# Good practice in constructing reinforced soil structures using granular, site-won and other non-'standard' reinforced fills

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Chief Civil Engineer

(Immediate Past-Chair of International Geosynthetics Society UK Chapter)

# Outine

- A brief historic overview
- Important considerations & Lessons learned
- Types of reinforced soil fills & case studies
- Conclusions

rian Mercer demonstrating the properties of Netlon to Salvador Dali

Soil Mechanics

# Geogrid origin

Frank Brian Mercer OBE (1927 – 1998)

'Father' of Geogrids

Portrait of Brian Mercer by Salvador Dali

- Extruded, non-orientated mesh/net was utilised succesfully in Japan in 1970s for ground stabilisation (Narita Tokyo International Airport 1978)

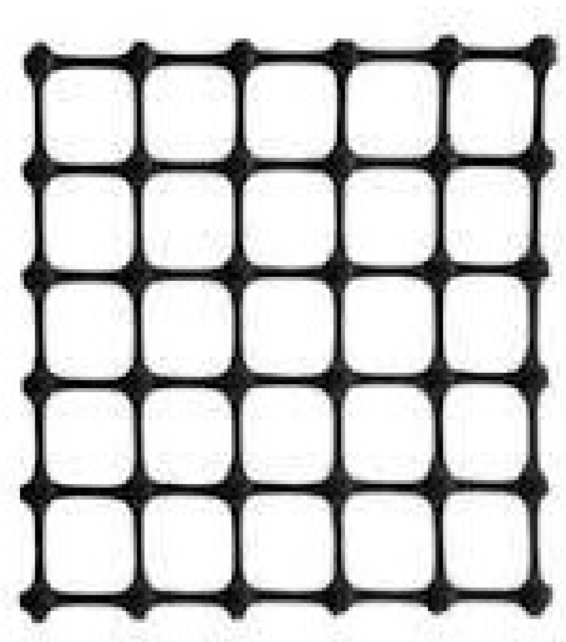

The World of Netlon 1978

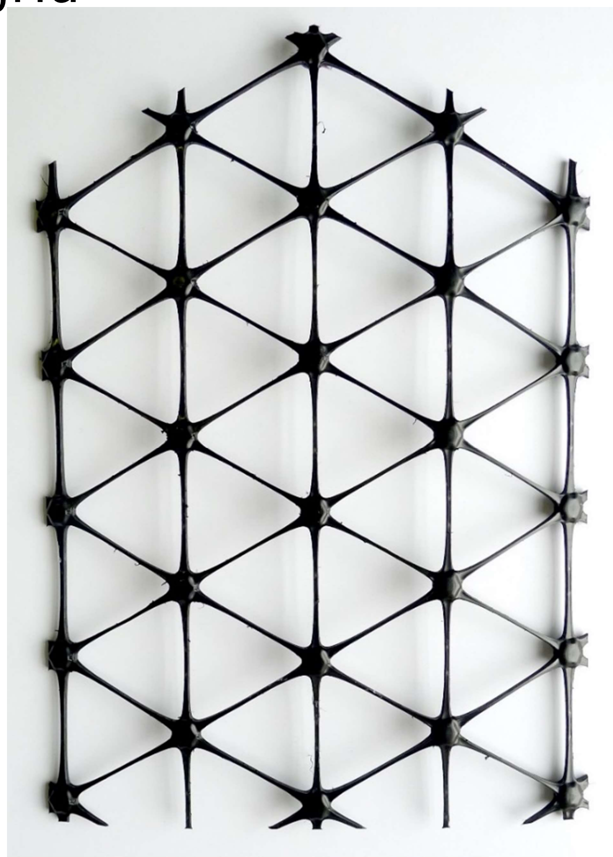

Sample
NETLON CE131


The World of Netlon 1978

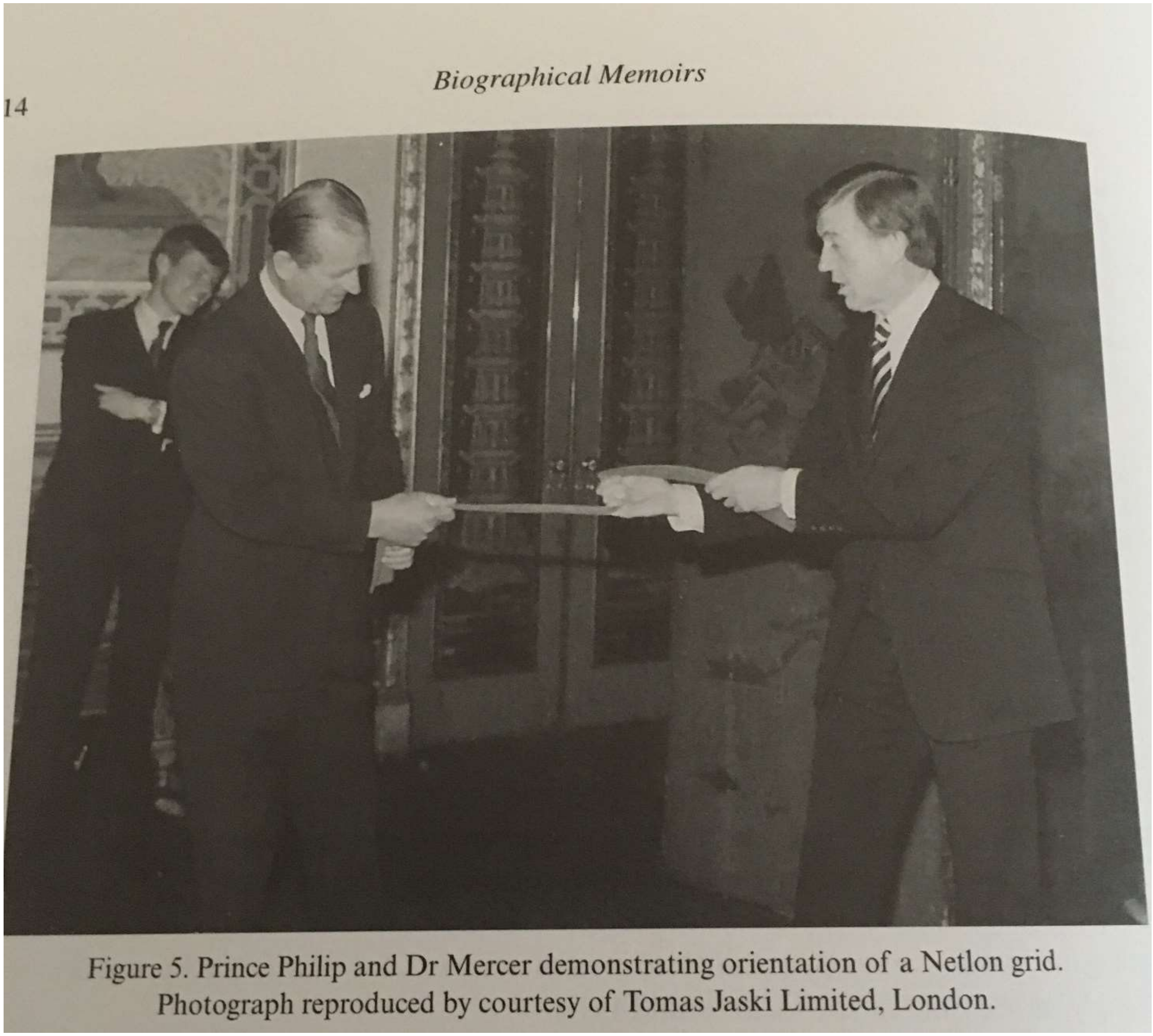
# Historic Background of Geogrids

- In 1978 he invented the 'Tensar' process (extruded, punched and stretched) and in 1980 first engineered 'plastic meshes' were made available to Civil Engineers
- Prof Peter Wroth (Cambridge, 1982): 'geogrid'





# Historic Background of Geogrids



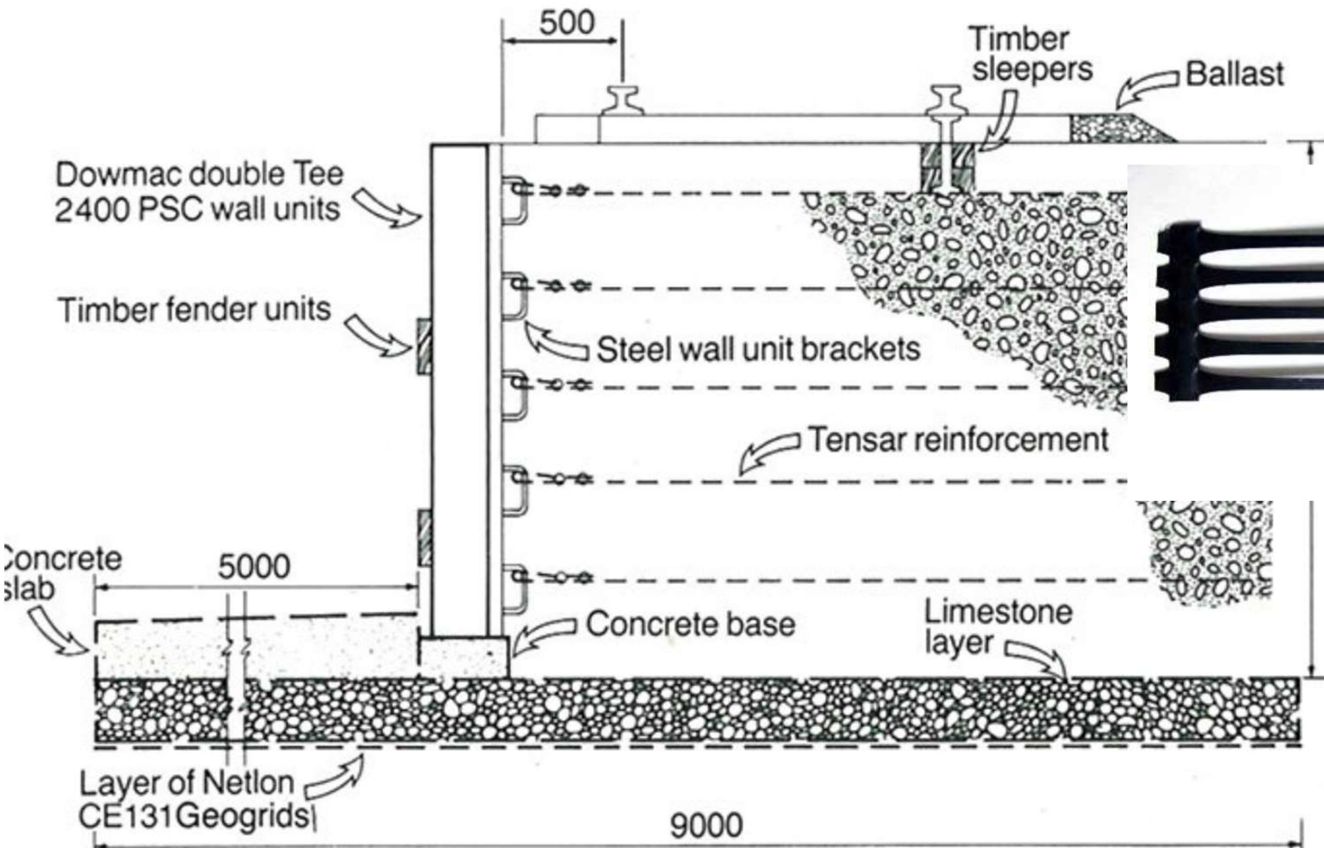
14 *Biographical Memoirs*

Figure 5. Prince Philip and Dr Mercer demonstrating orientation of a Netlon grid. Photograph reproduced by courtesy of Tomas Jaski Limited, London.

- Great invention! By Royal appointment…
- But how did an unknown entrepreneur form Blackburn, UK, convince our conservative Industry Globally to trust plastic in construction?
- With the support of visionaries like…

Tensar

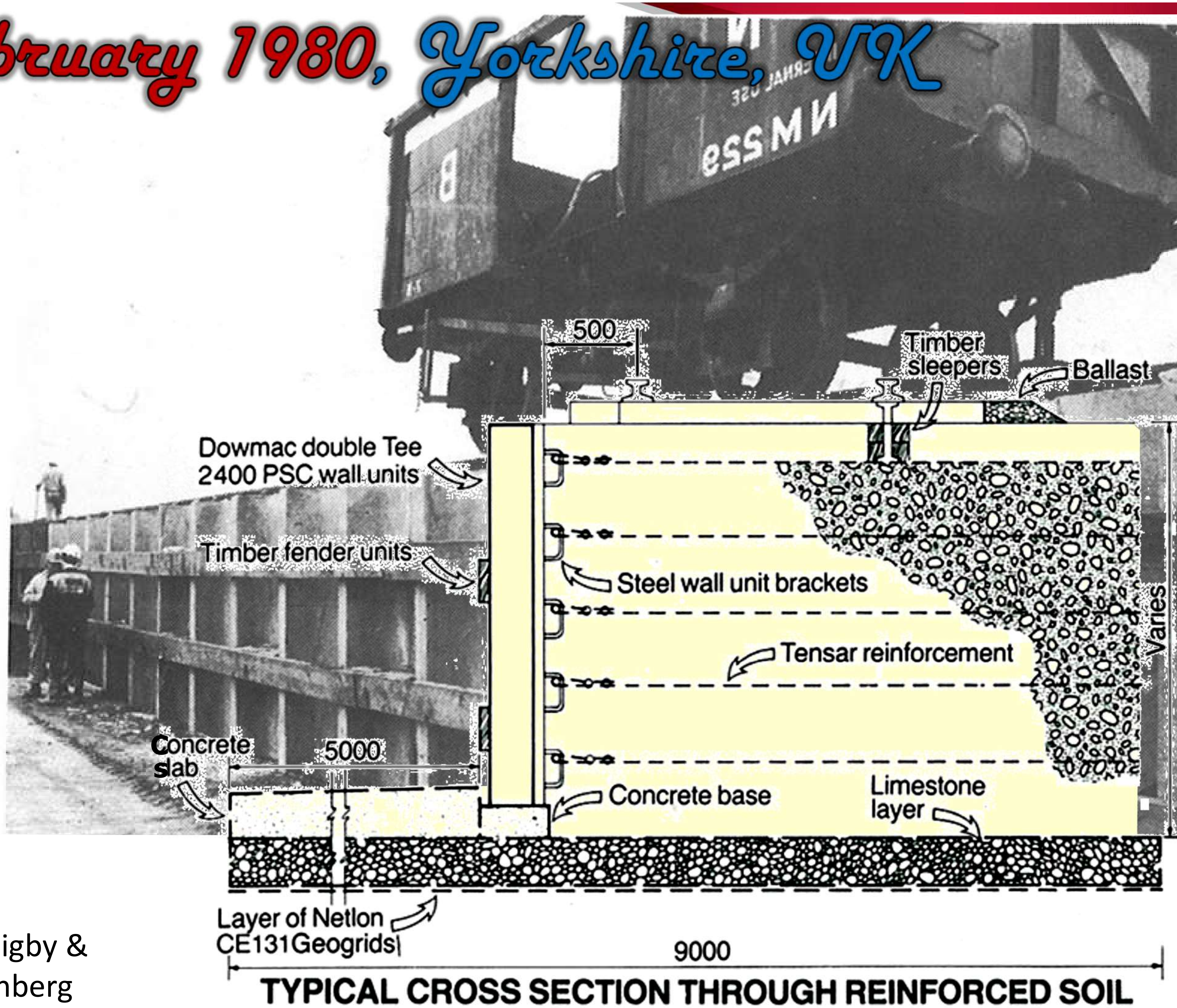
# First Polymeric Reinforced Soil Wall




TYPICAL CROSS SECTION THROUGH REINFORCED SOIL

- *February 1980 - Newmarket Silkstone Colliery, Yorkshire – reinforced fill was unburnt shale*

