NAUE

A Holistic Design Approach Using Modern Geogrids In Soft Ground Improvement

Australian Geomechanics Society

WA Seminar 2014

Geotechnics of Soft Soils

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ENGINEERS AUSTRALIA

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Outline of Presentation

1. Introduction

2. Principles of Geosynthetic Reinforcement

3. Independent Research findings from Large-Scale Laboratory Tests and Field trials

4. Guiding Factors for Reinforcement Benefit

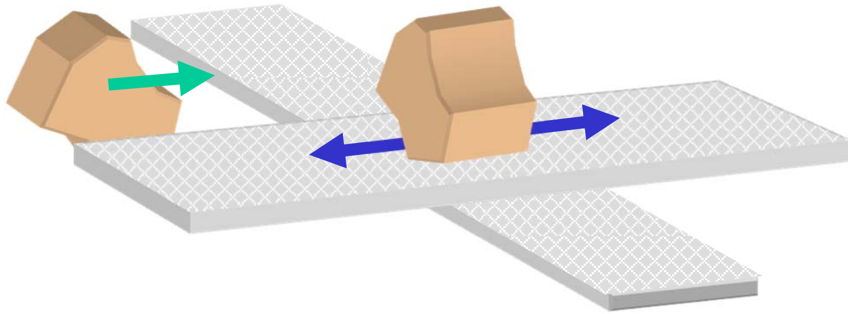
5. Case Study: Utah Point Berth Project (UPBP), Port Hedland

Agar-Quf Ziggurat
(1000 B.C.)

1. Introduction

The transmission of forces from soil to geosynthetic resulting from interaction between the aggregate and the geogrid by:

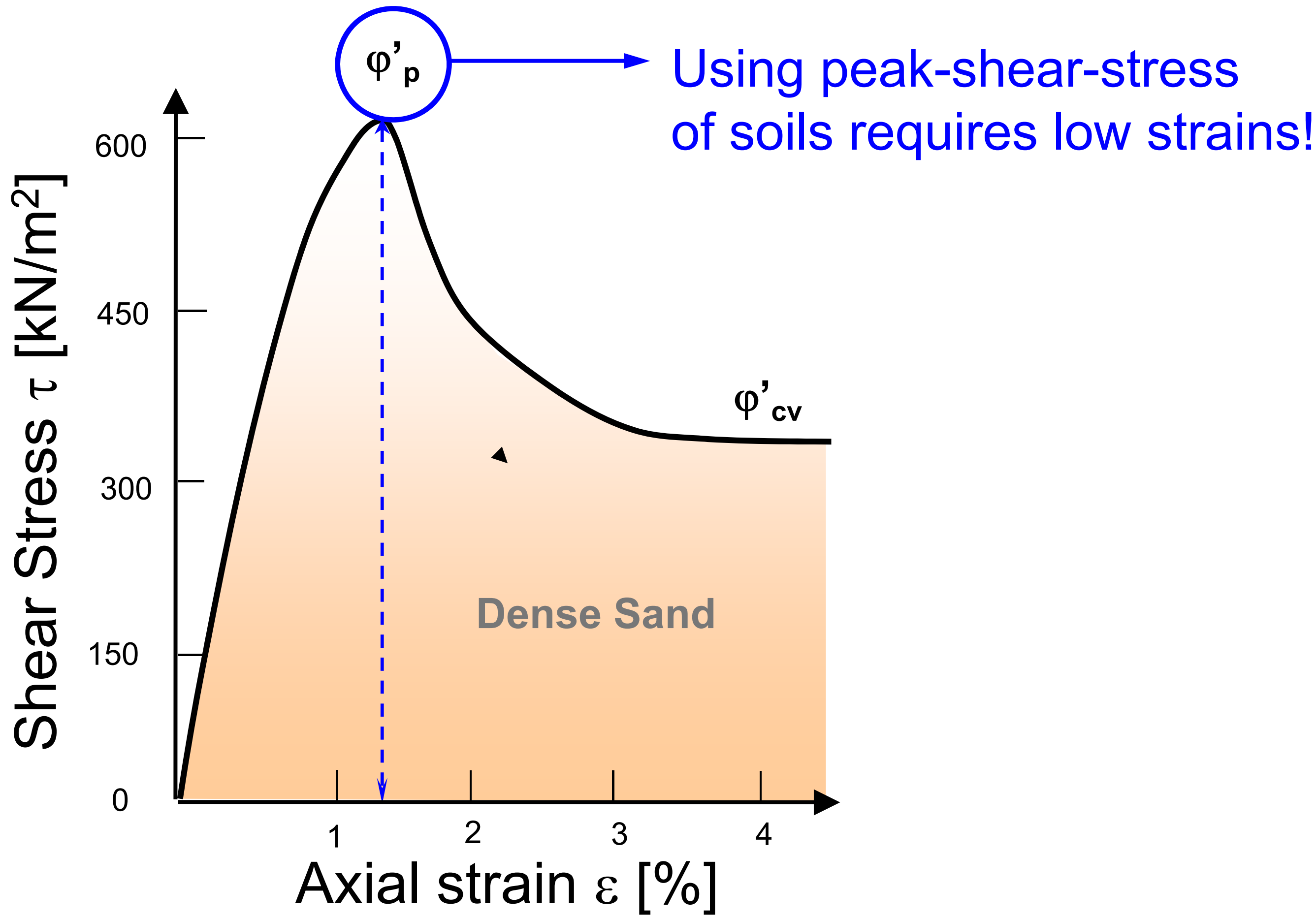
- friction
- interlocking



Aim:

Absorption of high tensile forces at possibly low deformation (high secant modulus)

Why is high secant modulus so important ?



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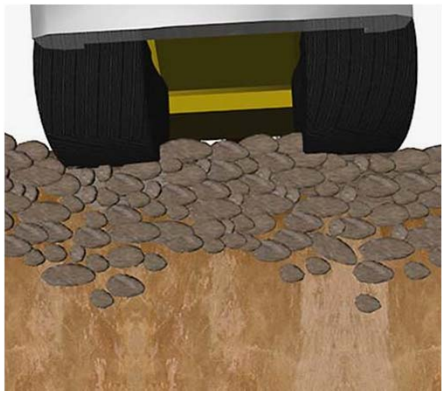
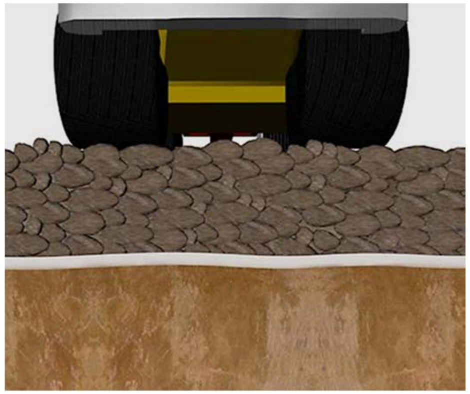
Why using reinforcement ?

