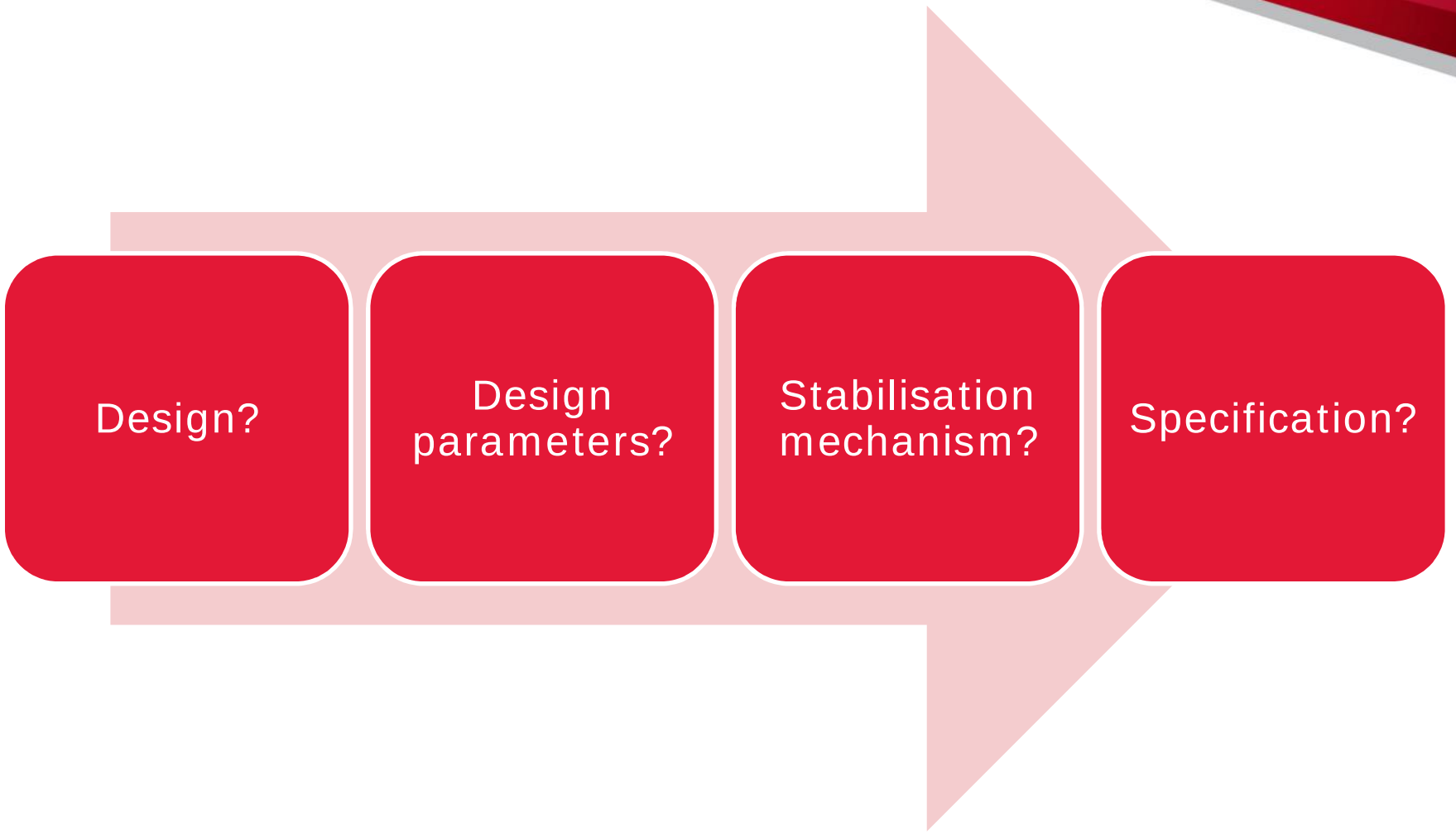


Note:

The membrane reinforcement geosynthetic has twice the strength of the stabilization geosynthetic

The stabilisation ‘phase’ reinforcement ‘phase’ hypothesis





Can we specify stabilisation?

OK – so stabilization is a real function and different from the reinforcement function

But a geogrid is a geogrid - why should I have to change the way I specify geogrids?

