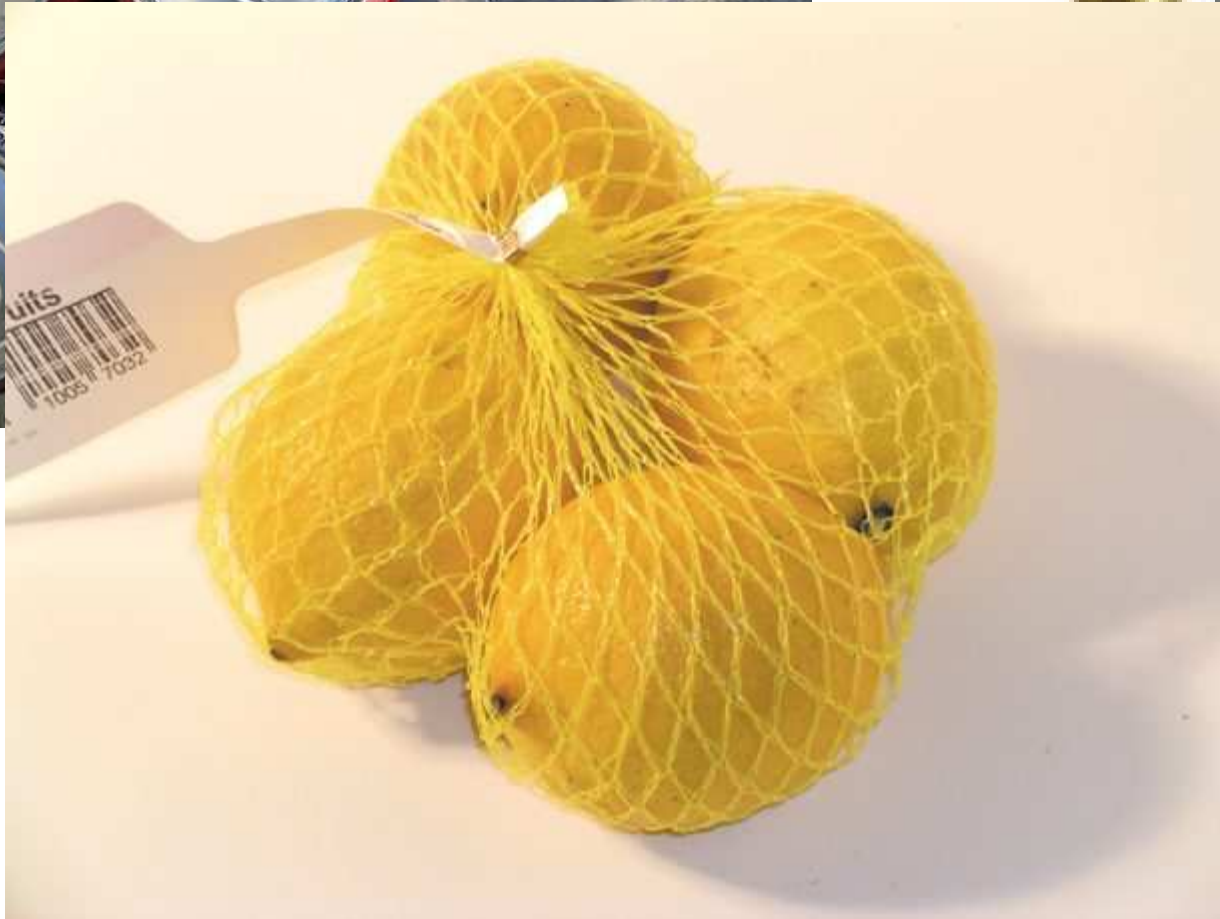


The design and construction of a 60m high reinforced soil retaining wall in the UAE