Soil-Geogrid Interaction

Geotextile functions in base courses:



Without Geotextile

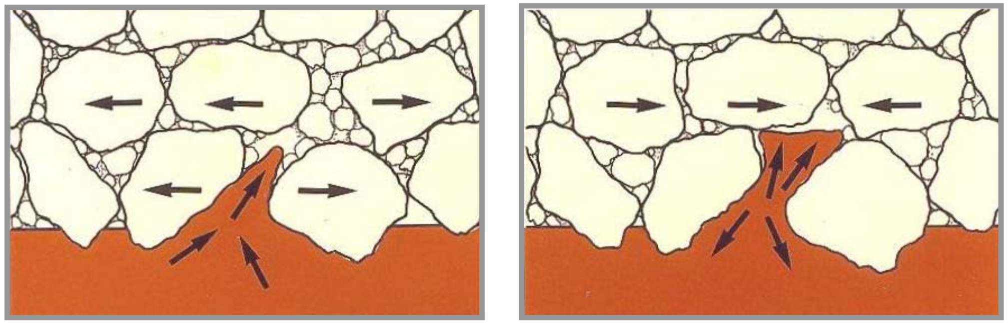


With Geotextile

The Geotextile has the following effects:

- *Separation:* Prevention of subgrade soil intruding into aggregate base, and prevention of aggregate base migrating into the subgrade (⇒ Reduction of pore pressure in the subgrade)
- *Filtration:* Restricting the movement of soil particles, while allowing water to move from the filtered soil to the coarser soil adjacent to it
- *Lateral Drainage*: Lateral movement of water within the plane of the geosynthetic

Geotextile functions in base courses:

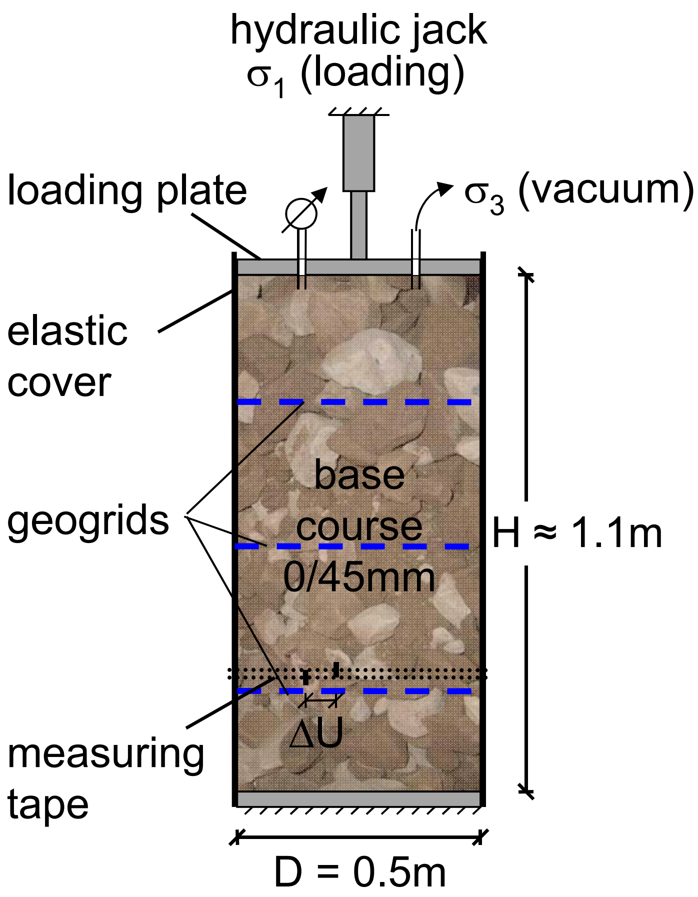


Pumping effect

The lack of separation, filtration & drainage leads to:

- Reduction of strength, stiffness and drainage characteristics of the base aggregate
- Higher risk of frost heaving, due to susceptibility of fine grained subgrade

Large triaxial Test (Technical University Aachen, Germany)



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$$\sigma_{1,\mathrm{unreinf.}} = \sigma_{1,\mathrm{reinf.}}$$

$$\varepsilon_{\mathrm{unreinf.}} >> \varepsilon_{\mathrm{reinf.}}$$

unreinforced

reinforced

Geogrid 1

Geogrid 2

Geogrid 3

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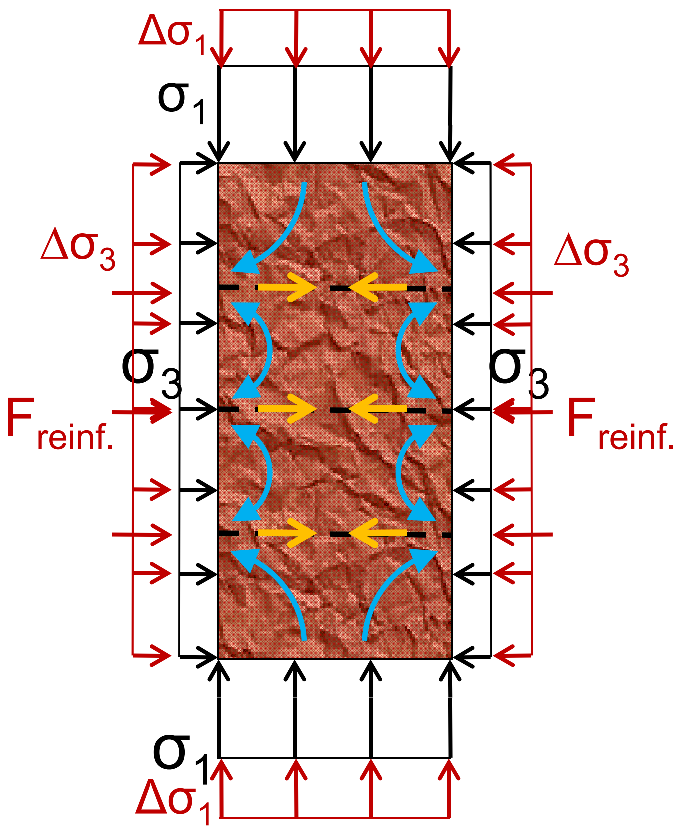
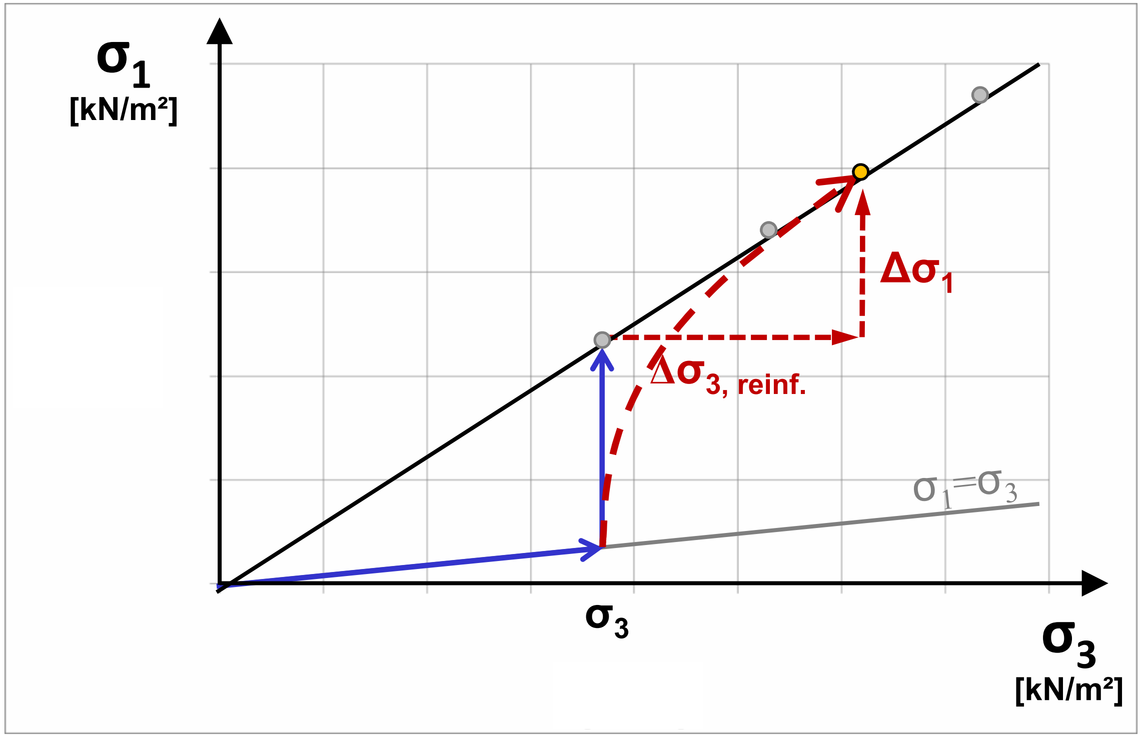
Stress path for reinforced triaxial test (CD)