The purpose of a specification

- A specification must protect the design
- If certain performance characteristics have ben assumed in the design, the specification must protect these assumptions

Specifying for stabilisation

- For permanent roads, surface deformations are critical
- Pavement design seeks to control surface deformation
- Correctly designed mechanically stabilised roads have reduced deformations.
- We are not interested in the effect of the geogrid at high strains – At high surface deformations THE ROAD WILL ALREADY HAVE FAILED.
- We need to specify to ensure that a stabilisation function is provided and performance assumptions in the design are met.
- We should be specifying performance of the stabilised layer

Performance specification?

Public Sector Procurement and EU Law

Article 41 of the Public Contracts Directive (2014/24/EU)

- This dictates how technical specifications should be developed for
  - Works
  - Services
  - Supplies

- Implementation into national legislation of each Member state was 18th April 2016

Included within the key principles

Article 42 allows the Contracting Authority to set out specification requirements by reference to:

- Performance or Functional requirements
- European or other technical specifications (in a specific order)
- A combination of both

Order of acceptable technical specifications

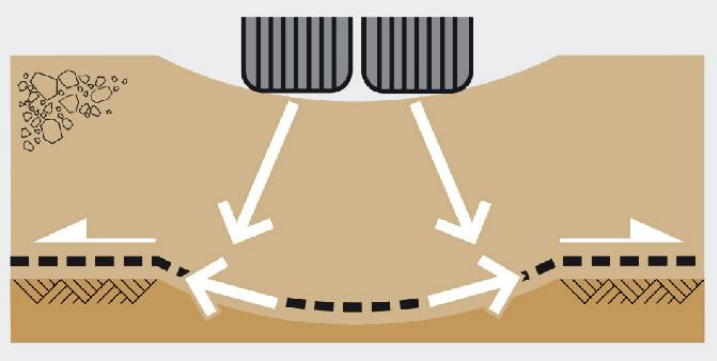
- Harmonised Standards (CEN)
- ETA
- International standards (ISO etc.)
- Other technical references established by European standardisation bodies
- National standards
- National technical approvals or specifications

So performance can be specified

Or use technical specifications where they exist:

- Harmonised Standard,
- ETA etc.

Do the Harmonised Standards help for specification of stabilisation function?



EN 13249

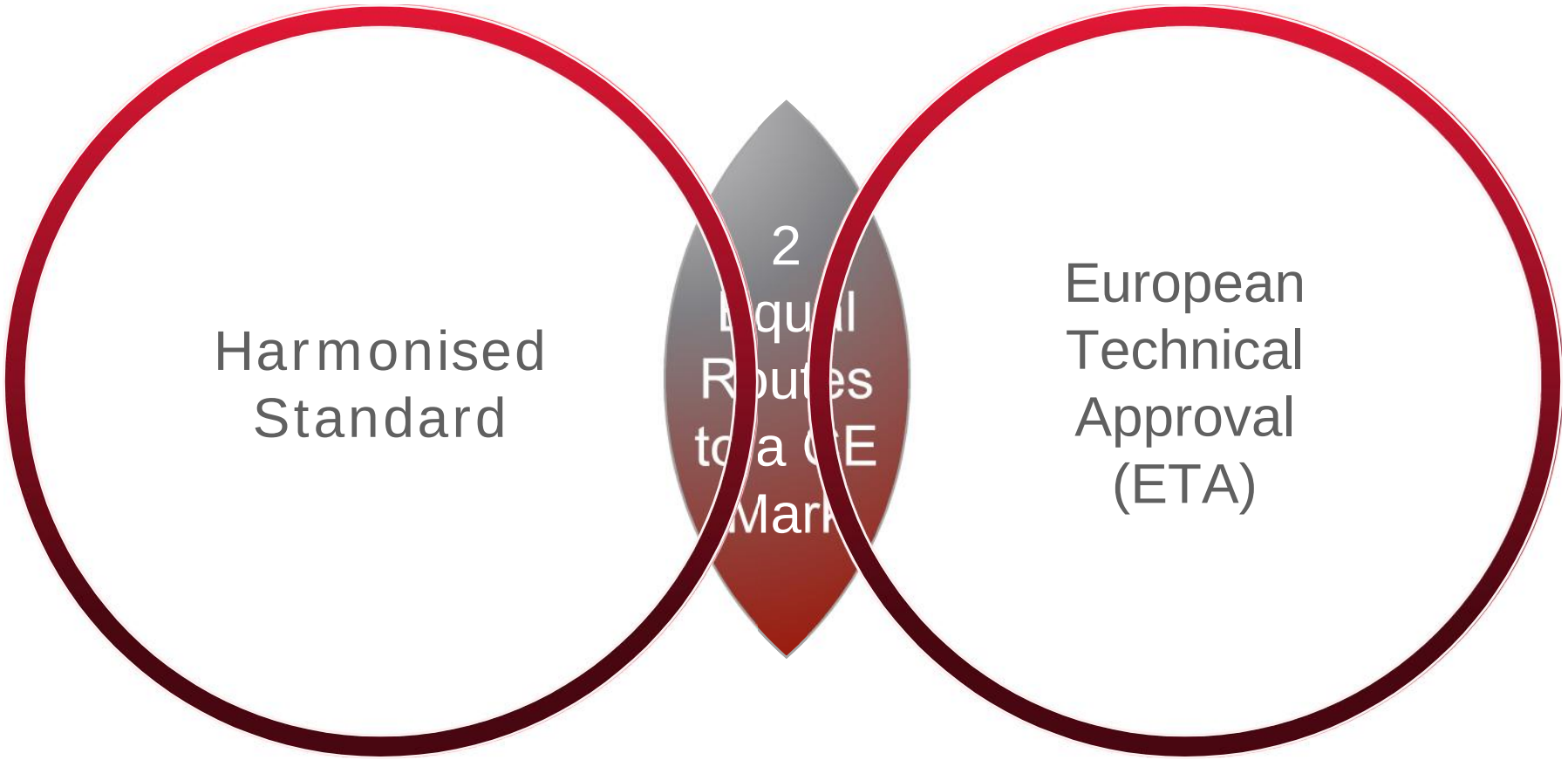
Geosynthetics for Roads and Trafficked Areas