Ir Chaido Doulala-Rigby (Yuli) MHKIE CEng FICE
Chief Civil Engineer

1. A few words about Tensar
2. Case Study – a 60m high reinforced soil wall in the UAE





Portrait of Brian Mercer by Salvador Dali



Established in 1952 as
Netlon

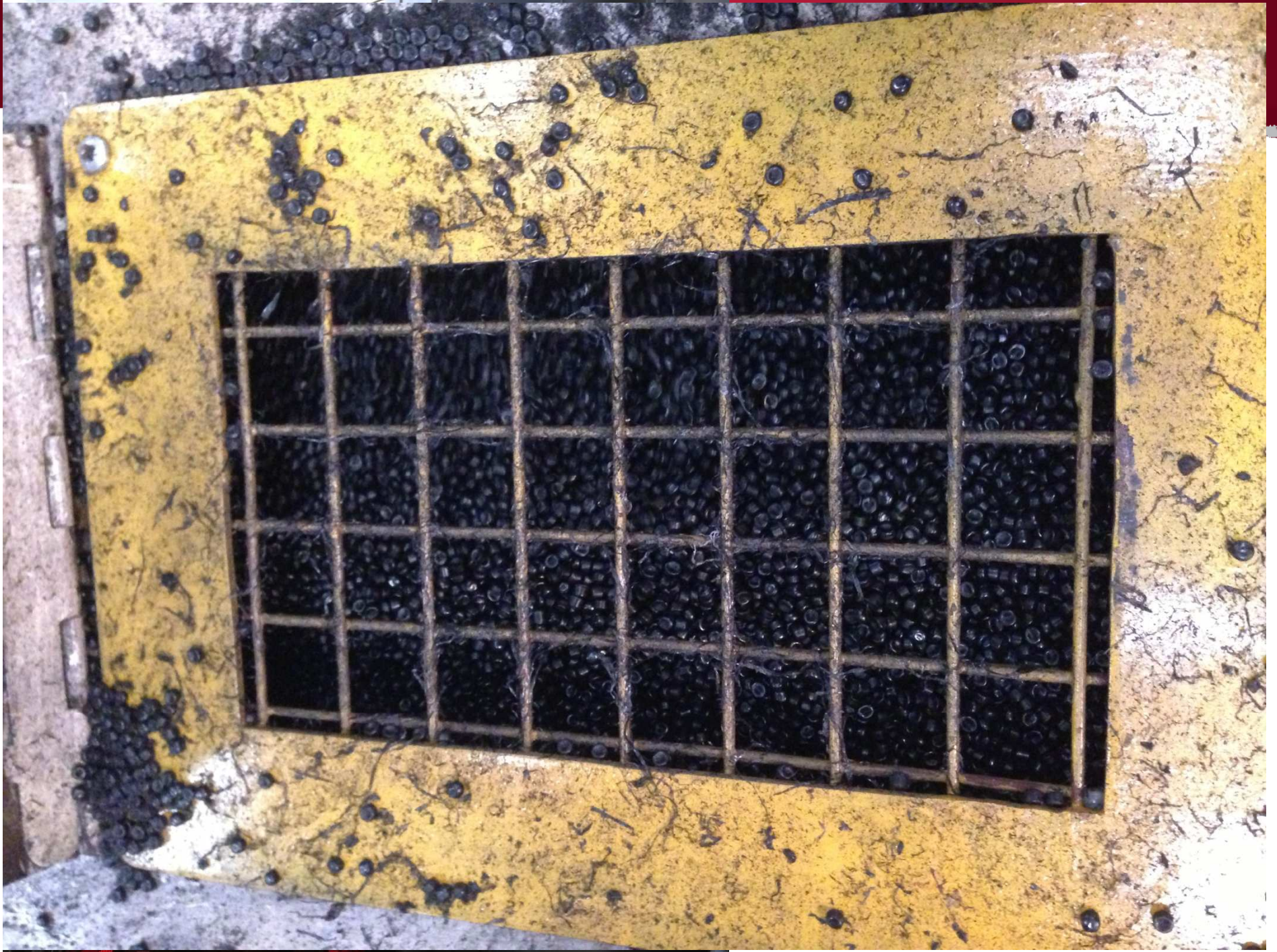
In 1980 invented the first
polymeric structural geogrid
ever

In 2002 renamed as Tensar

>400 Patented Products

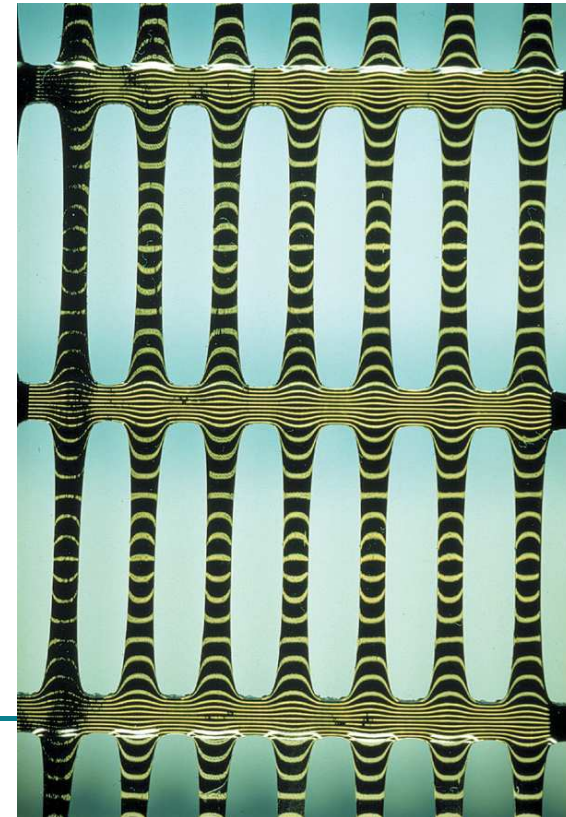
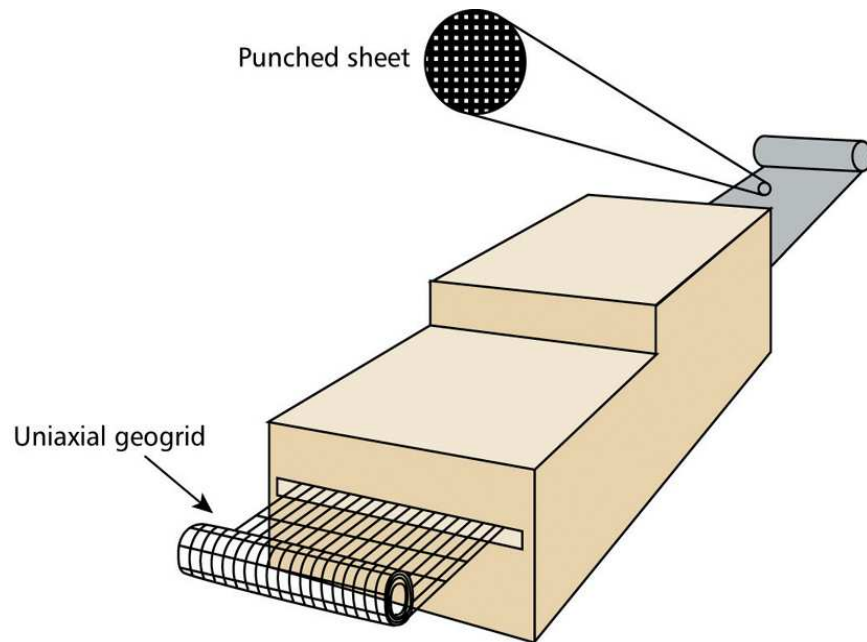
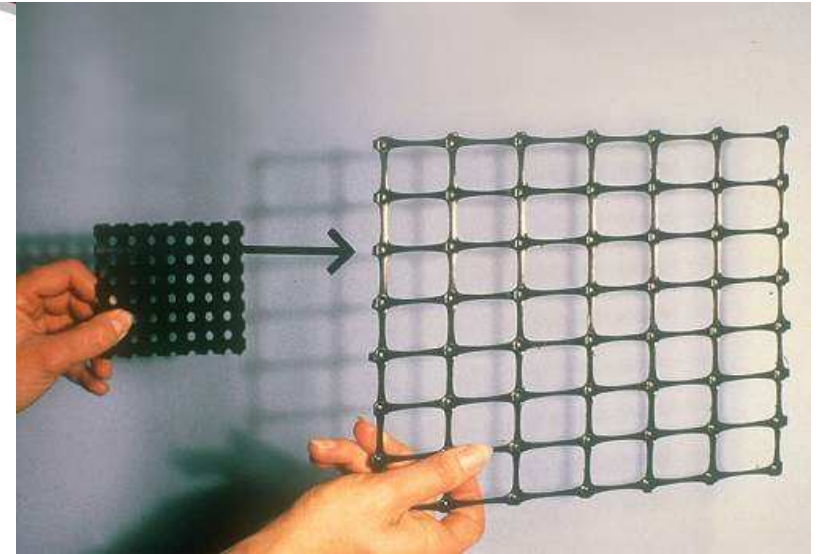
>700 Employees