Activation of the Reinforcement → $\Delta\sigma_3$: Additional Confining Effect → $\Delta\sigma_1$: Increase of the Load Bearing Capacity

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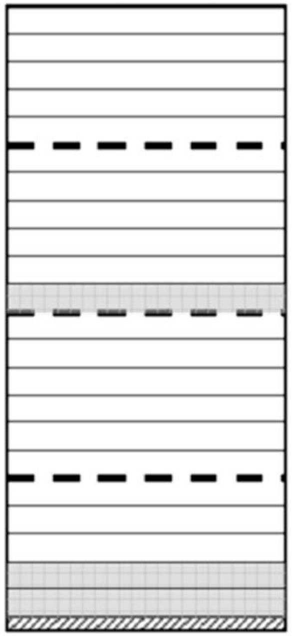
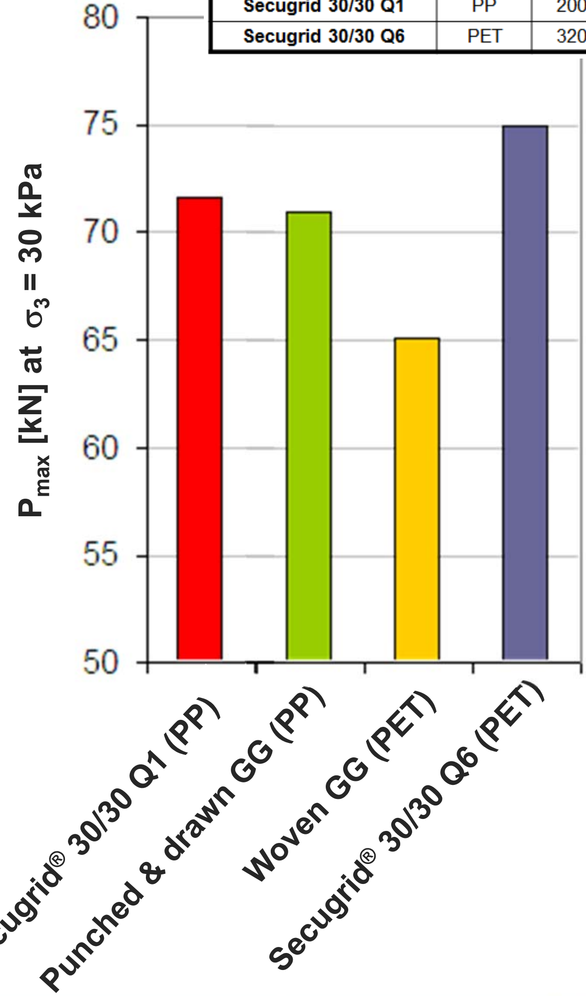
Max. Stress absorption capacity

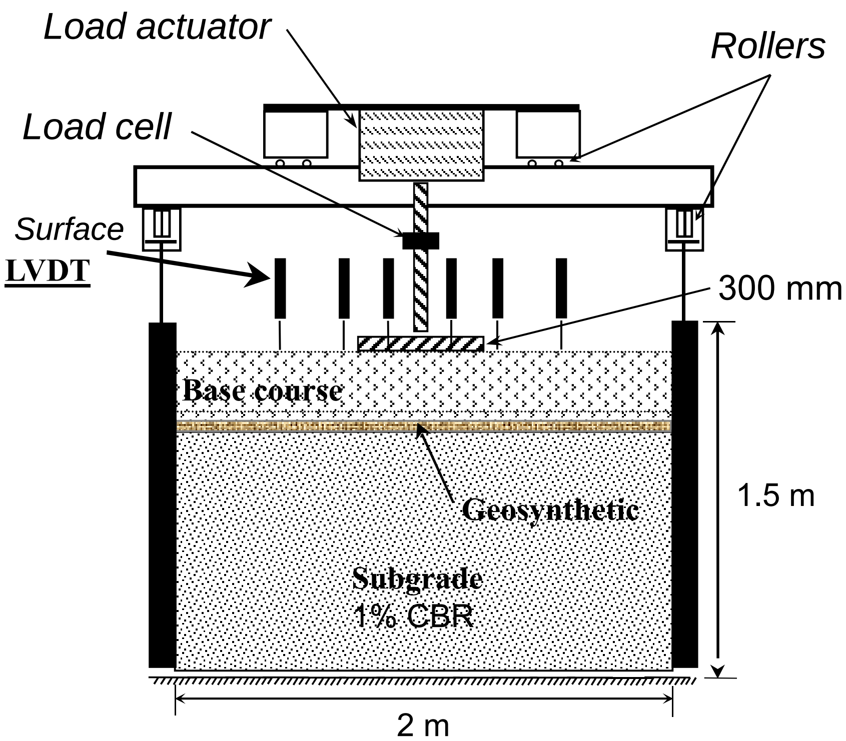
Geosynthetic	Polymer	Unit weight [g/m²]	Tensile Strength at 2% [kN/m] MD/CMD	Tensile Strength at 5% [kN/m] MD/CMD	Tensile Strength Ultimate [kN/m] MD/CMD
Woven GG	PP	300	8/8	15/15	35/35
Punched & Drawn GG	PP	160	10.5/10.5	21/21	30/30
Secugrid 30/30 Q1	PP	200	12/12	24/24	30/30
Secugrid 30/30 Q6	PET	320	13.5/13.5	24/24	30/30