EN 13249 lists the following functions of geosynthetics:

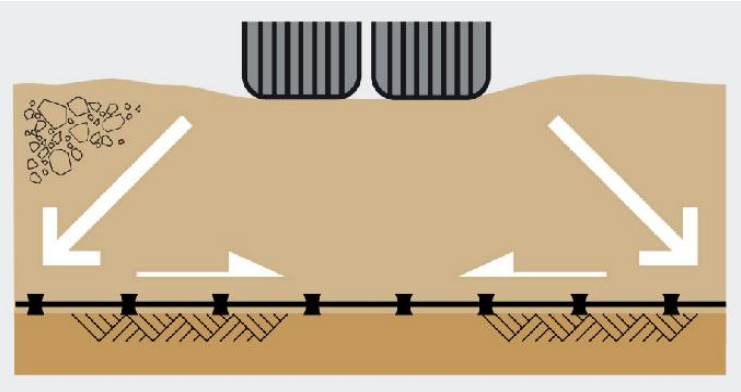
- Separation
- Filtration
- Reinforcement

	Essential Reinforcement Characteristics	Requirement Clauses in this European Standard	Units
1	Tensile Strength	4.1, Table 1(1) and 5.1	kN/m
2	Elongation	4.1, Table 1 (2) and 5.1	%

Two routes to CE Marking



ETA for stabilisation?



ETA

for Hexagonal Geogrid Stabilisation of Unbound Layers

No.	Product Characteristic	Method of Testing	Unit or Characteristic
1	Radial Secant Stiffness at 0.5% strain	TR 041 B.1	kN/m
2	Radial Secant Stiffness Ratio	TR 041 B.1	-
3	Junction Efficiency	TR 041 B.2	%
4	Hexagonal Pitch	TR 041 B.4	mm

Giroud - describing geosynthetic mechanisms 10 years ago

JP Giroud (2006)

"Functions of Geosynthetics in Road Applications"

The only mechanism of reinforcement that is effective in paved roads is the load distribution improvement that results from lateral restraint because this mechanism works with small deformation.

Lateral restrain = mechanical stabilisation

Summary

- **Stabilisation function is different to the reinforcement function**
- **There are real economic benefits to be gained from correct use of mechanical stabilization in permanent roads**
- **Proven design methods exist based upon performance – We should specify performance**

Thank you

Tensar®