The Tensar process

- **Polymer Extrusion**
- **Punch**
- **Stretch**



Tensor Applications – Reinforcement



Tensor Applications – Stabilisation

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Tensor Applications – Stabilisation

Tensor



Tensar Applications – Asphalt Reinforcement





Reinforced Soil Wall components

Tensar Structural Solutions

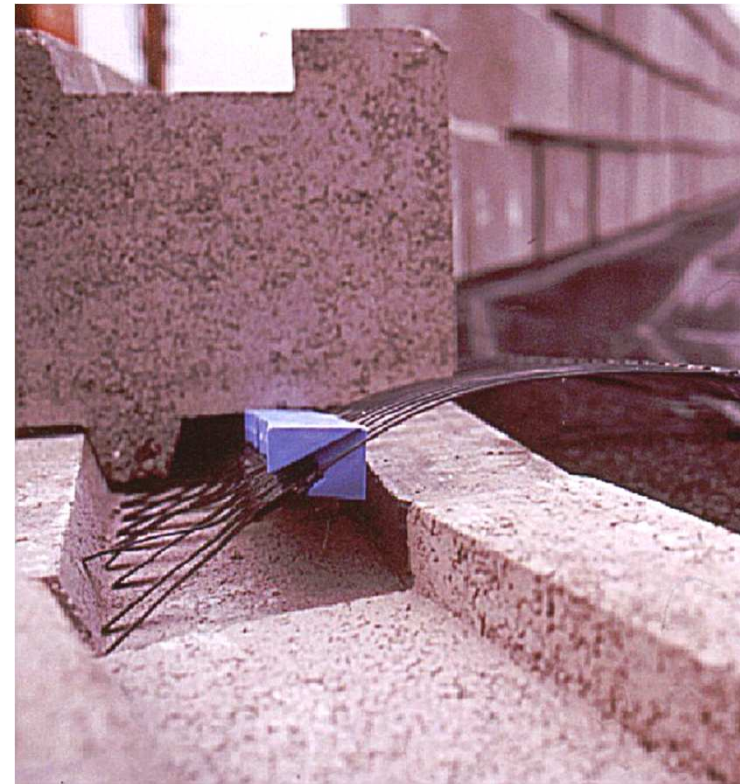
- 'System' comprise Four major components :
- modular face blocks, HDPE uniaxial geogrids, polymeric mechanical block connectors between the face blocks and geogrids and the reinforced fill material
- The modular face blocks are produced from an automated factory process using unreinforced, semi-dry concrete mix with minimum crushing strength at 28 days of 30 Mpa
- The uniaxially orientated HDPE geogrids are manufactured in the UK and tested in accordance with international recognised standards
- The mechanical polymeric connectors are also made of HDPE, specifically for the 'System' to provide high level of load transfer at the geogrid-block connection at all levels
- The fill!