3 layers of geogrids





Test Setup



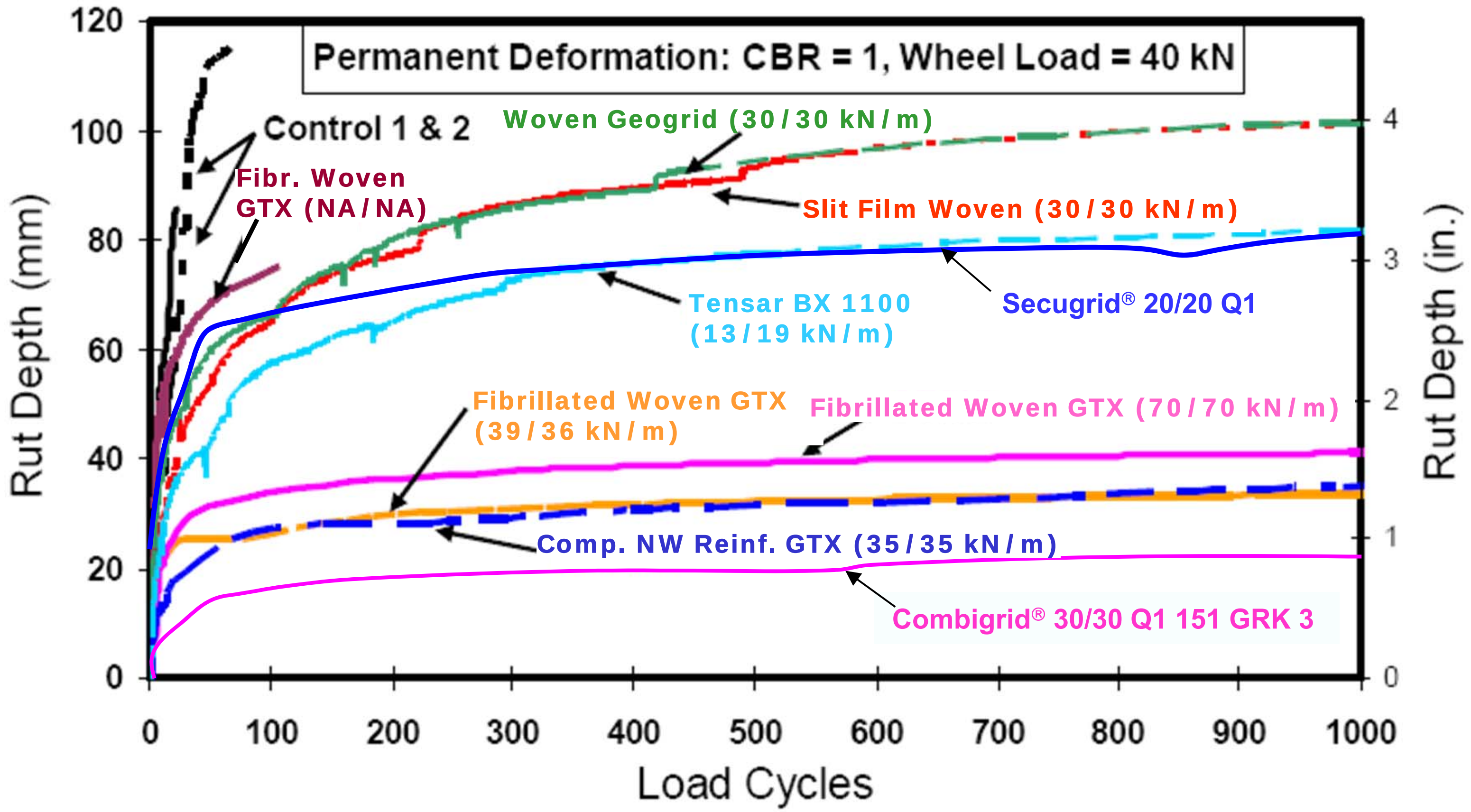
Boundary Conditions:

- Silt Subgrade (CBR = 1%)
- Subgrade thickness: 1.0 m
- Aggregate: Well graded gravel (0/30 mm)
- Aggregate thickness: 300 mm
- Cyclic load of 40 kN (dynamic wheel load)
- Three Test Sections:
  1. Secugrid® 20/20 Q1
  2. Combigrid® 30/30 Q1 151 GRK 3
  3. Control Section: No reinforcement!
- Displ. transducer measure surface deformation
- Strain gauges measure strain in geogrid

3. Independent Research Findings (Performance)

Load Plate and Displacement Transducer on aggregate surface

Permanent Deformation Response vs. Load Cycles



Source: *"Roadway Subgrade Stabilization Study"*, B.R. Christopher, B. Lacina
The First Pan American Geosynthetic Conference & Exhibition, 2-5 March Cancun, Mexico

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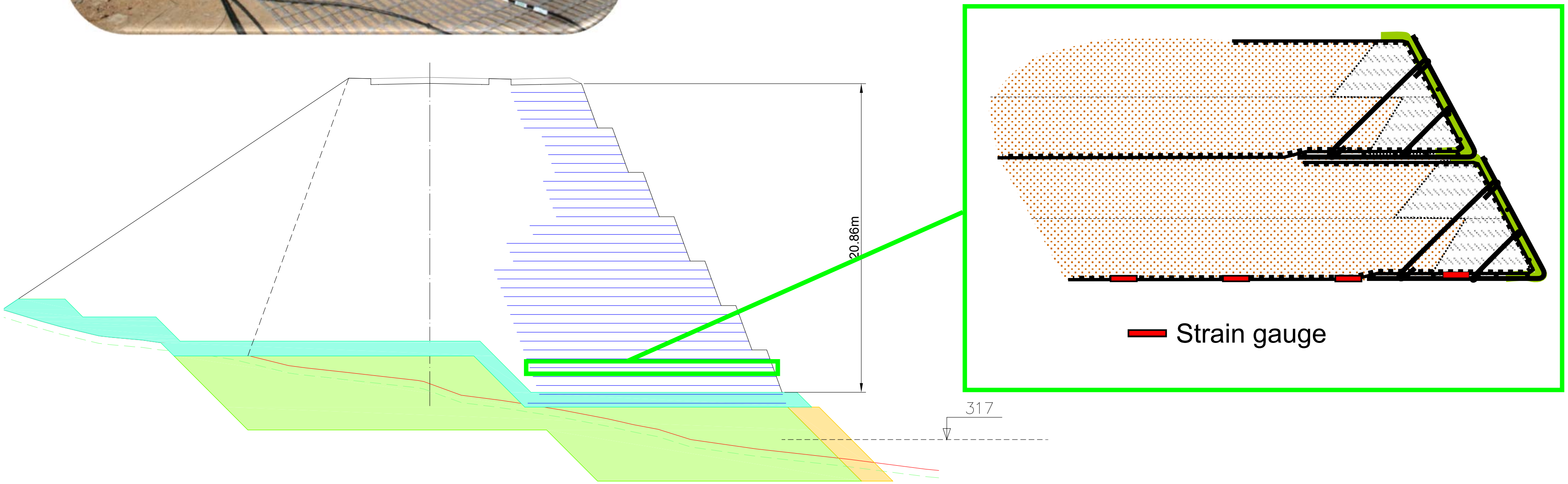
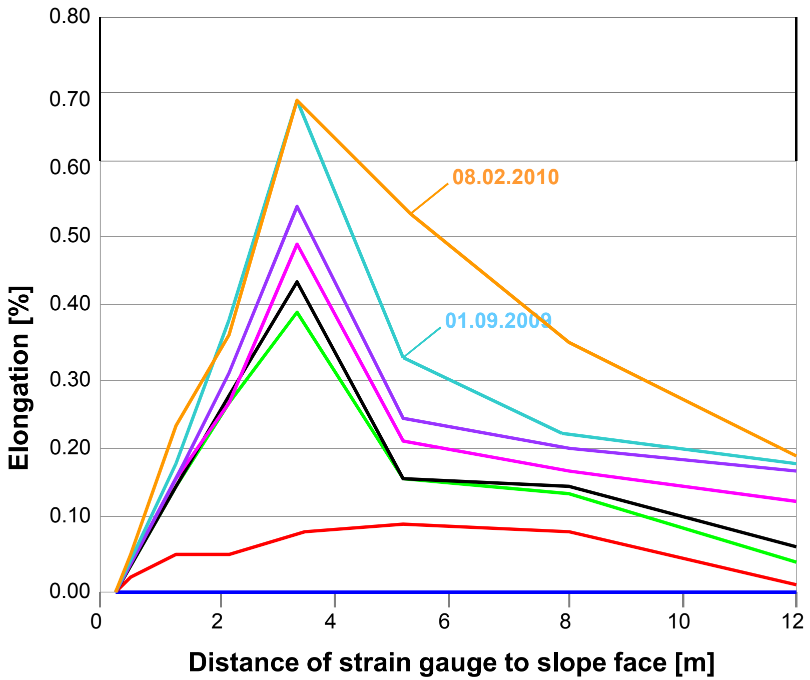
Long-term Strain Monitoring