# February 1980, Yorkshire, UK

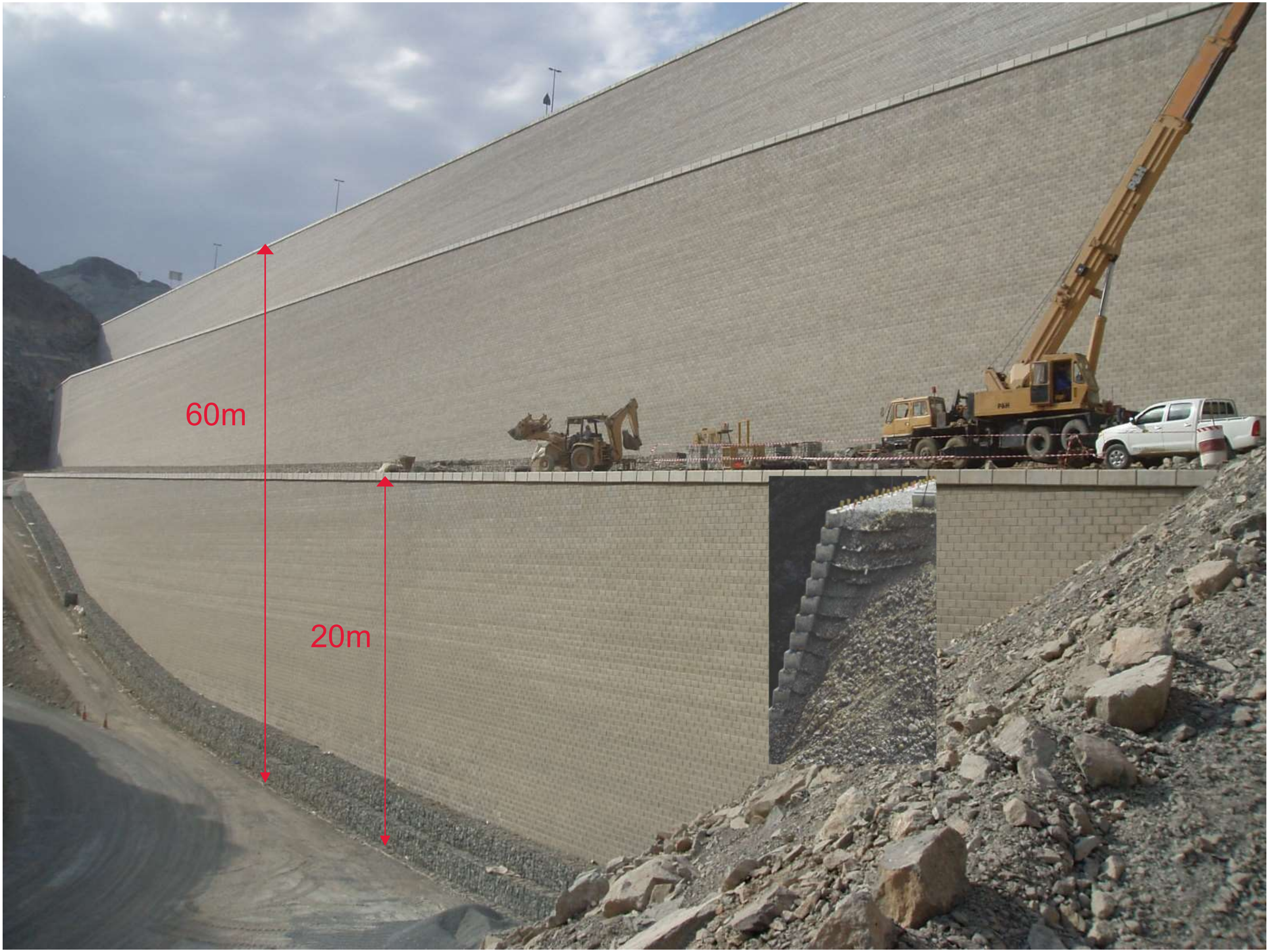



Doulala-Rigby &
Jorge Zornberg

# First Polymeric Reinforced Soil Wall

Tomorrows World


- *February 1980 - Newmarket Silkstone Colliery, Yorkshire – reinforced fill was unburnt shale*


60m
20m

# Our Global Reach

*Offices*


**16** Offices

**600+** Employees

## Our Global Reach

*Manufacturing Facilities*

Our Global Reach

*A global network of distribution partners*

Partners

# Recognition

ROYAL ACADEMY OF ENGINEERING



"The innovation that revolutionised Civil Engineering"

# Products, Systems & Solutions







Stabilisation

CPD
CERTIFIED


sarens
sarens

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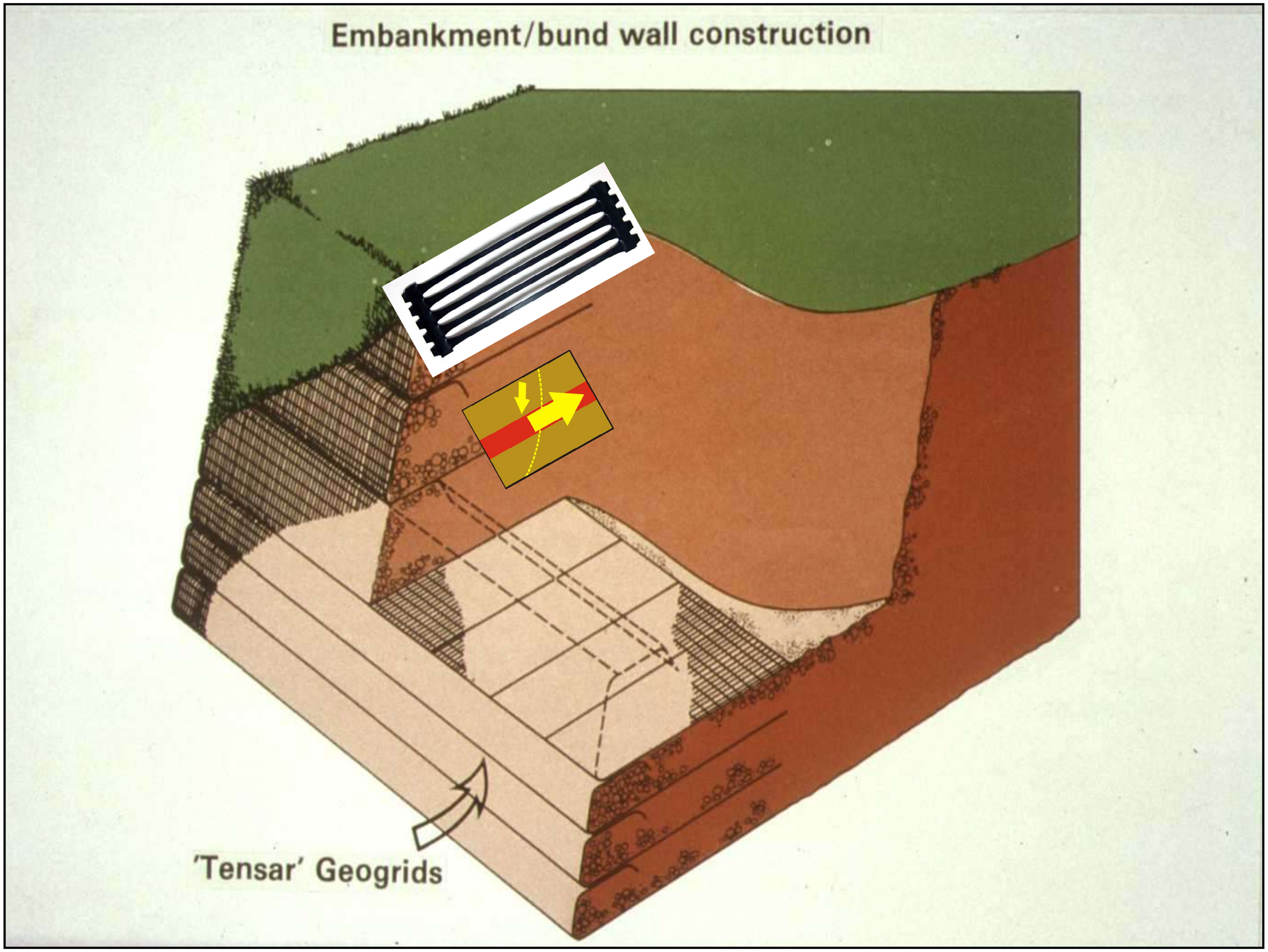
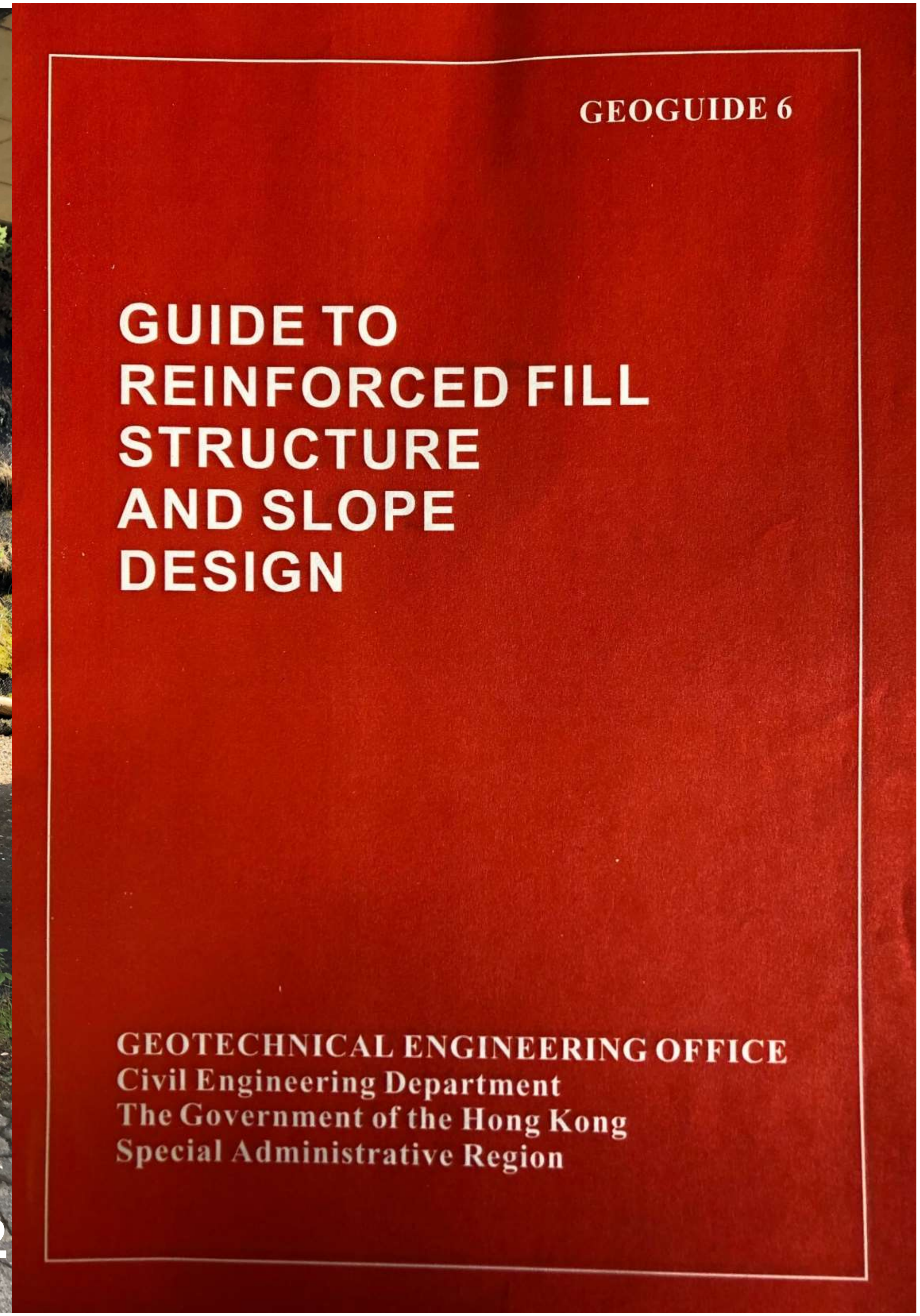
Important considerations:

Geogrid type and strength

# Reinforced Soil Walls & Slopes:
# Geogrid + Soil




July 2


GEOGUIDE 6
GUIDE TO REINFORCED FILL STRUCTURE AND SLOPE DESIGN
GEOTECHNICAL ENGINEERING OFFICE
Civil Engineering Department
The Government of the Hong Kong
Special Administrative Region

Tensar

## Design tensile strength

According to Geoguide 6 - Guide to Reinforced Fill Structure and Slope Design (GEO, 2002), the design tensile strength, $T_D$, per unit width of reinforcement is:

$$T_D = \frac{T_{ult}}{\gamma_m \gamma_n}$$

where $T_{ult}$ = characteristic short-term tensile strength guaranteed by Tensar International Limited (see Table 2)

$\gamma_m$ = partial material factor on tensile strength of geogrid (see Note (c))

$\gamma_n$ = partial consequence factor to account for consequence of failure

The design tensile strengths of the Tensar RE500 geogrids in the longitudinal direction given in Tables 3 to 7, which have been agreed with Tensar International Limited, shall be used.

| Particle size of fill material (mm) | $\gamma_m$ | Design tensile strength (kN/m) | |
|---|---|---|---|
| | | $\gamma_n = 1.0$ | $\gamma_n = 1.1$ |
| $D_{85} \le 10$ | 2.48 | 21.3 | 19.4 |
| $10 < D_{85} \le 50$ | 2.88 | 18.3 | 16.6 |
| $50 < D_{85} \le 100$ | 3.46 | 15.3 | 13.9 |
| $100 < D_{85} \le 125$ | 3.72 | 14.2 | 12.9 |

Table 3 – Design tensile strengths of Tensar RE520 geogrid

| Product grade | RE520 | RE540 | RE560 | RE570 | RE580 |
|---|---|---|---|---|---|
| Characteristic short-term tensile strength (kN/m) | 52.8 | 64.5 | 88.7 | 118.4 | 137.3 |

Table 2 – Characteristic short-term tensile strength (longitudinal direction)

(c) The partial material factor, $\gamma_m$, applies to the tensile strength of the individual grades of Tensar RE500 geogrid. It has taken into account the environmental effects on material durability, construction damage and other special factors including hydrolysis, creep and stress rupture for a 120-year design life at a design temperature of 30°C.