Tensar Reinforced Wall System Components

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Polymeric mechanical connector



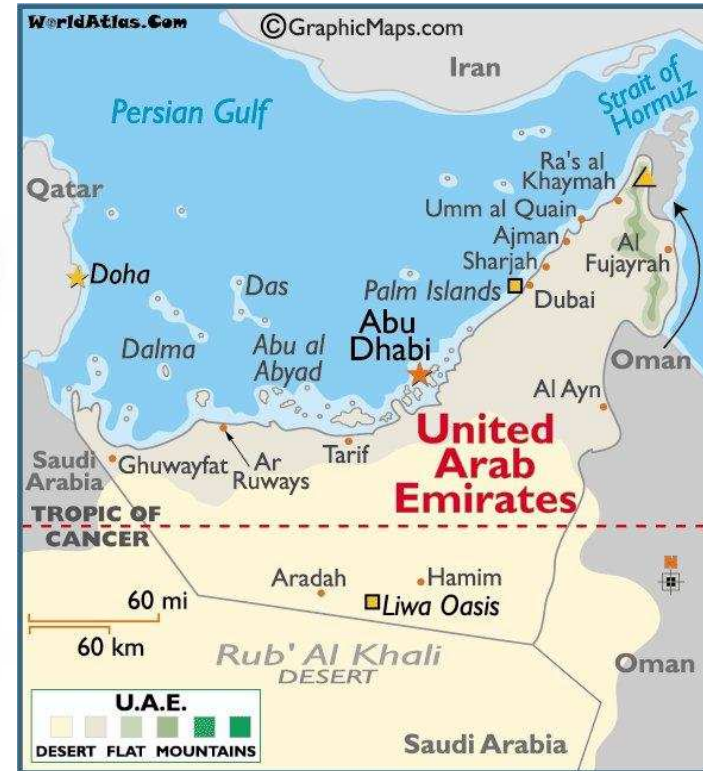
Modular face block with polymeric mechanical connector and geogrid



Case Study

Tensar Structural Solutions

Fujairah Project Location



What won the region's trust in Reinforced Soil? Dibba Road

Concrete Panel wall alternative

- 2005, 29km long, 8-lane wide new highway
- Mountainous region, road alignment through numerous gullies and steep sided valleys had to be bridged.
- Single tier walls with maximum height of 18m, 15m average wall height
- Cut and fill operation – 2.5 million m³ site won fill