Project: Isla Marina de Valdecañas, Spain (2008)



Strain Measurement

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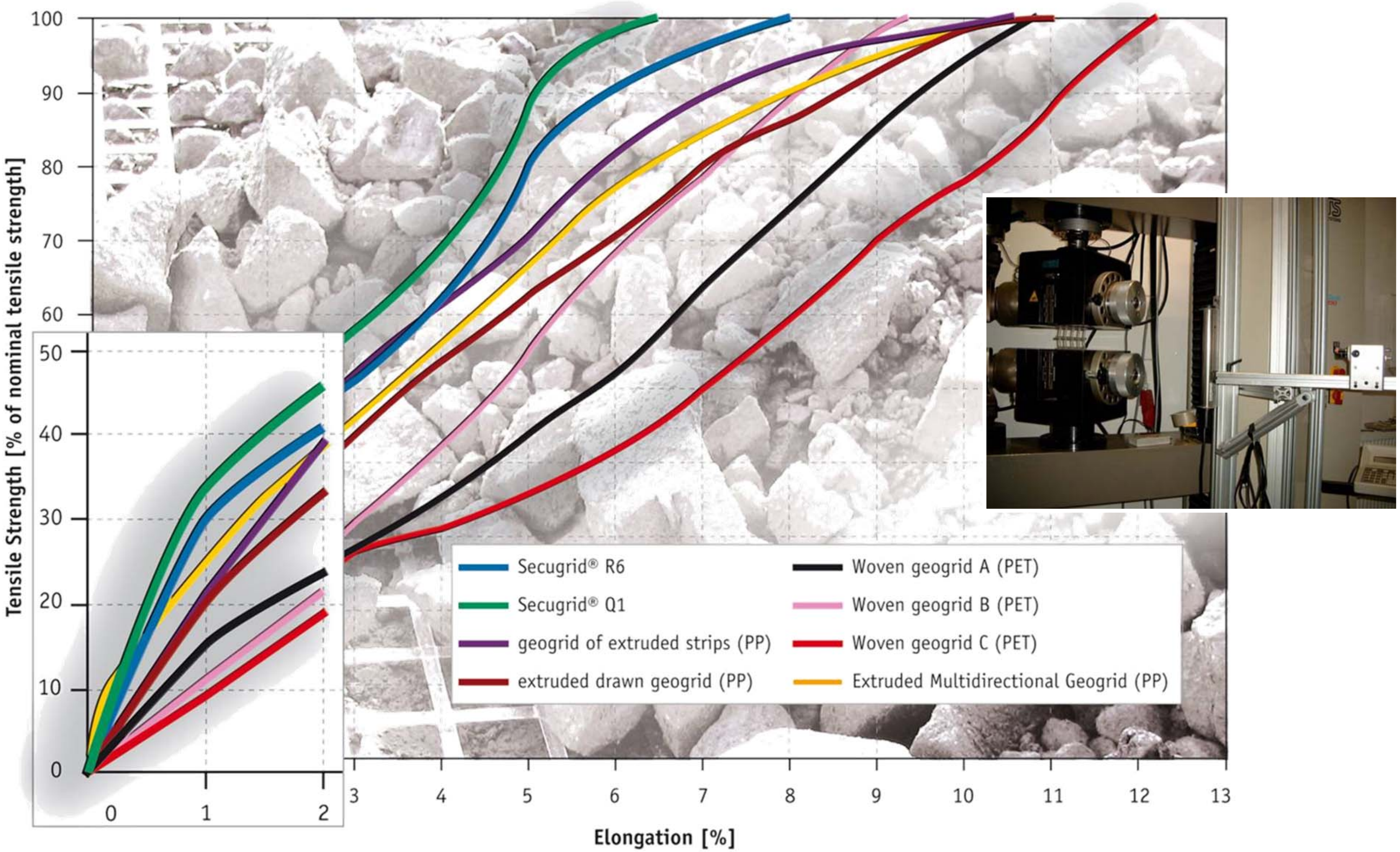
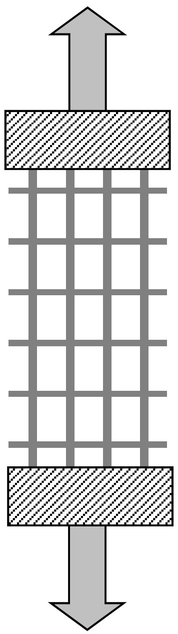
Biaxial Stress-strain behaviour (Secant Stiffness)

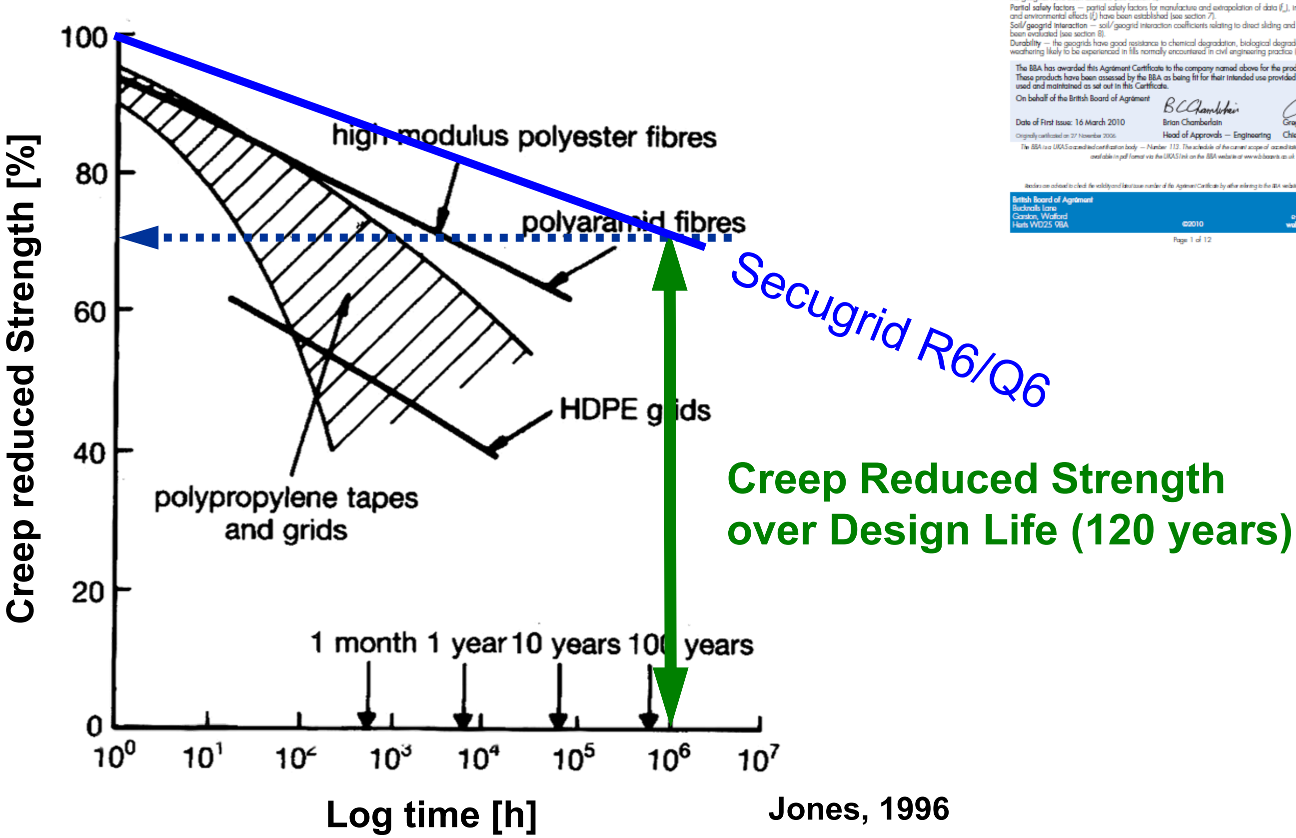


The behaviour of Geogrids made of polymers is mainly influenced by its thermoplastic characteristics,