## Long term sustained load test (creep test)

- Tests carried out at varying loads
- Creep testing laboratories at various temperatures

  10°C

  20°C

  30°C

  40°C

  50°C

# Creep - HDPE vs PP

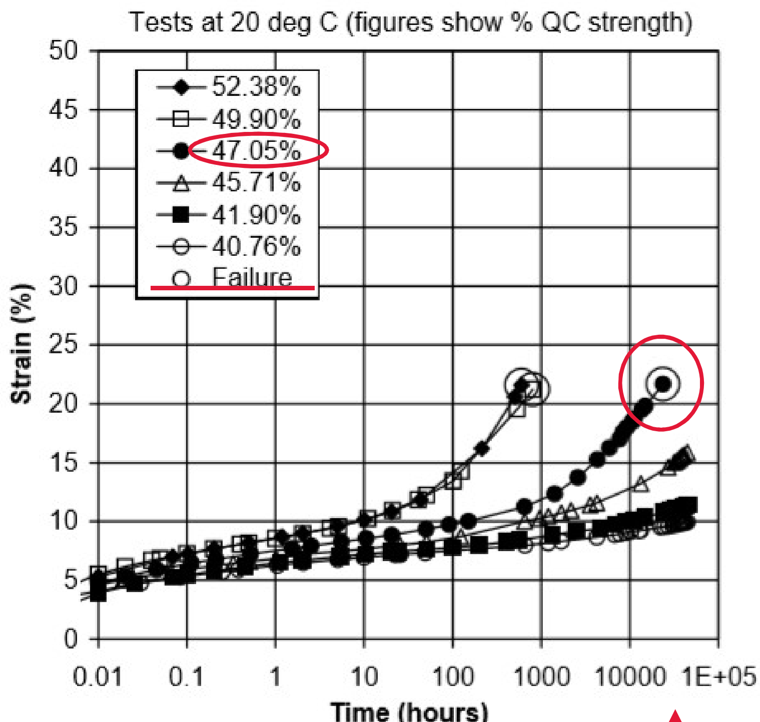



*Figure 4b Creep test results on HDPE geogrid*

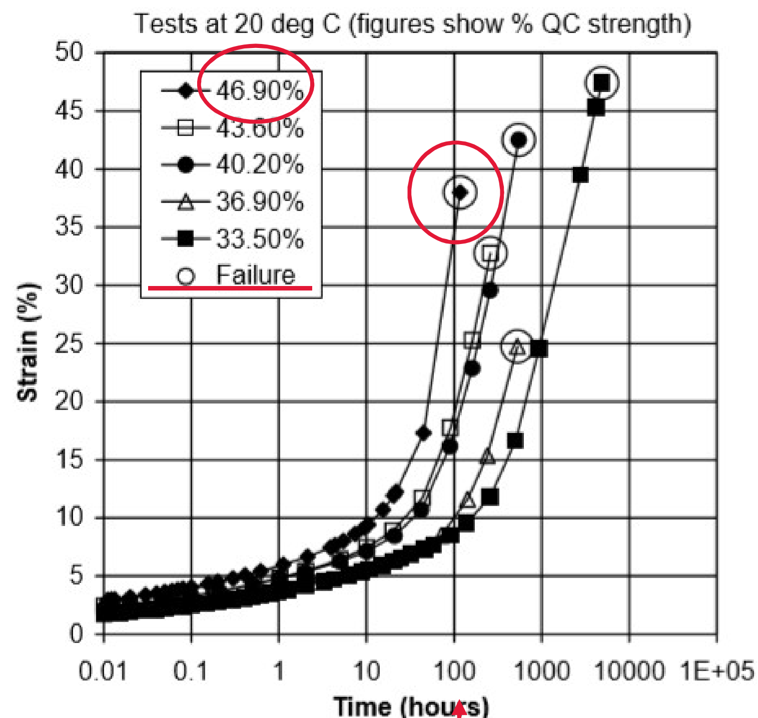



*Figure 4a Creep test results on PP geogrid*

( ~2 yrs)

(~ 4 days!!)

# Creep - HDPE vs PP

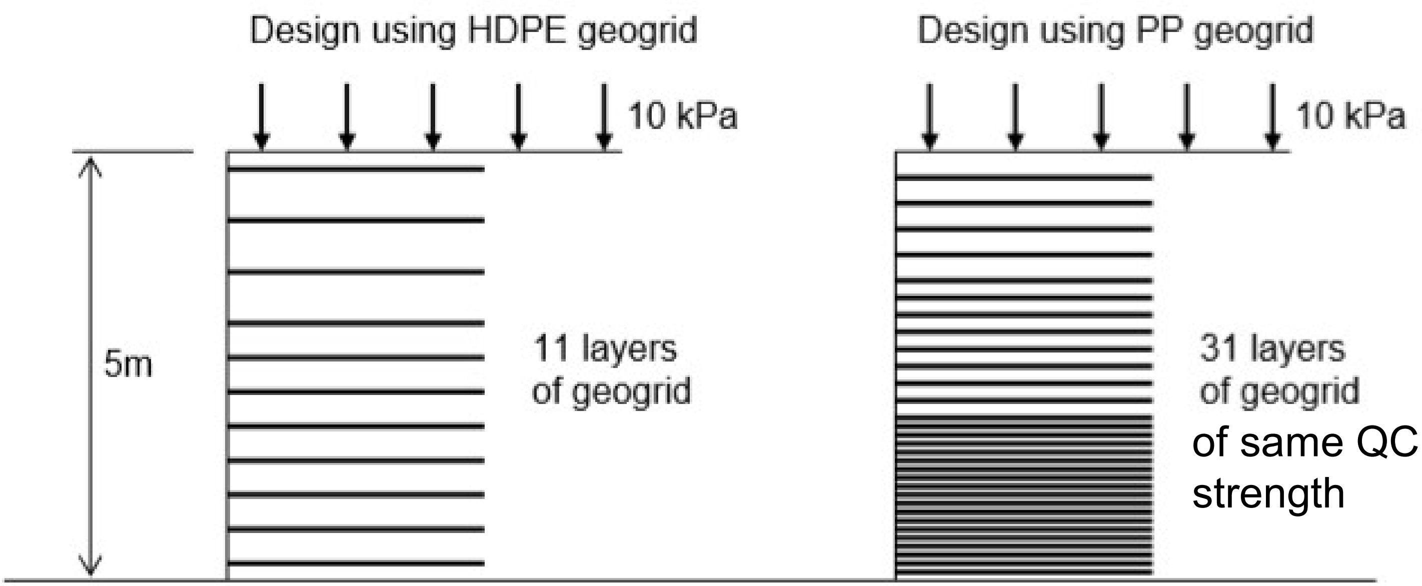



*Figure 7 Design of 5m high retaining wall comparing HDPE and PP geogrids*

**HDPE** ✓ **PP** ✗

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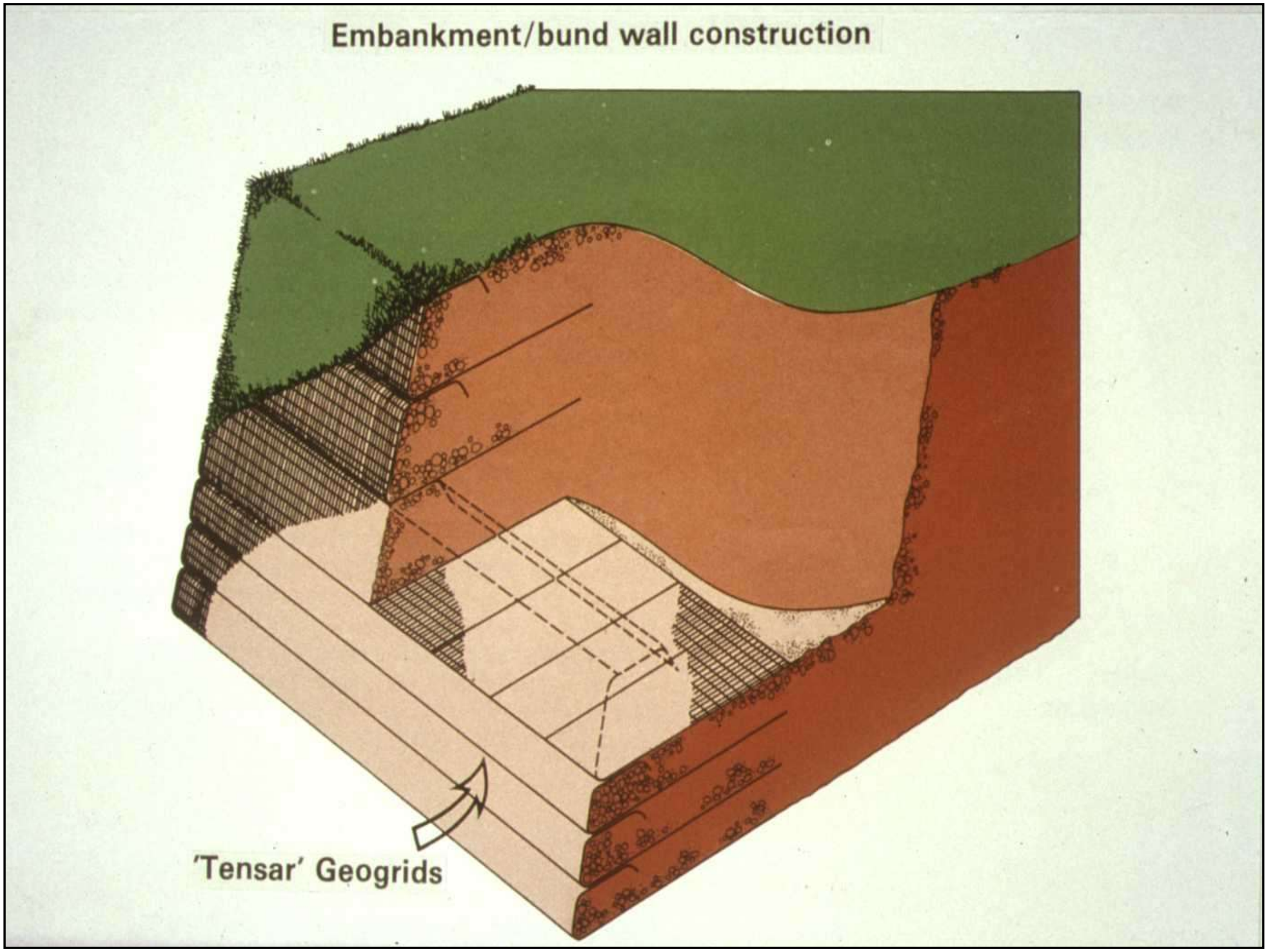
# Important considerations:

## Reinforced Fill Site Control

# Reinforced Soil Walls & Slopes: Geogrid + Soil



# ‘Standard’ Reinforced soil fill

- Majority of reinforce soil structures have been constructed with ‘standard’ fill, which is selected, good quality, well graded, preferably angular (crushed), granular fill free from organic substances

- So what is important?

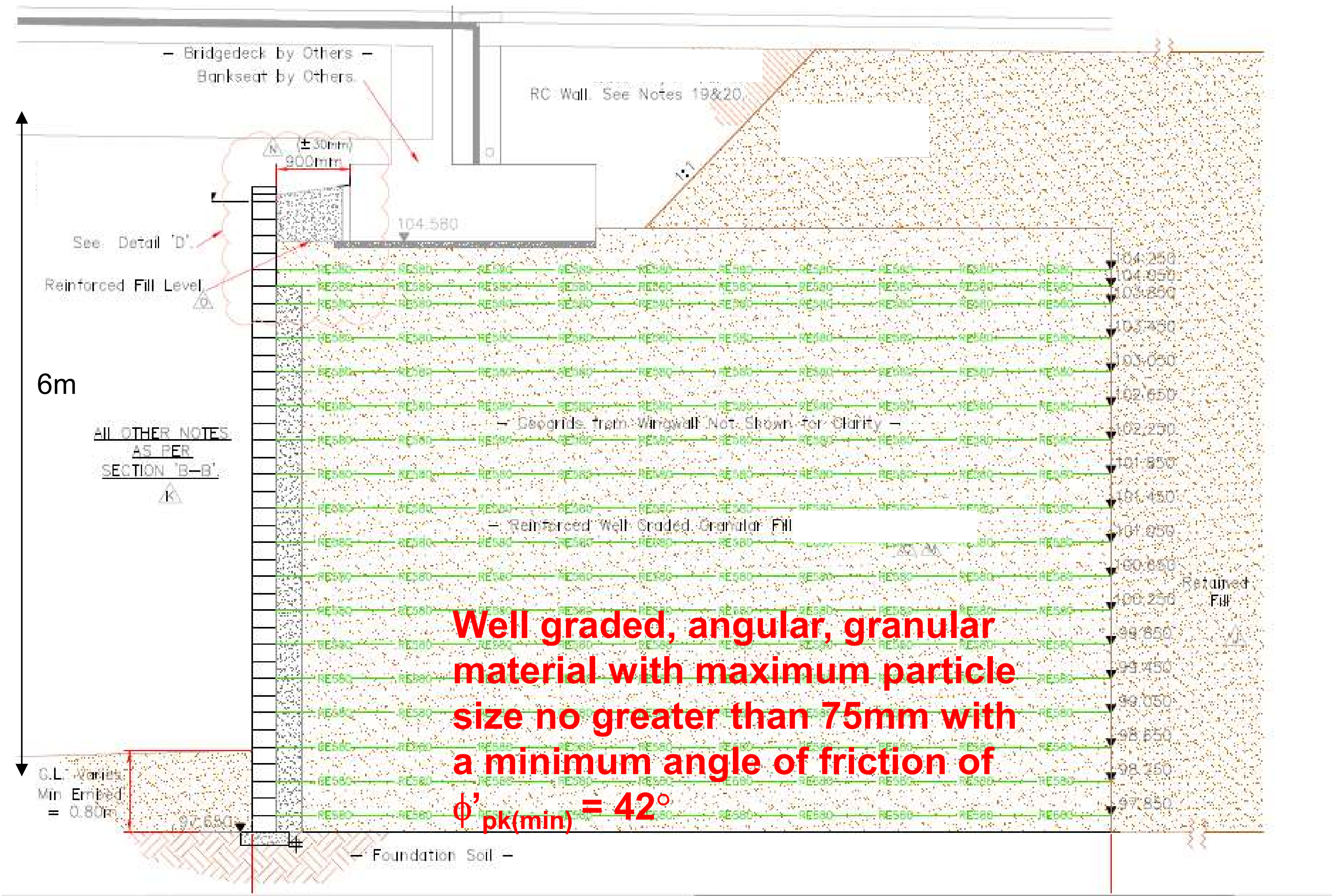
- Fill quality provided meets the spec
- Fill placement (compaction & workmanship)

- Both Common sense to an engineer?? However…

# Reinforced fill Site Control

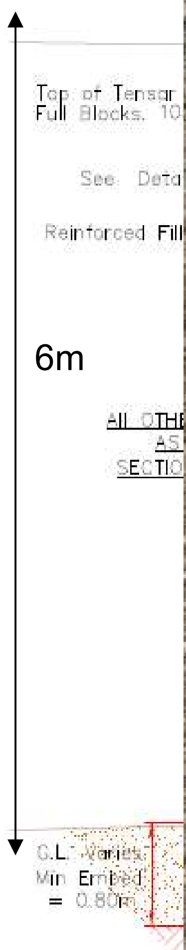
- Most of us provide design & supply and site ‘assistance’ rather than full time ‘supervision’
- Reinforced fill specified, must always be verified on site – especially in high risk applications with tight serviceability limits!!!
- You’d think this is obvious….