Tensor walls in Dibba, UAE – 18m high

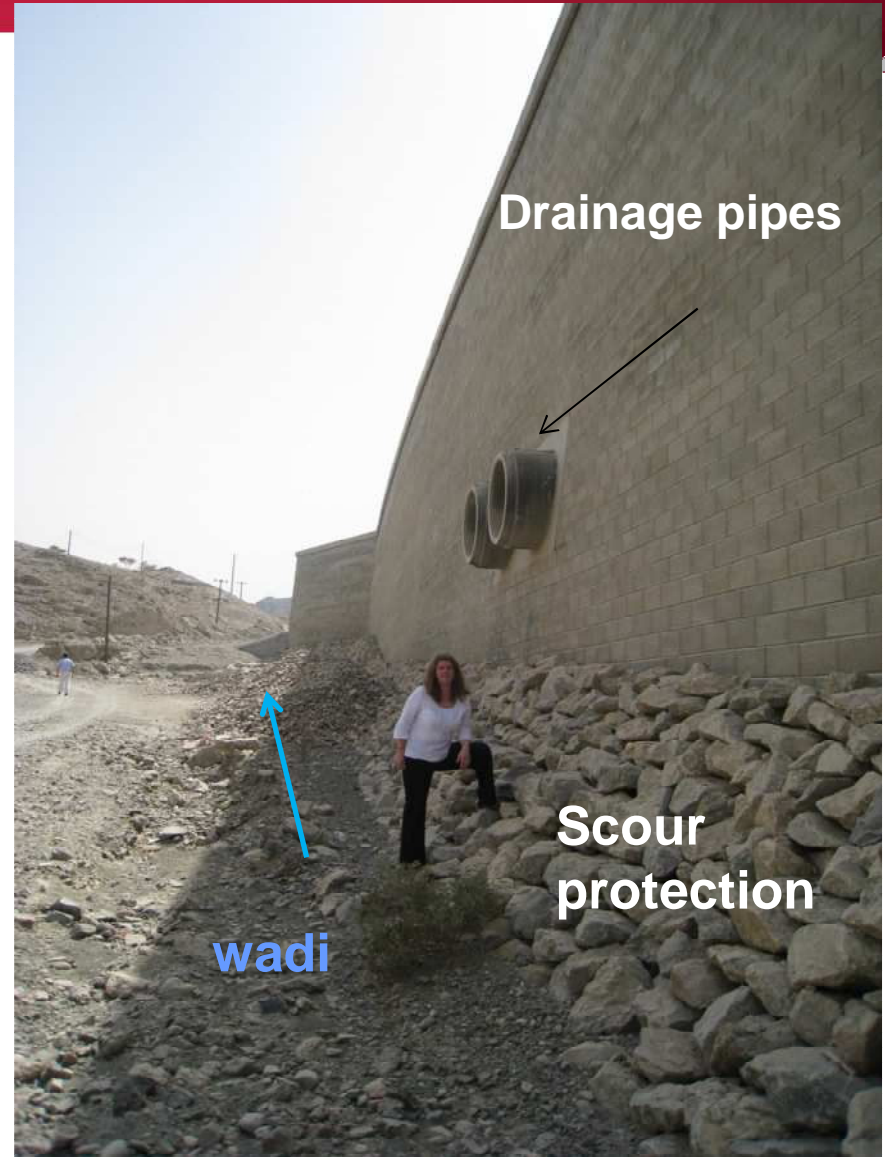
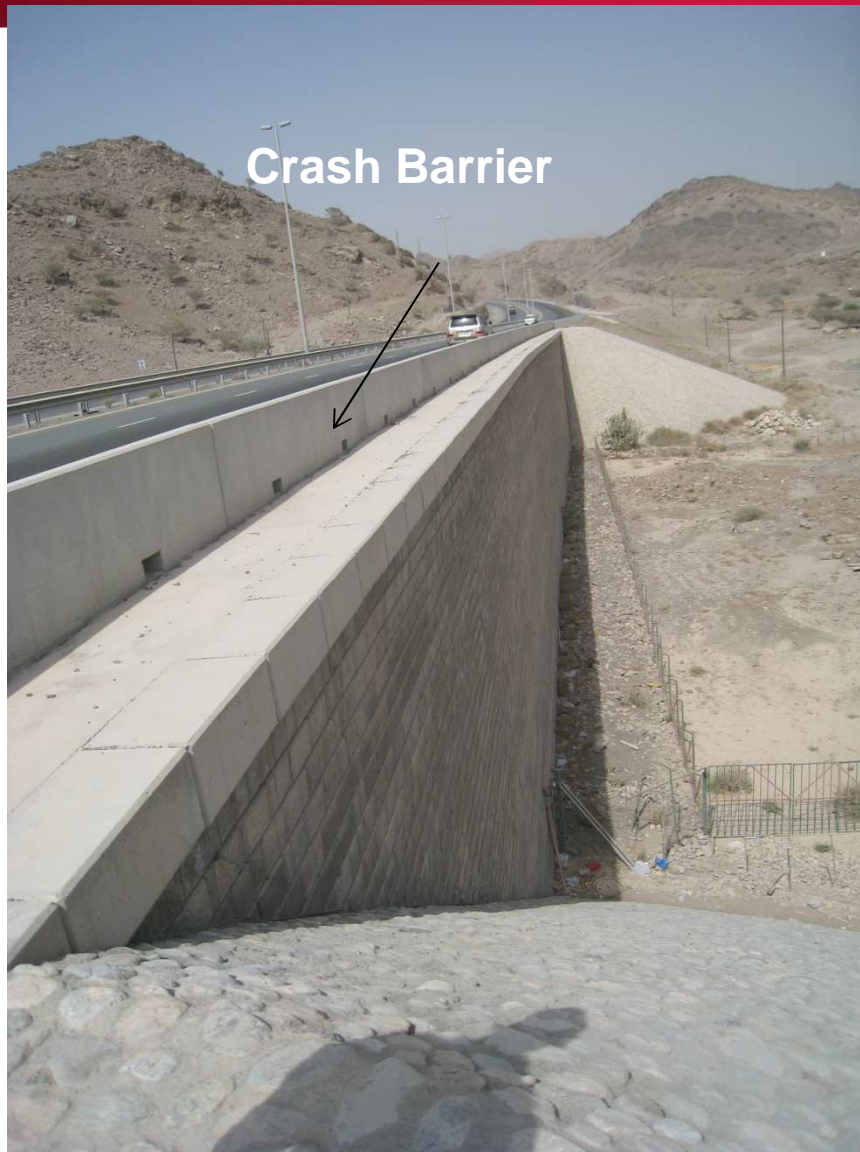
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Tensor Structural Solutions

Dibba Road Reinforced Soil Walls

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Dibba Road Reinforced Soil Walls

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Dibba Road Reinforced Soil Walls

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Dibba Road Reinforced Soil Walls

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Storm flood occurred before scour protection placement was completed at the wall toe



Dibba Road Reinforced Soil Walls

Tensar®

Face blocks displaced due to wash out of fines at the base of the wall due to inadequate scour protection but reinforced soil wall remained perfectly stable and highway above remained totally serviceable and open to traffic through the face restoration period



Dibba Road Reinforced Soil Walls

Tensar[®]

Restored face blocks and adequate scour protection placement complete at wall toe