defined by

- **Temperature** (approx. constant in soil)
- **<u>Stress</u>**
- **<u>Time</u>**





Jones, 1996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BBA APPROVAL INSPECTION TESTING CERTIFICATION

Roads and Bridges
Agrément Certificate
06/R141
Product Sheet 1

SECUGRID GEOGRIDS

SECUGRID PET GEOGRIDS FOR REINFORCED SOIL EMBANKMENTS

The Highways Agency requirements to which this Certificate is subject are detailed on page 2

PRODUCT SCOPE AND SUMMARY OF CERTIFICATE

This Certificate relates to Secugrid PET Geogrids for Reinforced Soil Embankments, polymeric geogrids for use as reinforcement in embankments with slope angles up to 70°.

AGRÉMENT CERTIFICATION INCLUDES:

- factors relating to compliance with Highways Agency requirements where applicable
- factors relating to compliance with Regulations where applicable
- independently verified technical specification
- assessment criteria and technical investigations
- design considerations
- installation guidance
- regular surveillance of production
- formal three-yearly review.

KEY FACTORS ASSESSED

Mechanical properties — short-term tensile strength and strain properties and long-term tensile strength properties of the geogrids have been assessed (see section 6).

Partial safety factors — partial safety factors for manufacture and extrapolation of data, installation damage and environmental effects have been established (see section 7).

Soil/geogrid interaction — soil/geogrid interaction coefficients relating to direct sliding and pull-out resistance have been evaluated (see section 8).

Durability — the geogrids have good resistance to chemical degradation, biological degradation, temperature and weathering likely to be experienced in fills normally encountered in civil engineering practice (see section 10).

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Long-Term Design Strength (LTDS)

The design- strength P_{des} of a geosynthetic reinforcing element according to BS 8006 is defined as follows:

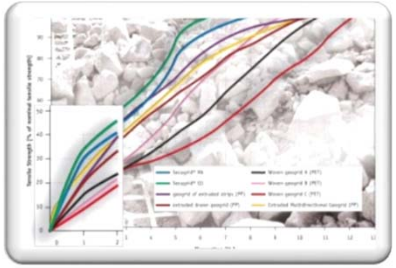
$$P_{des} = P_C / (f_d \bullet f_e \bullet f_m)$$

85.7 kN/m	P_C	**Tensile creep-rupture strength** (Secugrid® 120/40 R6, 120 year design life, (P_{STS}/1.40 for PET)
1.05	f_d	**Partial material factor – mechanical installation damage** (Coarse gravel < 35mm)
1.0	f_e	**Partial material factor – environmental effects (high pH soils)** (pH 4.1 - 8.9)
1.11	f_m	**Partial material factor – manufacture & extrapolation of test data** (120 year design life)

73.5 kN/m

73.5 kN/m / 120 kN/m * 100 ≈ 61.3 % Utilisation-Ratio

Geogrid:



- **Tensile Modulus**
  ⇒ **High strength absorption capacity at low strain, e.g. @ 2 %**

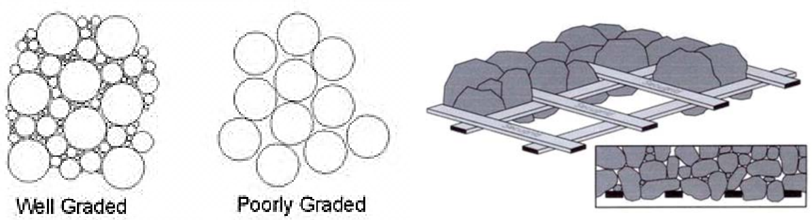
- **Long-term Design Strength**
  ⇒ **High residual creep-rupture strength**
  Low creep strain

- **Junction Strength**
  ⇒ **Sufficient strength at relevant stress level**

- **Robustness**
  ⇒ **High residual strength after installation**

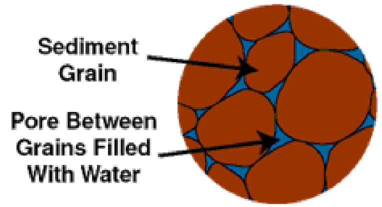
Fill Material:

- Particle shape / Angularity
  - Crushed / rounded
    - ⇒ Internal shear strength
    - ⇒ Interlocking with geogrid



- Particle size distribution / Grading
  - Well graded / poorly graded
    - ⇒ Interlocking with geogrid
    - ⇒ Degree of compaction

- Strength
  - Resistance to fragmentation (LA Coefficient)
    - ⇒ Internal shear Strength
    - ⇒ Interlocking capacity with geogrid



- Permeability
  - Fines content
    - ⇒ Potential development of pore water pressure
    - ⇒ Soil deformation behavior

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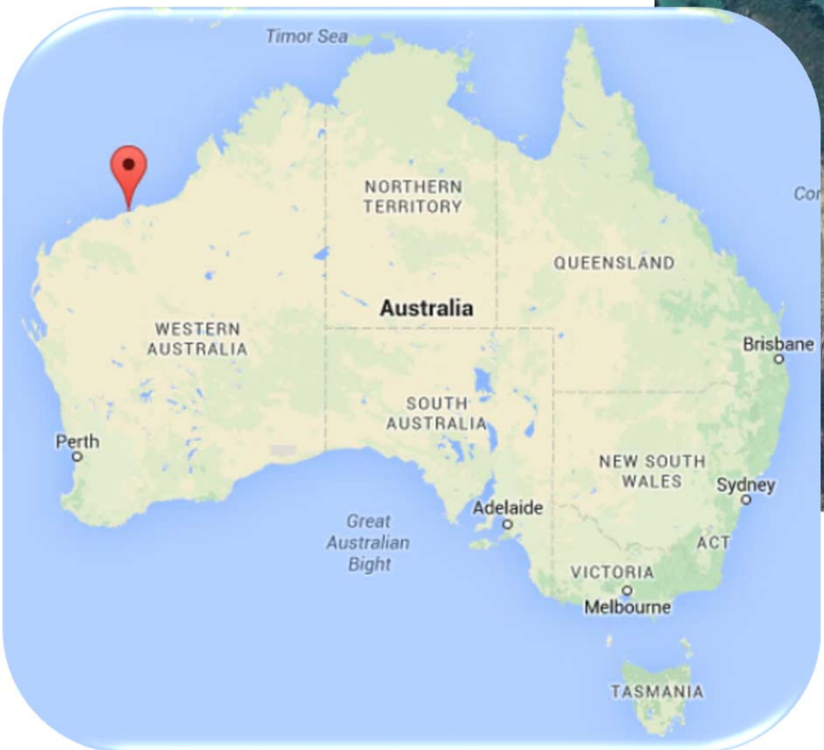
Utah Point Berth Project (UPBP) at Port Hedland