# 'Standard' high quality Reinforced Fill – not!




**Well graded, angular, granular material with maximum particle size no greater than 75mm with a minimum angle of friction of $\phi'_{pk(min)} = 42°$**

# ‘Star
not!


Top of Tensar
Full Blocks. 10
See Deta
Reinforced Fill
6m
G.L. Varies
Min Embed
= 0.80m


( >11.5 yrs)

# Reinforced Fill Site Control

Lesson learnt???!

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Important considerations:

Reinforced fill compaction/workmanship


Compaction!

# Compaction importance?


TOYOTA
52064


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Important considerations:

Drainage!

## Some important principles

- A well compacted clay fill is likely to be in a state of suction
- You want to prevent prolonged contact with free water at ALL edges of the clay fill, including the base
- REMEMBER: drainage intended to let water out of a system can let it in if badly detailed

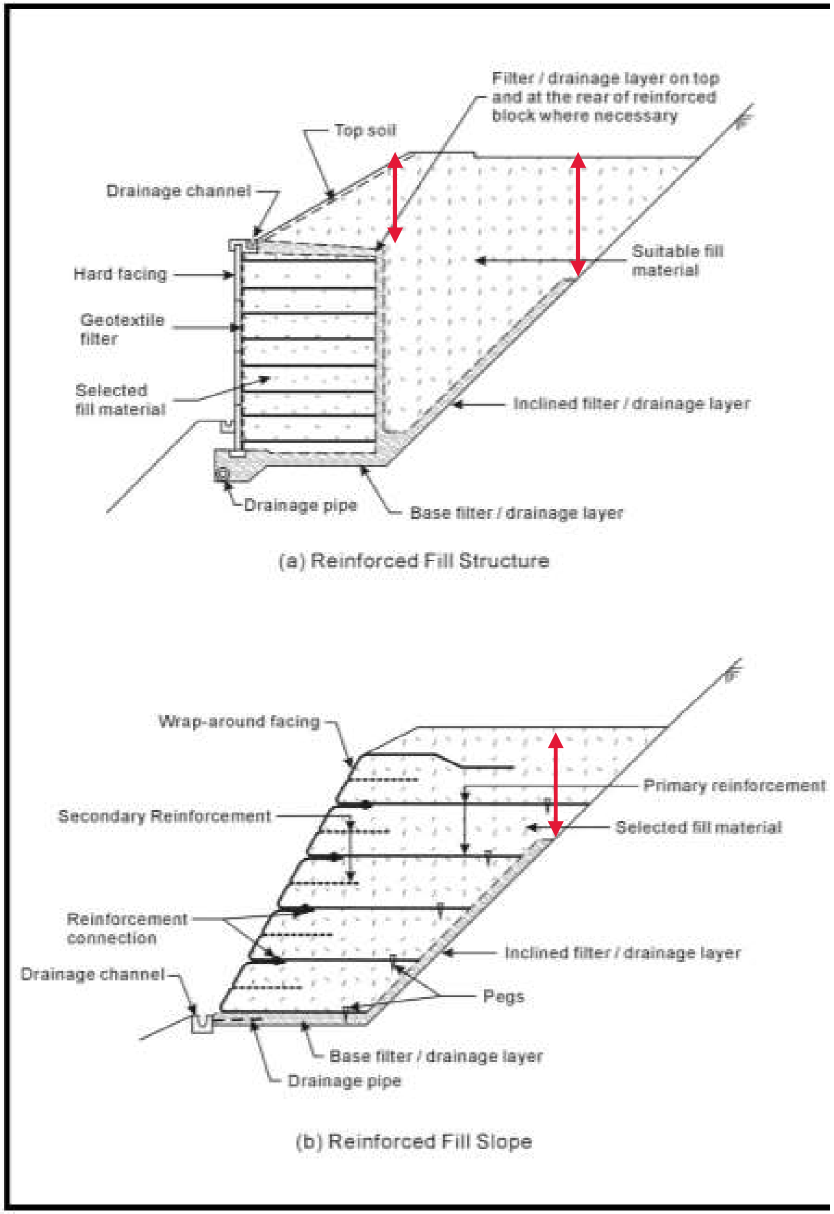



**Figure 43 – Typical Drainage Layouts for Reinforced Fill Structures and Slopes**



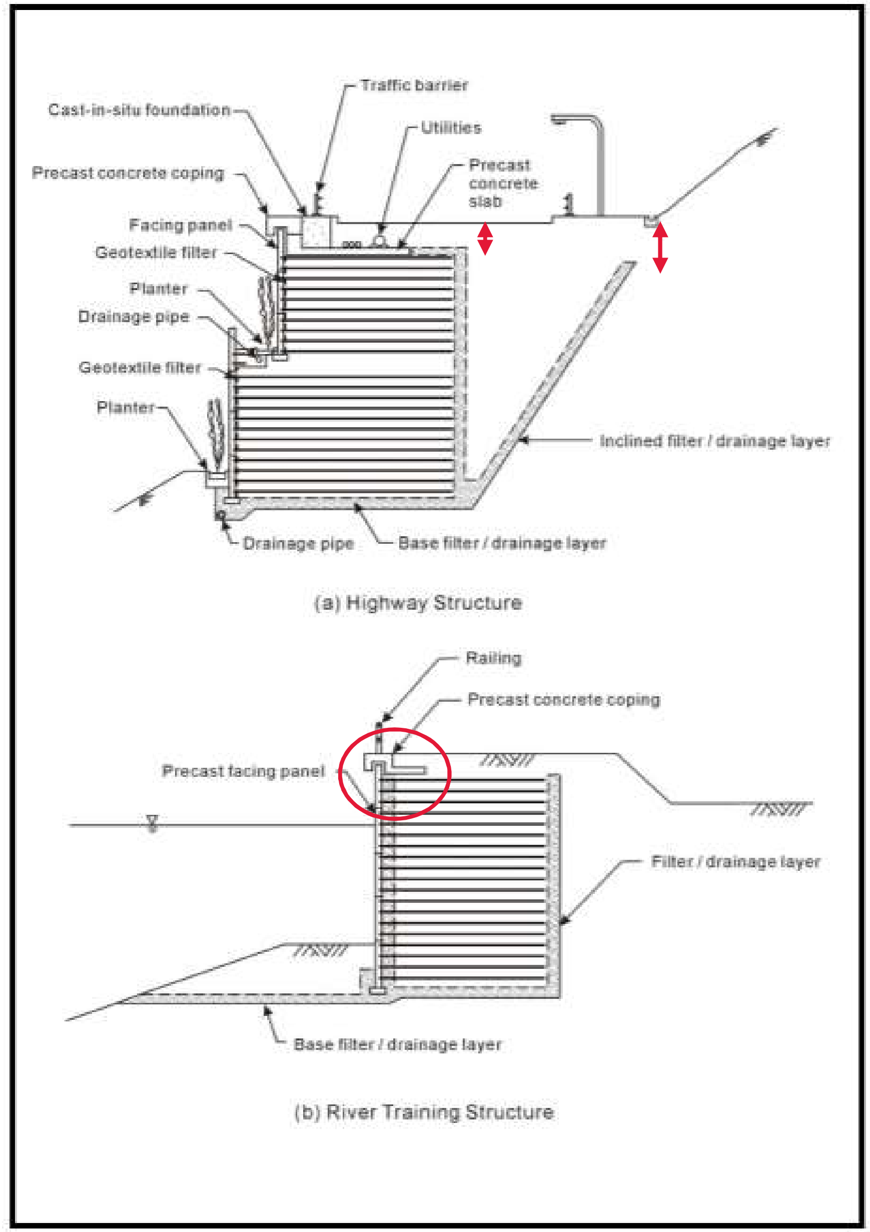



**Figure 44 – Typical Drainage Layouts for Highway and River Training Applications**

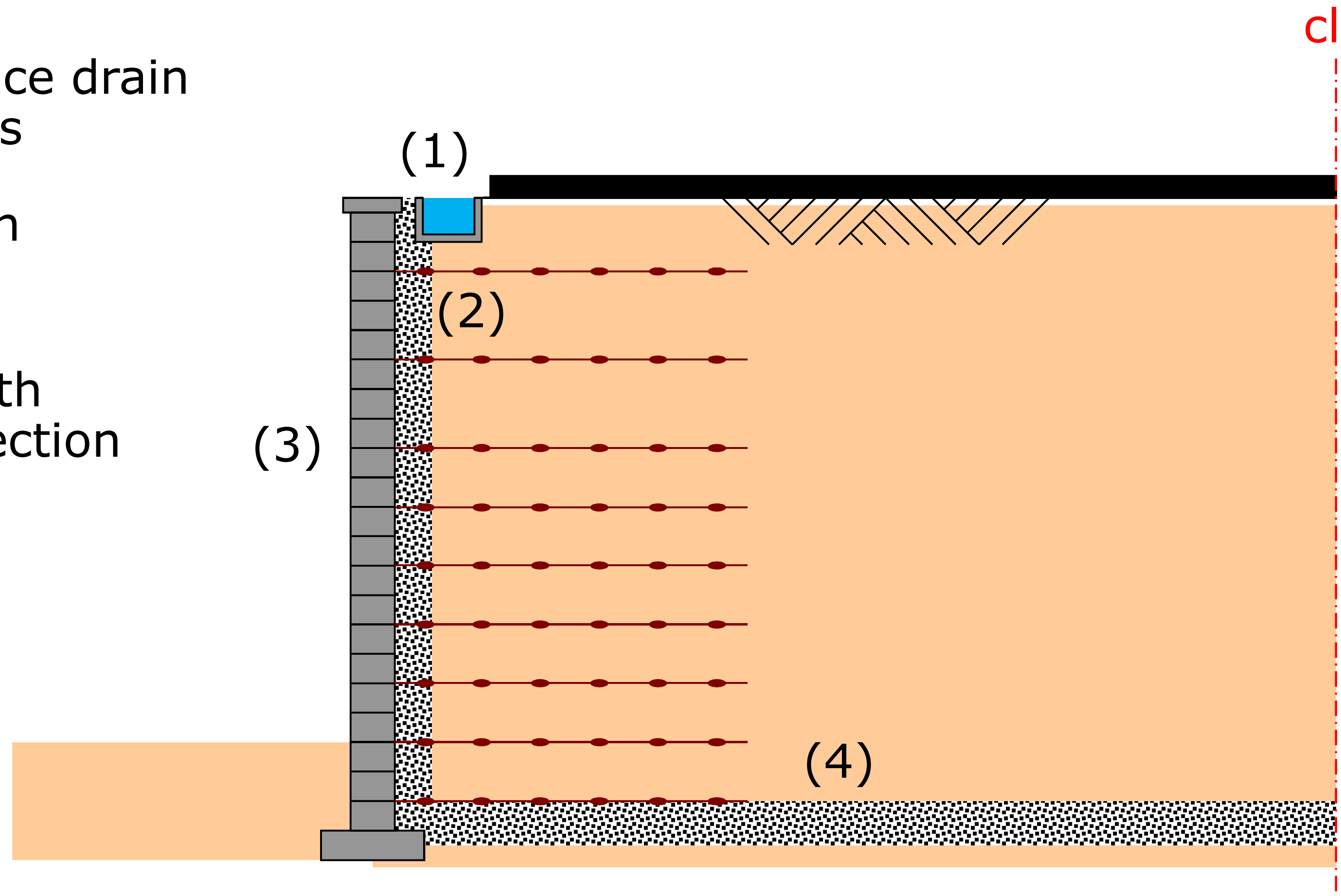
# Modular block Walls:
# Some common errors when detailing drainage

(1) Small surface drain which overflows

(2) Facing drain daylights

(3) Low strength frictional connection

(4) Base drain below external ground level



# Drainage – extent

- Clay fill structure with modular block facing
- Inadequate surface drain for tropical rainfall

# Drainage – extent

- Facing drainage continued to ground surface so that surface water can enter fill

# Drainage – extent

- Free water entry from crest, clay fill softens and swells putting extra force on back of facing
- No sign of mechanical face connection
- Facing blocks have been pushed off face