Fujairah Tensar Walls, UAE

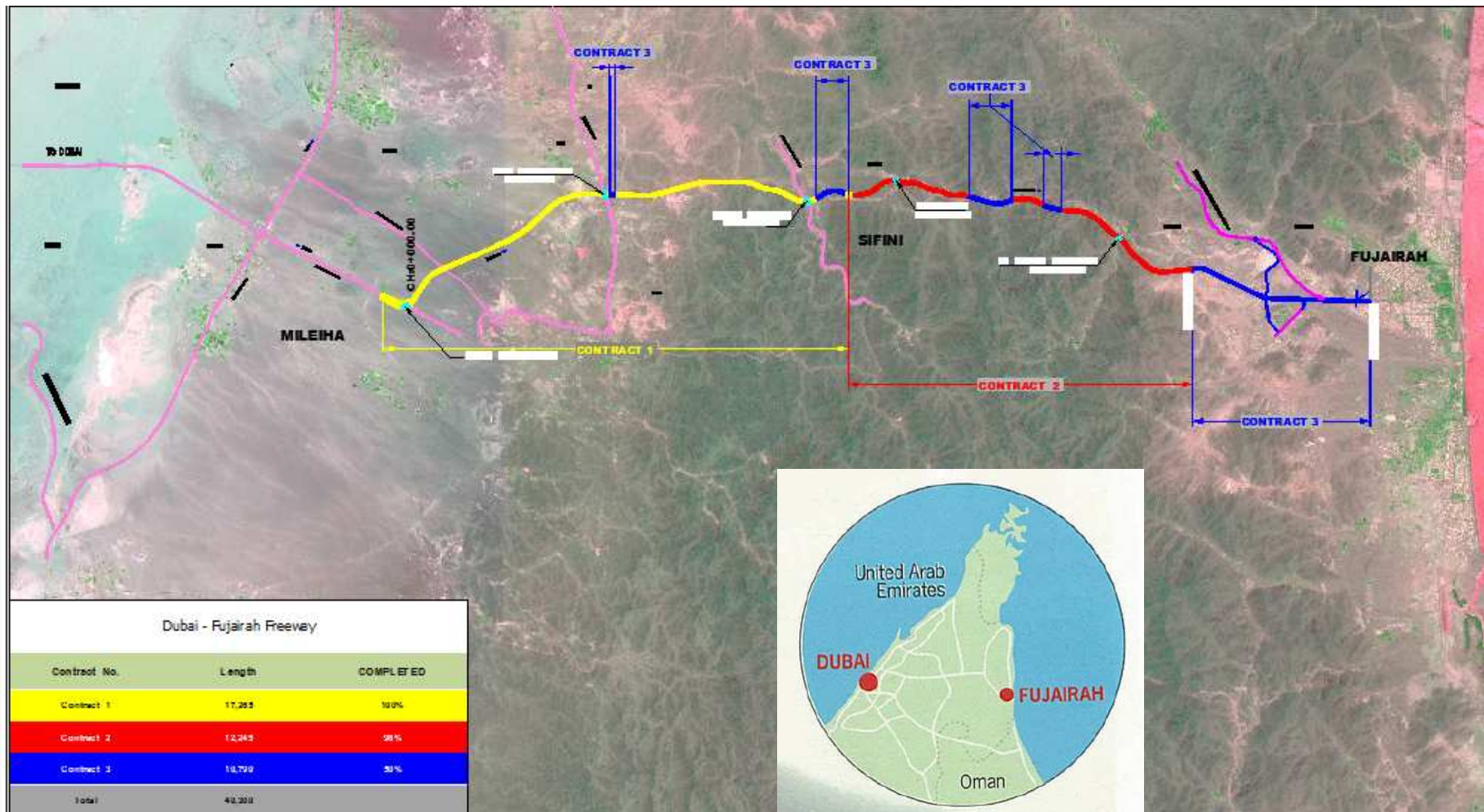
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Project Overview

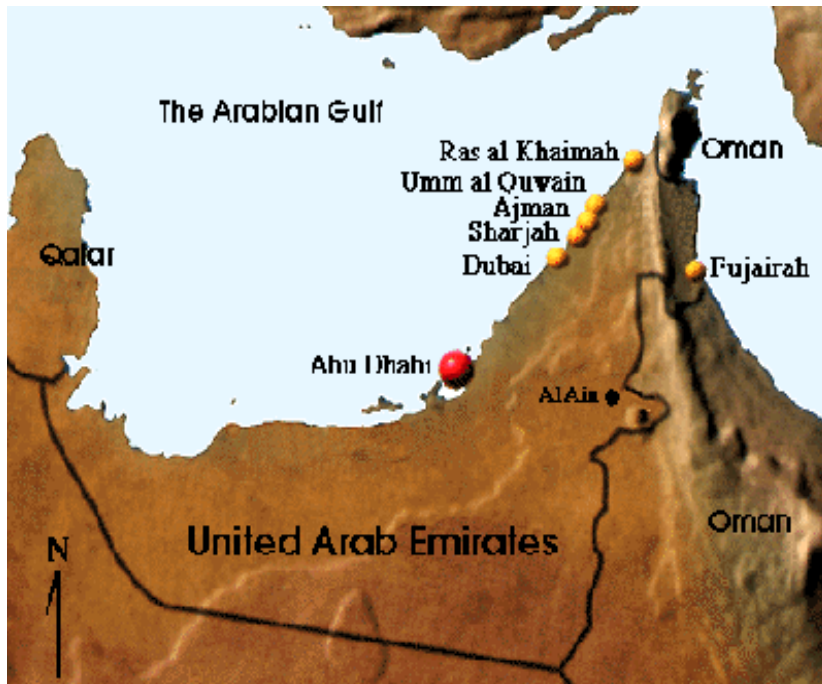
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- Next project in the region a new 10-lane Freeway to connect Dubai and Abu Dhabi to Fujairah
- Because Fujairah is the 5th largest Emirate in UAE and a busy port
- Project split in 3 Contracts: we will look at Contract 2
- Total freeway length when complete 80 Km, Contract 2 alone 45 Km
- Value of Contract 2 US\$300 million

Project Overview



3 Contracts, 80km long, 10 lane wide new highway



- Fujairah is on eastern coast characterised by narrow coastal plain
- Fujairah mountains are part of the Oman mountain range comprising Gabbro
- Topography dominated by the formation of deep gullies and wadis