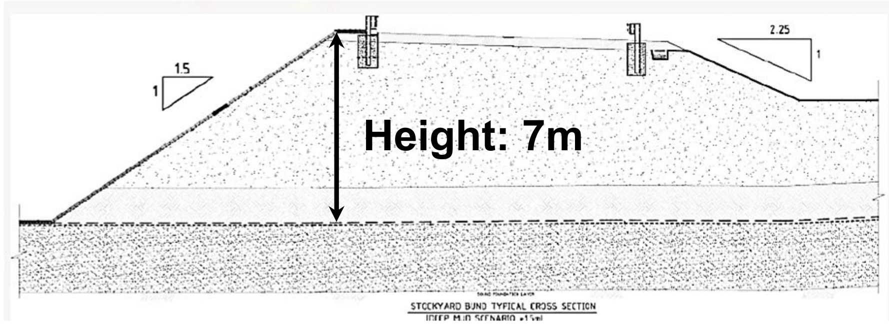
Project Boundary Conditions

- Australia is the world's largest iron ore exporter
- Ores from major mines in Western Australia's Hamersley Province of Pilbara region are hauled from working faces to the port sites
- Port Hedland is one of the largest ore export facilities in Australia
- Facilities have been under expansion based on growing global demand
- In 2008 Port Hedland Port Authority commenced construction of a multi-user bulk iron, manganese and chromite ore export facility comprising road, stockyards (13 stockpiles) etc.

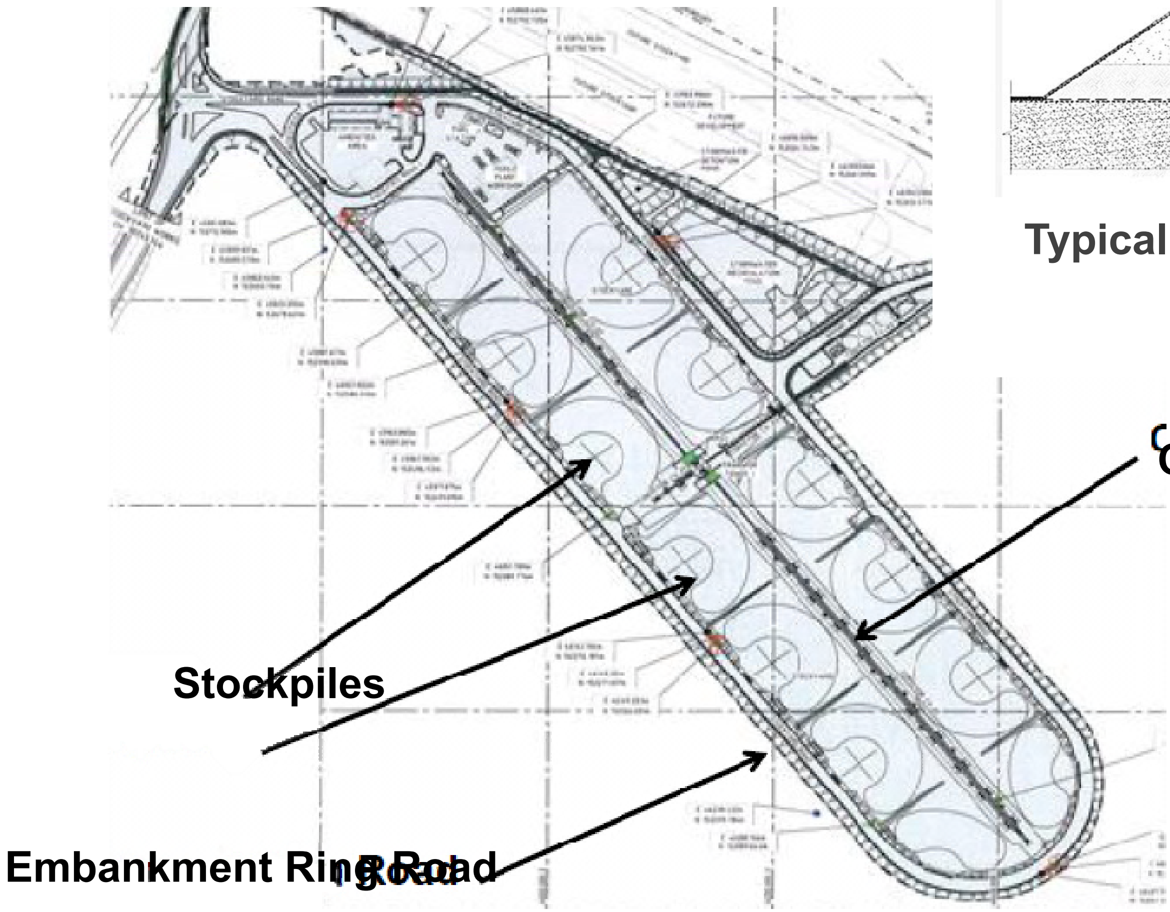
Site Location



Site Location



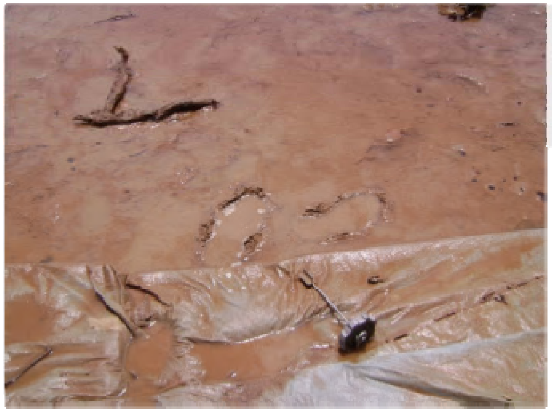
Typical Section: Embankment Ring Road



Multi-User Facility

Site Investigation – Access Issues

- Significant portion of the site was still covered with impenetrable mangroves at the time of fieldwork.
- Poor trafficability for machinery and personal access across areas with soft muds.



Soft Mangrove Muds

Mangroves

Cleared mangrove Zone

Geotechnical Parameters

Soil Unit Weight, Permeability and Strength

Material	Dry Unit Weight (kN/m³)	Permeability (m/day)	Strength Properties	
			Undrained shear strength (kPa)	Friction Angle (°)
Mangrove Mud	17	0.000215	10	-

Material	Dry Unit Weight (kN/m³)	Permeability (m/day)	Undrained Shear Strength (kPa)	Friction Angle (°)
Dredged Material	18	1	-	38

Construction Options

Several options were considered for construction approaches. Due to cost and time constraints the three main options considered were:

- Option 1: Removal of the Mud
- Option 2: End tipping / Mud displacement
- Option 3: Engineered Construction using Geogrid / Geotextiles and staged loading.