# Drainage – extent

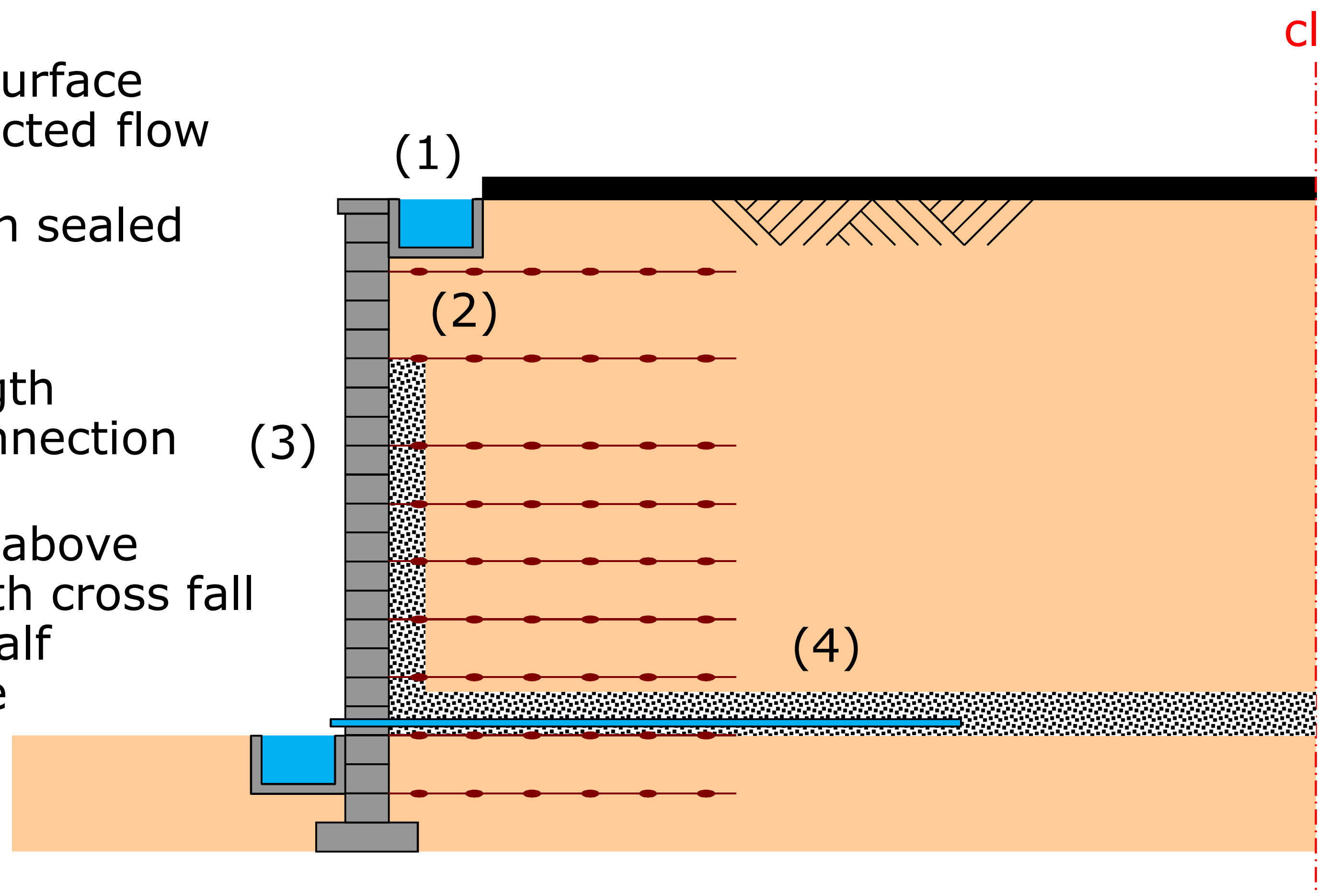
# Modular block Walls: Good Practice

(1) Adequate surface drains for expected flow

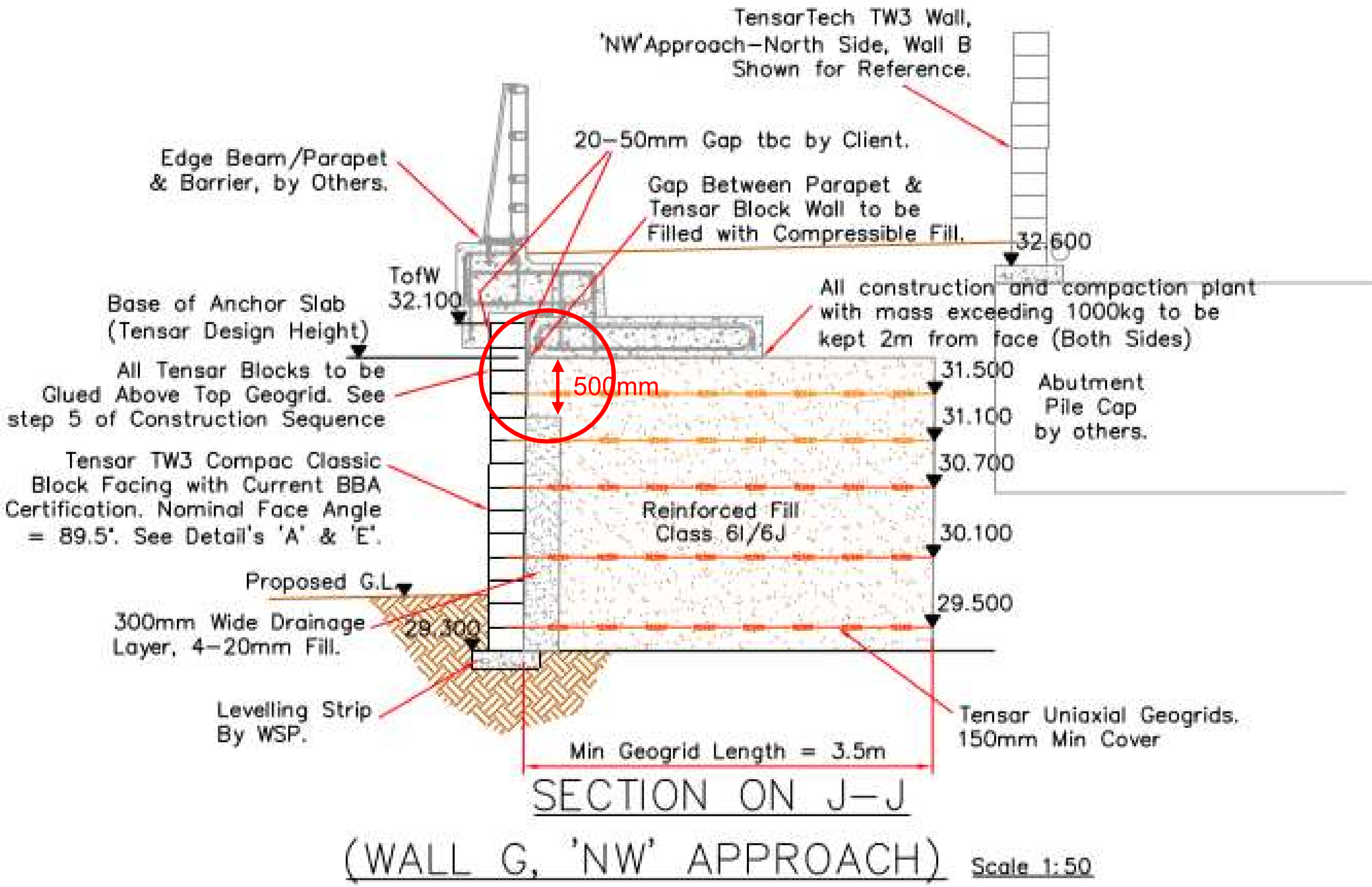
(2) Facing drain sealed from surface

(3) High strength mechanical connection

(4) Base drain above external GL with cross fall and consider half perforated pipe



# Drainage – extent



# Slope built against hillside - drainage should be detailed to prevent extended contact with free water

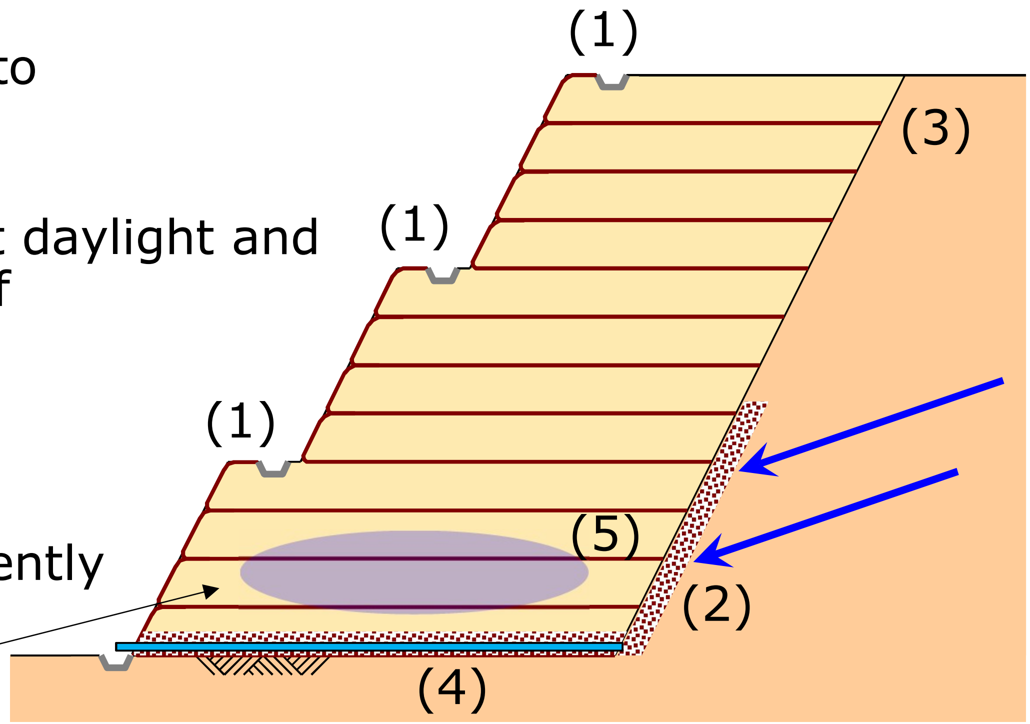
(1) Adequate surface drains for expected flow

(2) Adequate internal drains to intercept ground water flow

(3) Internal drains should not daylight and allow inflow of surface run-off

(4) Internal drains should be arranged to remain empty

(5) Drainage blanket insufficiently permeable acts as a water 'reservoir' that softens surrounding clays – must be very permeable!!



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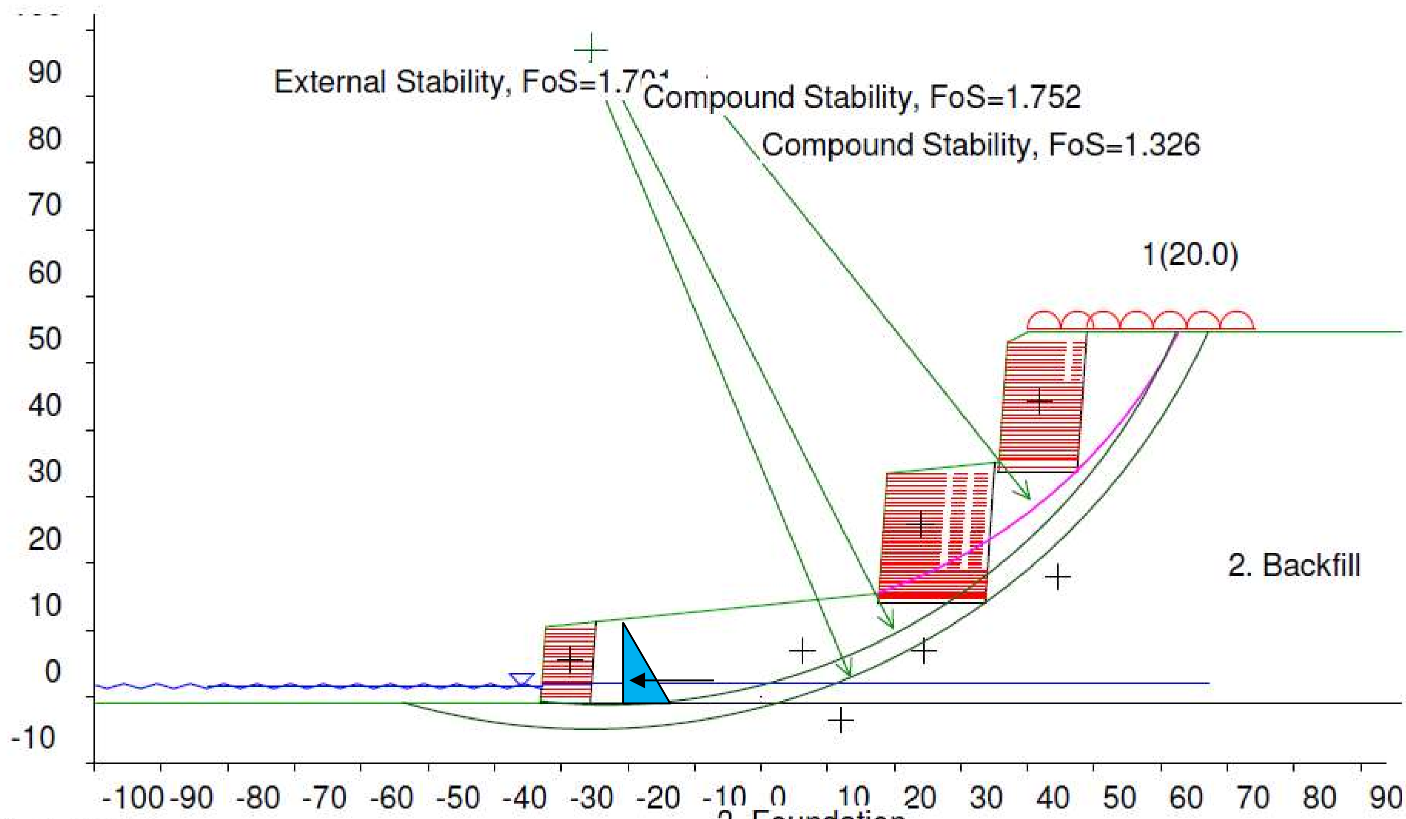
Important considerations:

Fill variability!

# Tensar Reinforced Soil Application Suggestion

Tensar International LLC,
PO Box 86454
Dubai
United Arab Emirates

Tel :
Fax : +9714 2617090
Email : sal226@emirates.net.ae

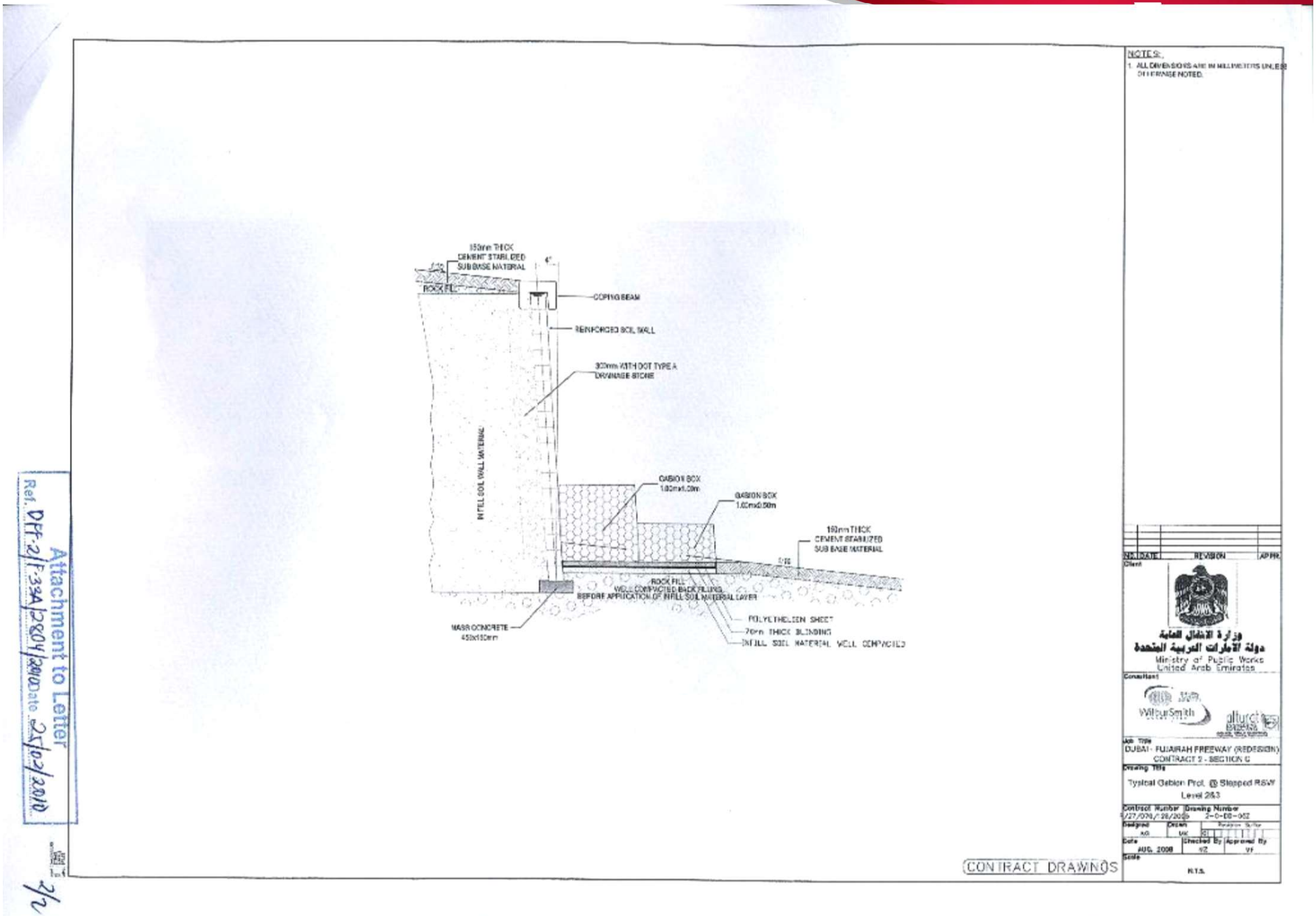



Scale 1:1250

| Soil | c' | ϕ' | γ |
|---|---|---|---|
| 1 Wall Fill | 0.0 | 42.0 | 22.40 |
| 2 Backfill | 0.0 | 40.0 | 22.40 |
| 3 Foundation | 0.0 | 40.0 | 22.40 |