Local Topography and Geology

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- Original proposal to bridge the valleys was viaducts
- Lack of access, lack of water resources and concrete curing being extreme difficult in the local extreme temperatures made viaduct option unfavourable
- Large amounts of available fill from the cut slopes to be used, reinforced soil modular block faced walls was the adopted alternative

Route Alignment proposal - Geometry

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Road alignment involved rock-cutting with depths up to 100m



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- Level difference in the deep valleys up to 60m
- In total, 22 valleys were bridged with 22 individual embankments formed with reinforced soil walls
- 3 types of reinforced soil walls were utilised:

Route Alignment proposal - Geometry

Tensar[®]

Single tiered walls with 86° face angle up to 22 m high







Route Alignment proposal - Geometry

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- Culverts at toe of Walls



Before



After

Geotechnical parameters

- Numerous shear box tests on sorted site won reinforced fill were carried out
- Effective internal angle of friction obtained in excess of $\phi' = 45^\circ$
- Peak Value adopted for design $\phi' = 42^\circ$,
- Constant Volume for internal stability , peak for external stability
- Density tests also carried out and density advised for design was $\gamma' = 22.4 \text{ kN/m}^3$

Soil Type	ϕ_{pk}' / ϕ_{cv}' ($^\circ$)	C' (kPa)	γ' (kN/m ³)
Reinforced fill (crushed Gabbro)	42/38*	0	22.4
Reinforced fill (crushed Gabbro, less graded)	40/36	0	22.4
Reinforced fill (in-situ Gabbro or engineered rock fill)	40/36	0	22.4

* ϕ_{cv}' : constant volume value

Site Won Fill Material - blasting

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Site Won Fill Material

Tensar®



Site Won Fill Material

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Site Won Fill Material

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Crushed and sorted reinforced fill stock pile, 37.5mm down



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Construction

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1. Construction of the 20m high earth-retaining reinforced walls
2. A cut section through the rugged mountain
3. Geogrid reinforcing the compacted Gabbro fill

polymer connector. The blocks are then laid dry without using mortar, removing the need for any water-based products to be used in the process. Fill is placed and compacted to 200mm thickness. The geogrid is laid between the compacted layers every 200mm-600mm.

After compaction, each layer of fill is tested to ensure that 95% or better compaction is achieved. Over 25 geogrid-reinforced walls are being installed, totalling 100,000m² of wall facing. This has required over 2.5M.m³ of fill.

All fill for the walls is taken from material removed in the cut section. The route is set on Gabbro, a solid rock that is harder than granite and which proved too strong for excavators to cut through. An intensive blasting operation, supervised by police officials, was necessary to remove over 9M.m³ of material.

The excavated material is crushed and graded to ensure it can be compacted to the requisite level. As well as minimising cost of material, the reuse of excavated site-won Gabbro also cut carbon emissions by reduc-

ing transport to and from site.

"It is a massive logistical challenge, but we have planned the construction of the cut and fill sections so we can simultaneously excavate materials from one site and reuse it immediately on the nearest fill section. This minimises the transfer of materials along the 45km site," says Christou.

Once the cut and fill sections are complete, surfacing works is carried out. Wet mix aggregate material is compacted to 98%-100% to create the base level, finished off with hot mix asphalt surfacing.

"This is a prestigious project in the Middle East. We have proved that development is possible in what was previously thought to be unworkable areas. Our solution has been quick and economical, without the construction of many tunnels and bridges to form the route in the mountainous regions," says Christou.

Between 100m³ to 150m³ of wall is being completed per day. With less than 18 months before handover to the Ministry of Public Works, over 60% of the route has been finished.

PROJECT FACTS

Client: Ministry of Public Works, United Arab Emirates
Contractor: National Wheel J&P (W J&P)
Consultant: Wilbur Smith
Supervising consultant: Dorsch Consultant
Geogrid designer and supplier: Tensar International
Project value: £202M

DESIGNING FOR DISASTER

Despite its location in the arid conditions of the UAE, the rugged ravines of Fujairah are susceptible to flooding.

Although downpours are rare in the Emirates, the consequences can be disastrous. Fast-flowing water rushes down the steep slopes and can wipe out entire villages. With one flood occurring in Fujairah every 20 years, the 45km road had to be designed with "the worst case scenario" in mind, says W J&P project manager Pantelis Christou.

Effective drainage will be installed throughout the arid land.

Pipe culverts will be incorporated below surface and in seven mountain, 4m wide culverts have been installed to drain rainwater.

In the retaining walls, the steepest ravine wide concrete box culverts are connected, creating a route that runs 16km reinforced soil-retaining walls.

Massive box culverts running through the reinforced retaining walls



- Geogrids were placed in between the compacted reinforced fill at vertical spacing typically varying from 200mm near the toe of the walls to 600mm near the crest of the slope
- Each compacted layer was tested on site to ensure 95% or better compaction was achieved – or at least that's what was specified!
- A 300mm wide drainage/filter layer was constructed behind the face blocks