The Design Solution

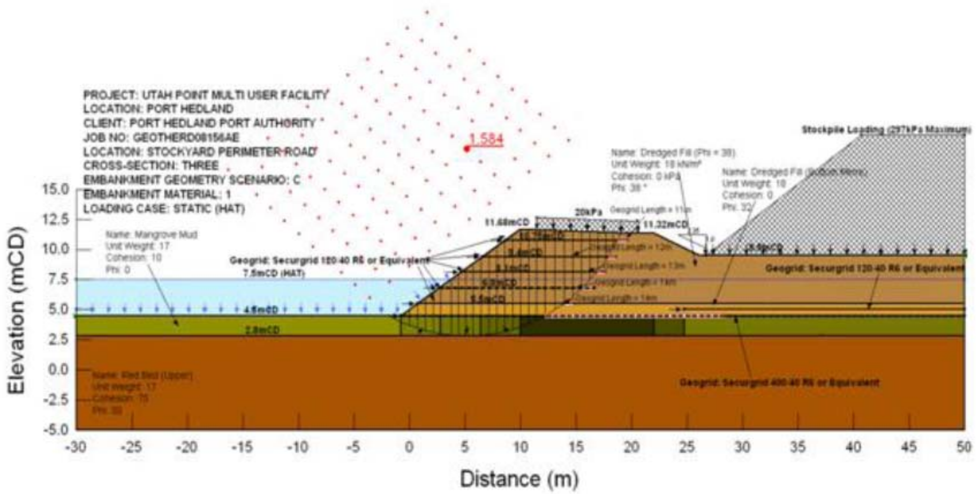
The final design solution offered by coffey included :

- Geotextile Base Layer
- Geogrid Basal Reinforcement Layer (Secugrid® 400/40 R6)
- Permeable Drainage Fill Layer (1.0m thickness)
- Embankment Geogrid Reinforcement (Secugrid® 120/40 R6)
- 500 mm lifts of fill with minimum 7 day consolidation periods between lifts

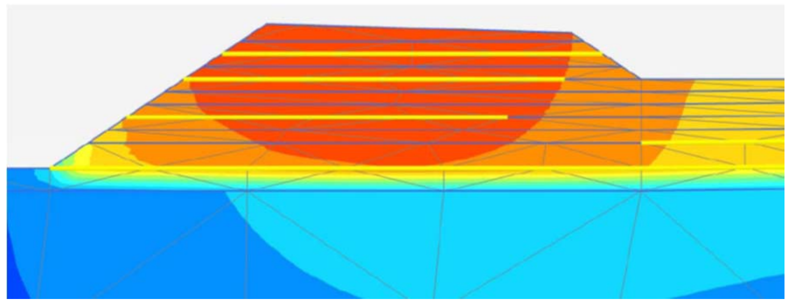
Stability and Deformation Analysis

Design

- Slope Stability Analysis for Road Embankment
- Finite Element (FE) Deformation and Stability Analysis
- 20 Year Design life of the structure



Slope Stability Analysis of Road Embankment
Highest Astronomical Tide Condition



Finite Element (FE)- Deformation Analysis
during Construction Phases

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Construction

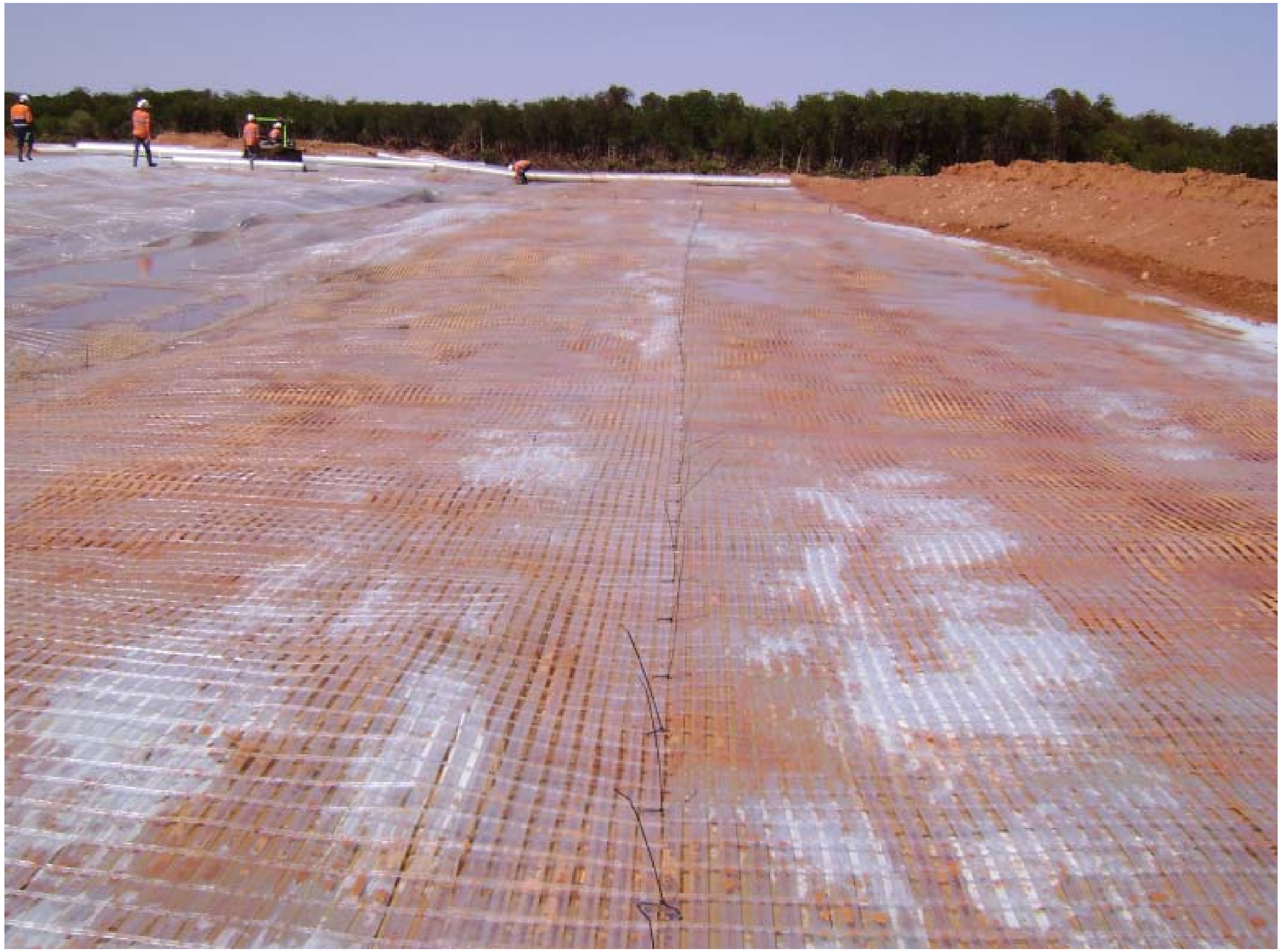
Step 1: Chainsaw Mangrove Tress

Construction

Step 2: Placement of Geotextile Layer

Construction

Step 3: Placement of Basal Geogrid (Secugrid® 400/40 R6)



Construction

Step 4 & 5: Placement of 1.0m thick fill layer & Embankment Geogrid (Secugrid® 120/40 R6)

Construction

Step 6 onwards: Placement of remaining fill & Embankment Reinforcement Layers

Conclusion

- The Utah Point Multi-User Facility was commissioned in 2010
- The instrumentation monitoring results at that point indicated settlements within the expected range
- The installation of high strength Secugrid® geogrid reinforcement allowed the most economical solution of all considered options
- The Utah Point Multi-User Facility won the 2011 “Australian Engineering Excellence Award” for implementing a range of innovative and new technologies

Thank you for your kind attention!