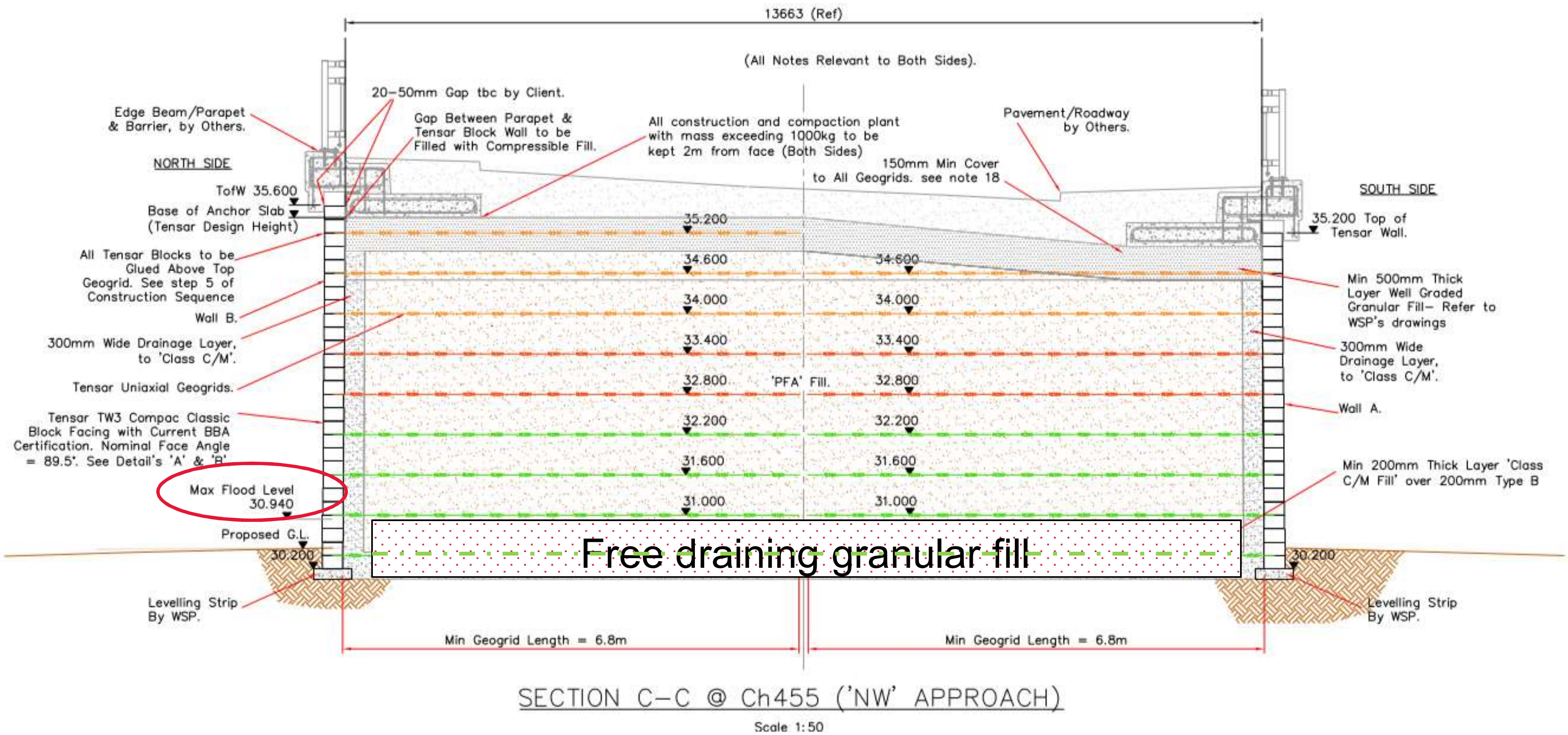
**Key / Material quantities**

| Grid Type | Quantity/m run |
|---|---|
| 2 No. Tensar RE510 | 23.6 m² |
| 7 No. Tensar RE520 | 51.1 m² |
| 10 No. Tensar RE540 | 125.2 m² |
| 32 No. Tensar RE560 | 442.4 m² |
| 8 No. Tensar RE570 | 94.4 m² |


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE NOTED.
150mm THICK CEMENT STABILIZED SUB BASE MATERIAL
ROCK FILL
COPING BEAM
REINFORCED SOIL WALL
300mm WITH DOT TYPE A DRAINAGE STONE
INFILL SOIL WALL MATERIAL
GABION BOX 1.00mx1.00m
GABION BOX 1.00mx0.50m
150mm THICK CEMENT STABILIZED SUB BASE MATERIAL
ROCK FILL
WELL COMPACTED BACK FILLING BEFORE APPLICATION OF INFILL SOIL MATERIAL LAYER
MASS CONCRETE 450x150mm
POLYETHELEEN SHEET
70mm THICK BLINDING
INFILL SOIL MATERIAL WELL COMPACTED
NO. DATE REVISION APPR.
Client
وزارة الاشغال العامة
دولة الامارات العربية المتحدة
Ministry of Public Works
United Arab Emirates
Consultant
WilburSmith
Job Title
DUBAI - FUJAIRAH FREEWAY (REDESIGN)
CONTRACT 2 - SECTION C
Drawing Title
Typical Gabion Prot. @ Stepped RSW Level 2&3
Contract Number
Drawing Number
2-0-DB-052
Designed
AG
Drawn
UK
Date
AUG. 2008
Checked By
Approved By
Scale
N.T.S.
CONTRACT DRAWINGS
Attachment to Letter
2/2


1:10

# Drainage – flood zones



# Drainage – holistic site assessment

- While under construction, if incline weather is expected, the finished levels at the end of each day must be left covered and at an angle so that any rain water can run off away from the reinforced soil block

- Surrounding topography must been adequately assessed and surface drainage need to be designed for adequate capacity

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Important considerations:

Water mains!

# Drainage

- Keep water mains as far as possible from reinforced soil retaining walls; if not possible then make sure they are water tight!

# Flooding due to water main burst

# Flooding due to water main burst

# Flooding due to water main burst

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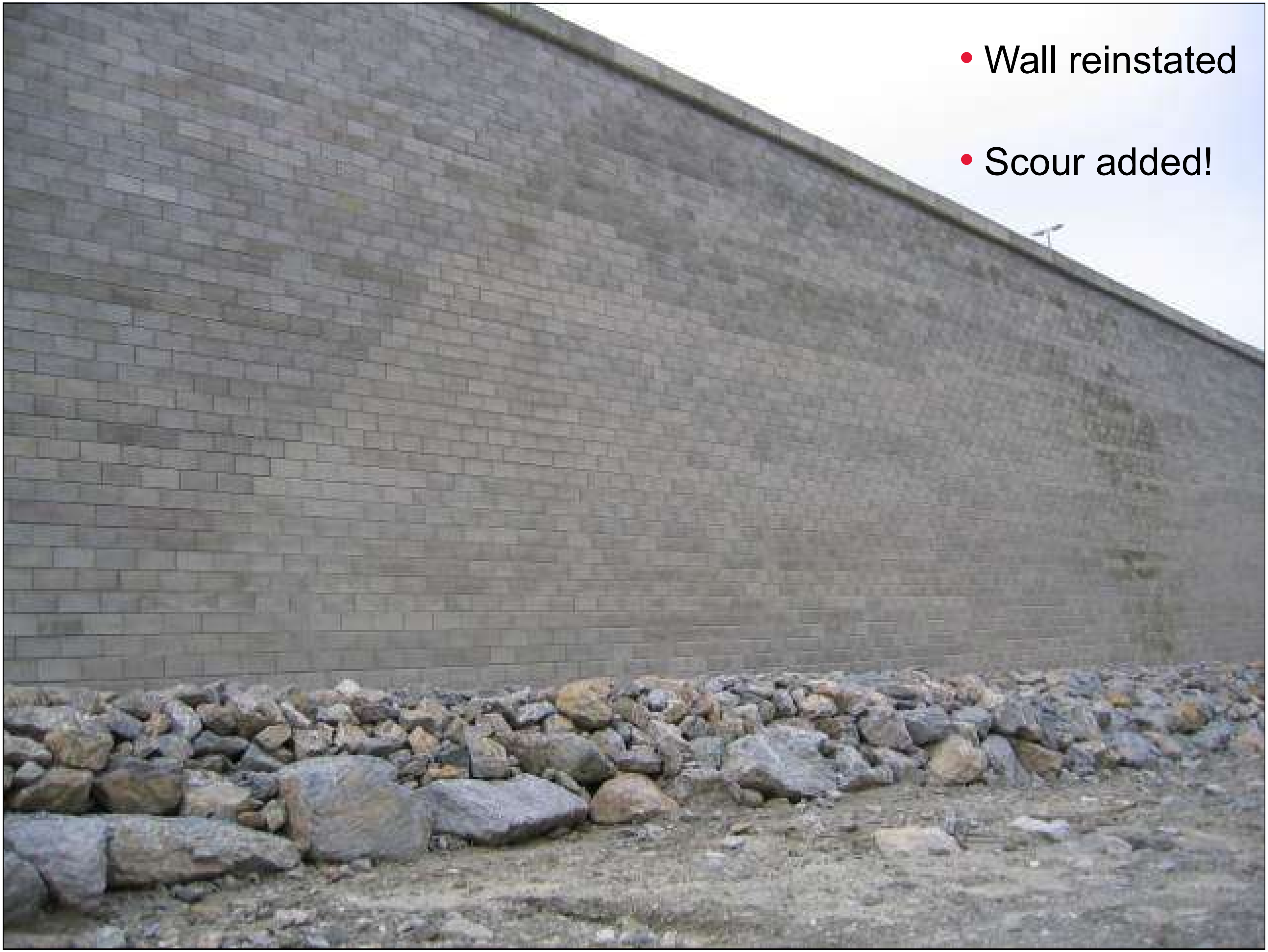
Important considerations:

Scour protection!

# Scour Protection

- Modular block walls up to 18m high built on side of stream bed
- Toe protection provided?


• Crash barrier straight
• Road remained open



• Wall reinstated
• Scour added!

# Non-Standard Reinforced soil fills

## Why?

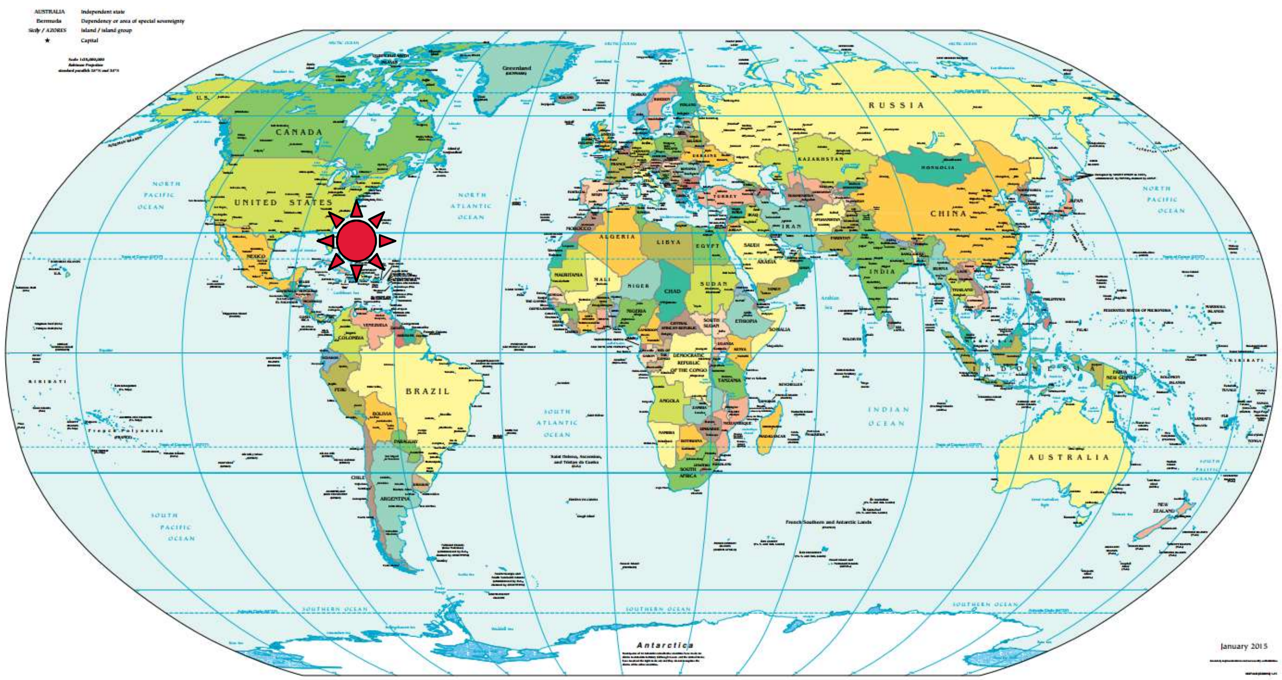
Cost and $CO_2$ reduction with non-standard fills like

- Site won cohesive material
- Even Landfill waste material
- and something else…

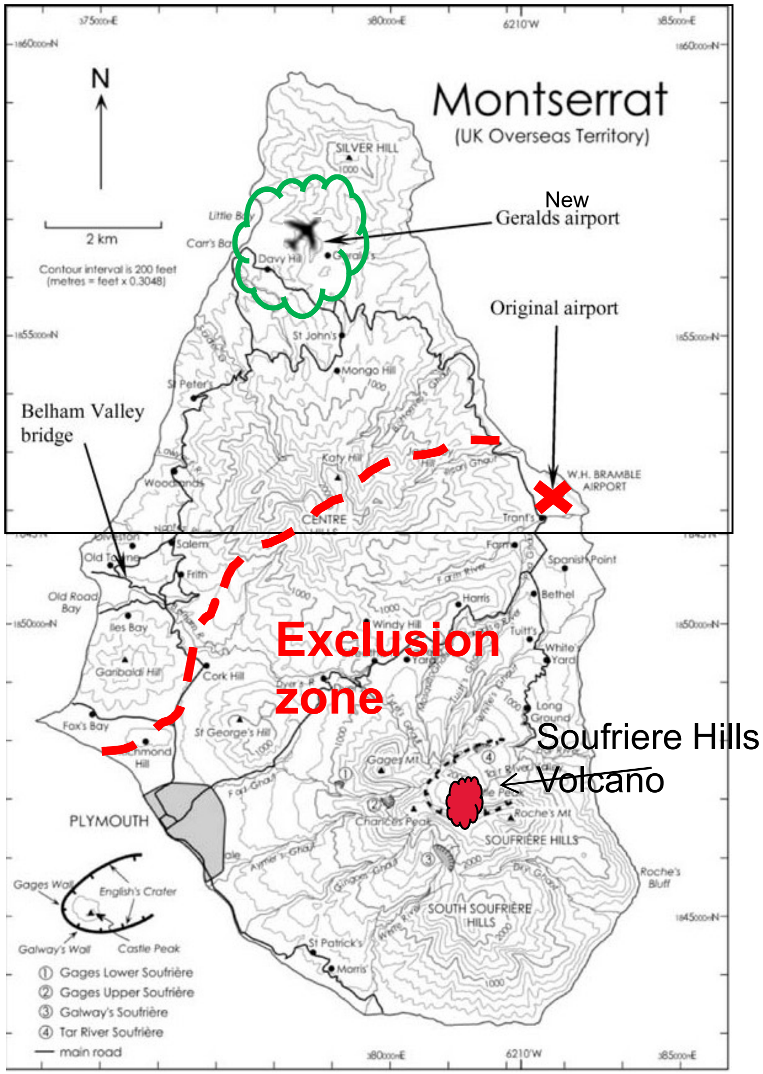
# Design considerations for 'non-standard' fills

- Upfront, CLEAR conversation with Client of additional controls:
- Fill specific installation damage/pull-out/shear testing
- Shear box – correct (slow) rate of shearing for 'non-standard', i.e. slow draining clay fills - drained conditions
- chemical analysis – i.e. HDPE is largely inert to chemical attack and to environments with pH2 - pH12.5 but not all soil reinforcement is so added FoS should be incorporated
- Adjusted rate of construction for PWP dissipation
- Compactability/trafficability of non-standard fill, especially cohesive
- DRAINAGE : even more important for fills like chalk or PFA
- Reinforced Fill site CONTROLS, especially in challenging climatic conditions or when critical end use

# Use of controlled site-won fills



# Use of site-won fills

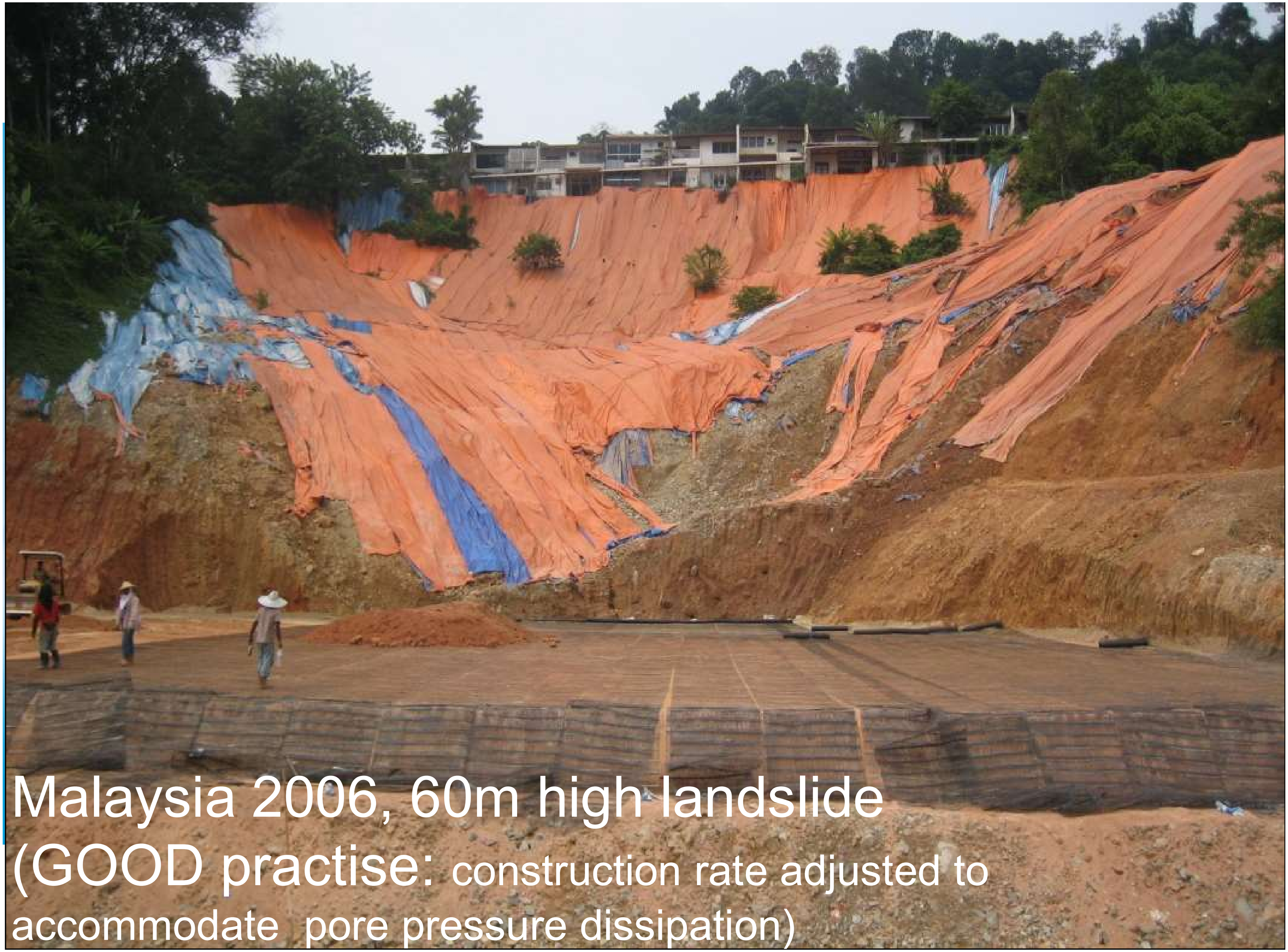



The original airport was completely destroyed during the eruption of Soufrière Hills Volcano in 1995.

Between 1995 and 2005, Montserrat had been accessible only by helicopters or boats

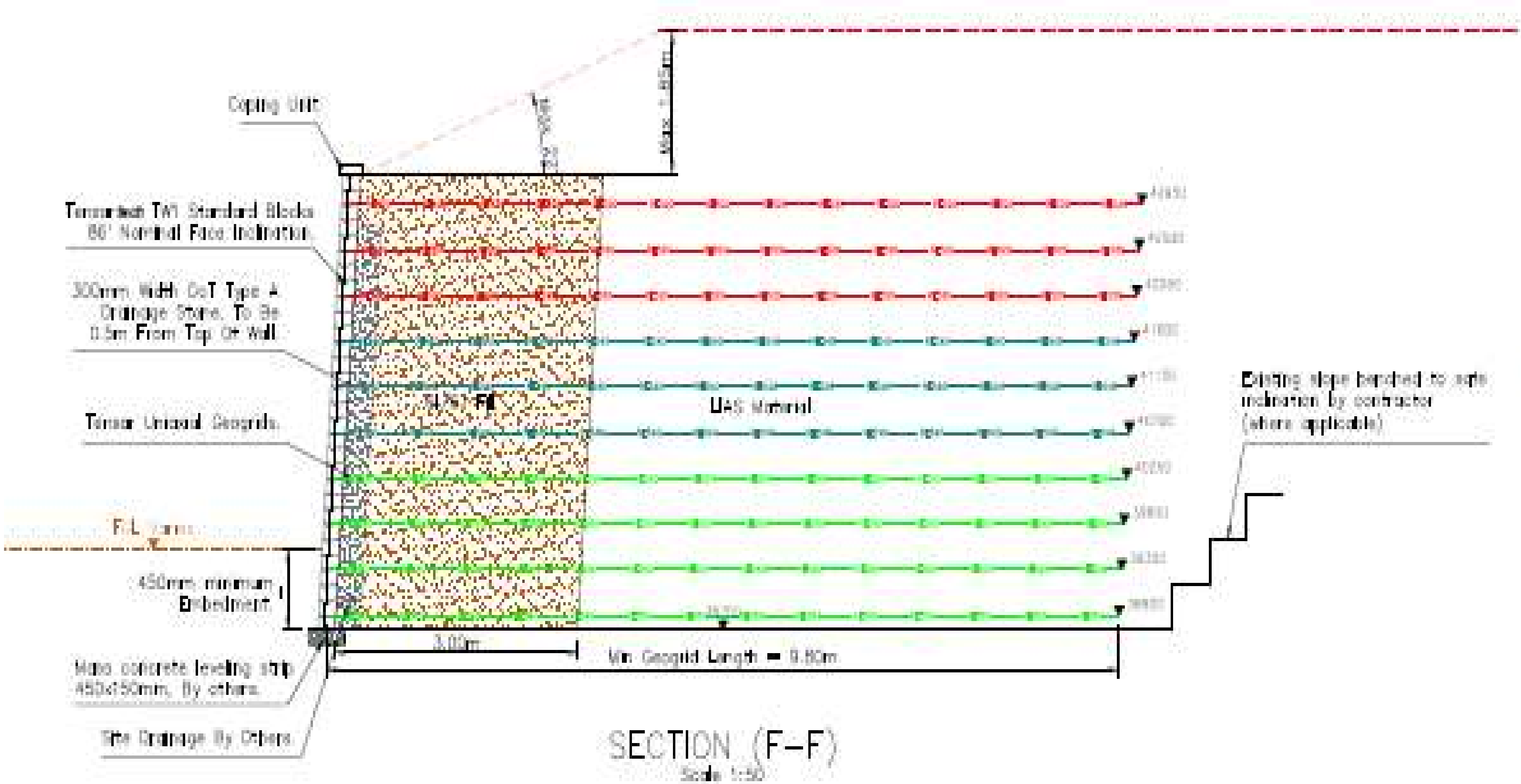

GOOD practise: screening of locally available material


Montserrat 2005, Airport Embankment 31.5m high



Malaysia 2006, 60m high landslide
(GOOD practise: construction rate adjusted to
accommodate pore pressure dissipation)

# GOOD practice: Use composite fill solution



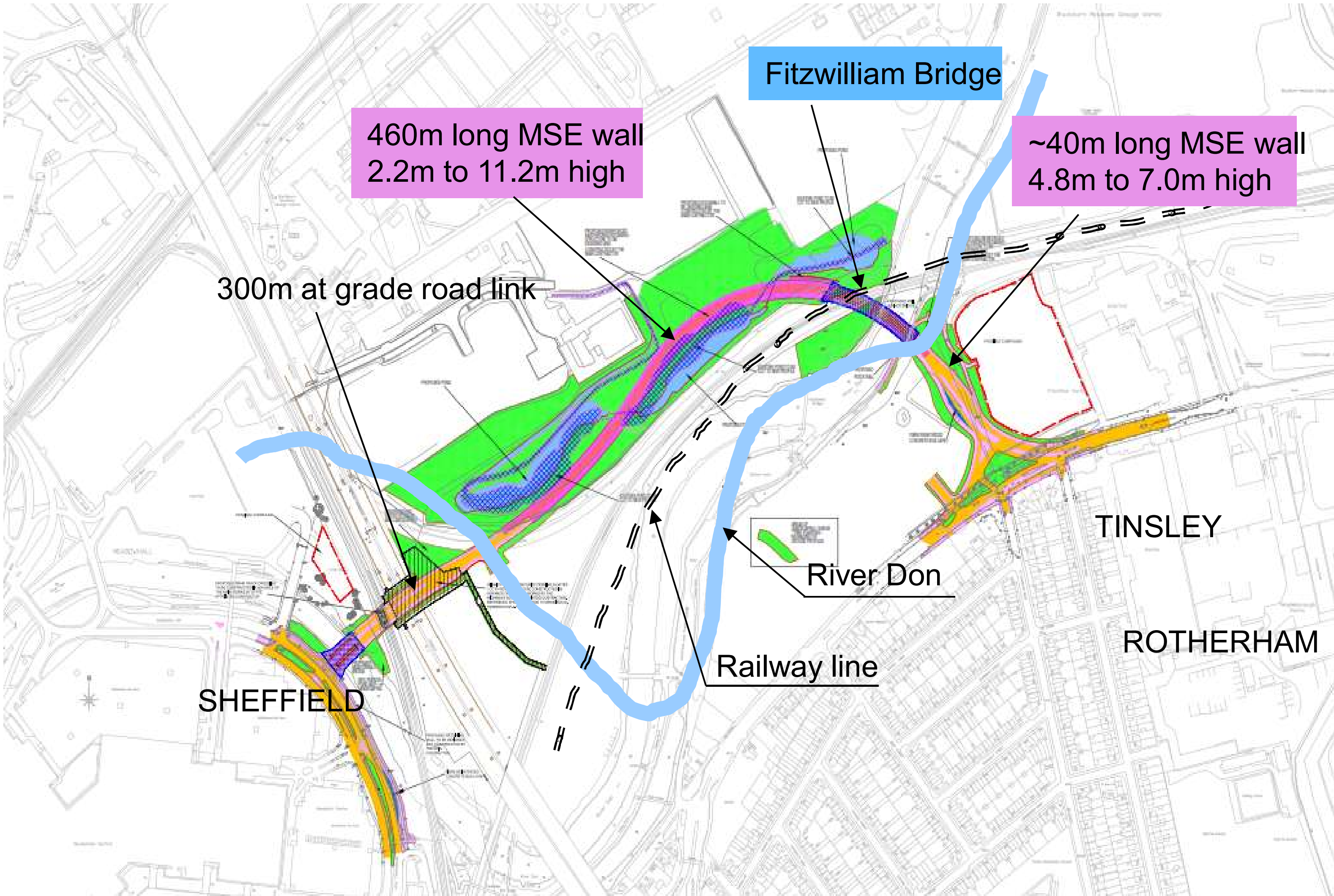
# Pulverised Fuel Ash (PFA)

Tensar

Pulverised fuel ash (PFA), is a very fine (0.1mm up to 10mm) waste product of coal fired power stations; cements in time and light(er) weight, ~ 15kN/m3

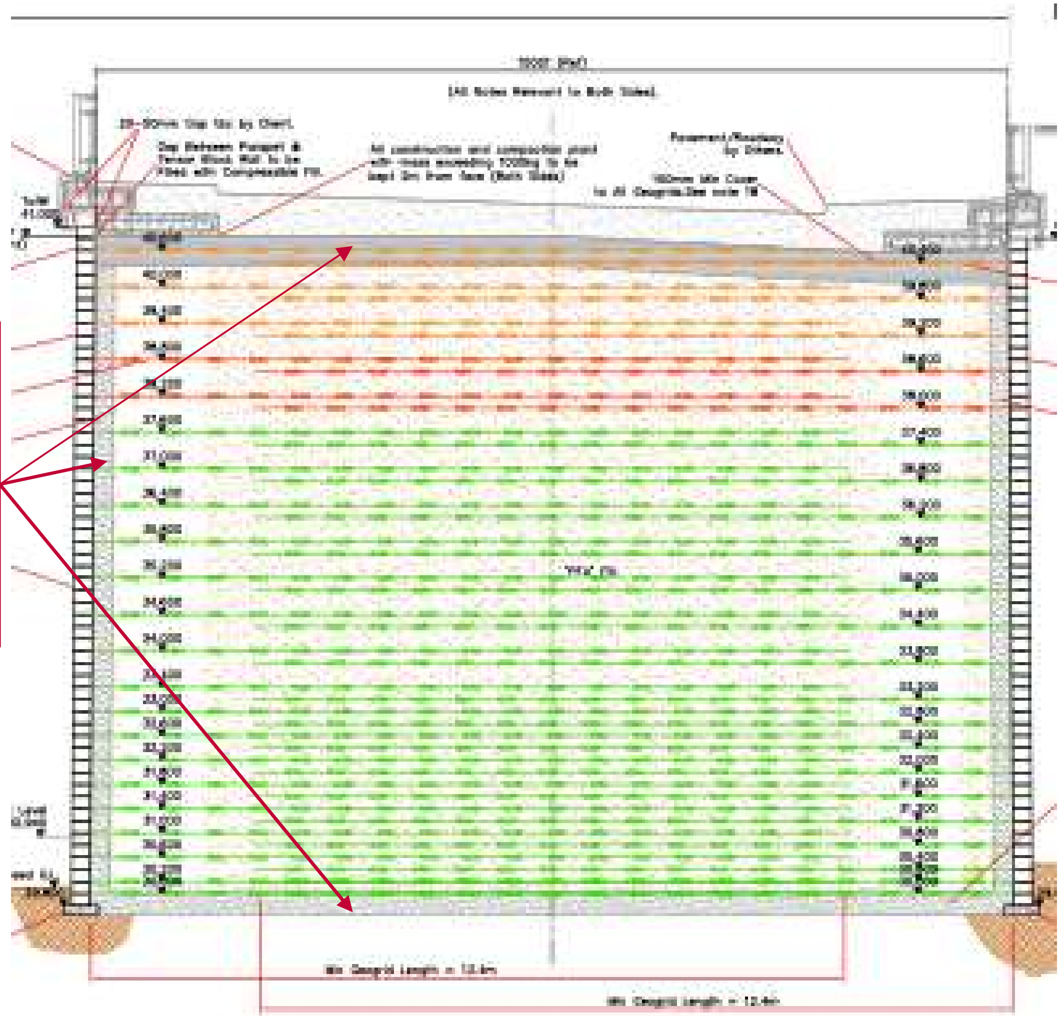
Highly alkaline, typically pH>9 : ok for HDPE geogrids but sensitive materials such as polyester or steel need to be factored in the design

# Use of Pulverised Fuel Ash (PFA)



# PFA constraints – DRAINAGE!!

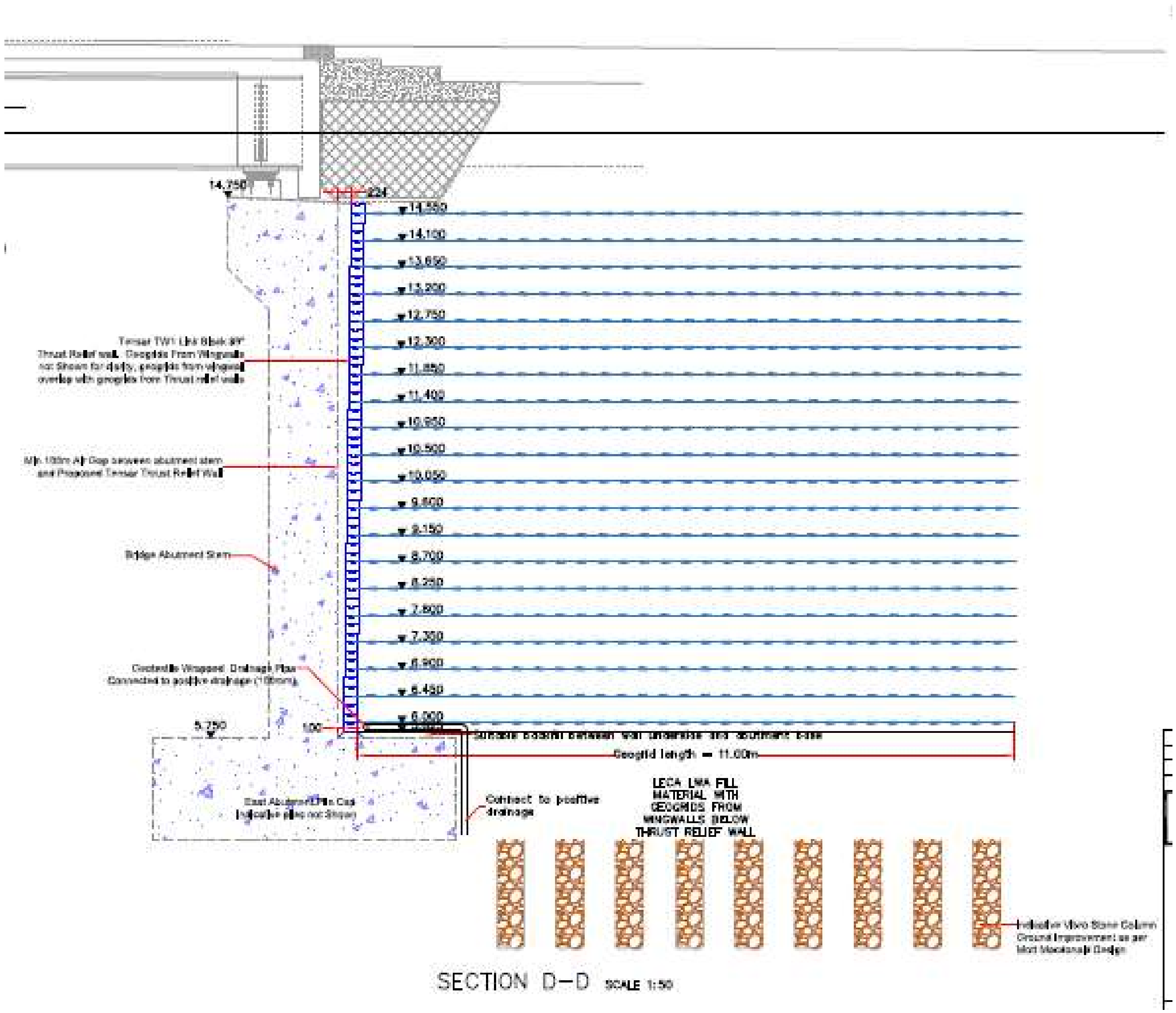
additional drainage measures must be made as outlined in BS8006:2010 Cl. 6.10.5.2, Cl. 6.10.5.3, and Cl. 6.10.2.6.3



SECTION A–A @ Ch640 ('NW' APPROACH)

GOOD practise: standard free draining granular fill up to flood levels

# PFA Thrust Relief wall behind bridge abutment



# ‘Tinsley Link’, 2015, up to 11m high wa


‘Tinsley Link’, 2015, up to 11m high walls


'Tinsley Link', 2015, up to 11m high walls

# Use of a landfill waste material

**Dan-Y-Lan Landfill (1955-1971) up to 30m high landslip remediation, 2004-6**

Contaminants of concern (COC) – ammonia, lead, Polyaromatic Hydrocarbons (PAHs), Polychlorinated biphenyls (PCBs), and Total Petroleum Hydrocarbons (TPH) - all of concern


Use of a landfill waste material
GOOD practise: Plant with vibrating rollers was replaced with multiple passages of tracked plant to avoid moisture concentration on surface

# Use of a landfill waste material

# Light Weight Aggregate

- **Leca® Light Weight Aggregate** (LLWA – previously also known as 'Maxit'), is an inorganic lightweight clay aggregate; it is manufactured by heating and firing of natural marine clay in a rotary kiln to 1150°C that transforms the clay into various sized lightweight ceramic granules varying in size 0-32mm

- **MUCH** Lighter than conventional fill
  - Bulk density varies between 3.5kN/m$^3$ – 5kN/m$^3$
  - less bearing pressure, less piles!
- High shear strength properties: $\phi'=36^o - 39^o$
- Design life in excess of **100 years**.

http://www.leca.co.uk/

, is an
g of natural
sized

N/m$^3$


# Light Weight Aggregate (LWA) reinforced fill

- No specific compaction required as pneumatically placed and just compacted by traffic lorries
- On weak foundations reduce the amount of foundation upgrade (piling) and therefore the project cost

GOOD practise: Geogrid/LWA specific testing must be carried out to obtain the interaction characteristics required for design

# Light Weight Aggregate (LWA) reinforced fill

Bridge approach ramps, up to 12.5m high, 2016

# Conclusions

- **Geosynthetics reinforced soil structures** have only been around for just under half of a century

- Geosynthtics managed to gain the Industry’s respect and to form our own ‘family’ of recognised, construction materials - sometimes the only solution (excessive heights) – as long as specs and good construction is followed!

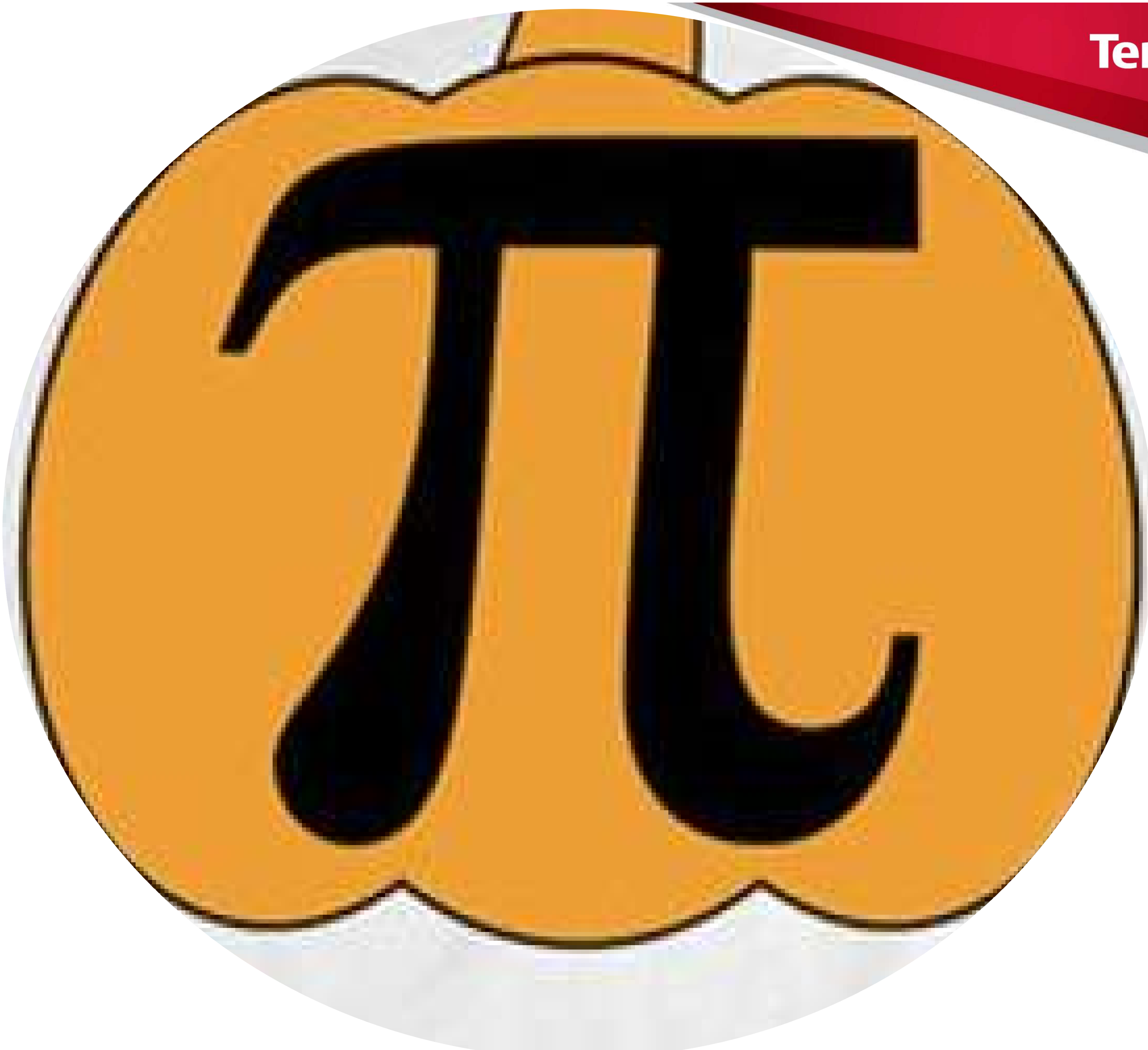
- Looking into the future, the choice towards Geosynthetics versus other earth retaining structures is expected to increase as it is closely linked with their outstanding performance, speed and easy of installation but above all their contribution towards more sustainable and environmentally friendly ‘Geosystems’

# Goals

Tensar

- Attract more young engineers into geosynthetics
- Convince that provide a robust solution, if constructed properly
- Differentiate & educate our industry/younger generation that not all plastic is ‘bad’
- join forces and lobby the ‘law makers’/educators together to include in syllabus
- share and adopt good practises that are product neutral
- share and learn from lessons learnt
- Encourage good practice on site

- Collectively protect our industry from cheap, sub-standard ‘plastic’!



# Special Thanks

- Leca® Light Weight Aggregate
- Prof Colin Jones
- Tensar

***you!***

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# Thank you
# Any questions?