Wall construction

- A 300mm wide drainage/filter layer was constructed behind the face blocks



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Wall construction

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KEEP OUT

MINIMUM HEIGHT 3.8m

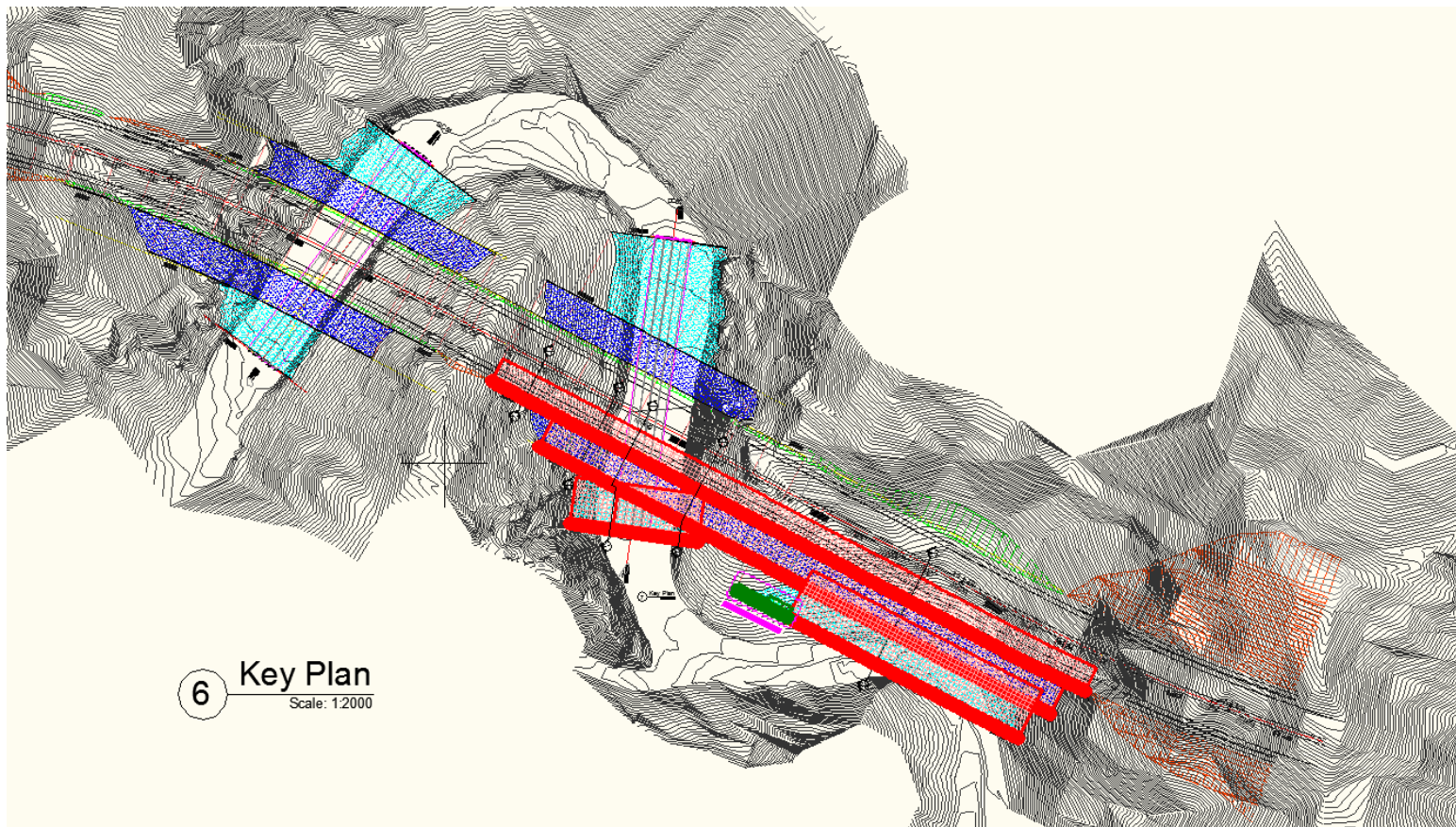
ENTER HERE

MAX SPEED 5 km/h



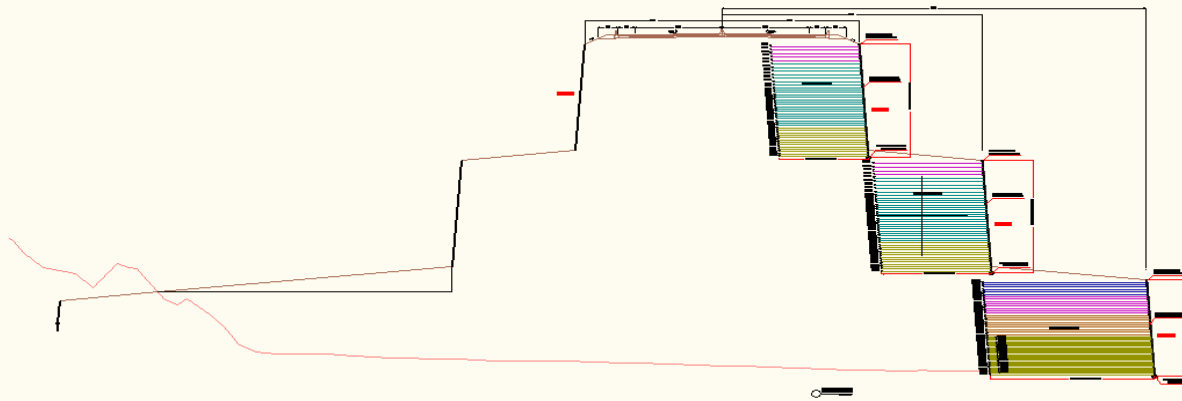
A Typical valley bridging

- Plan

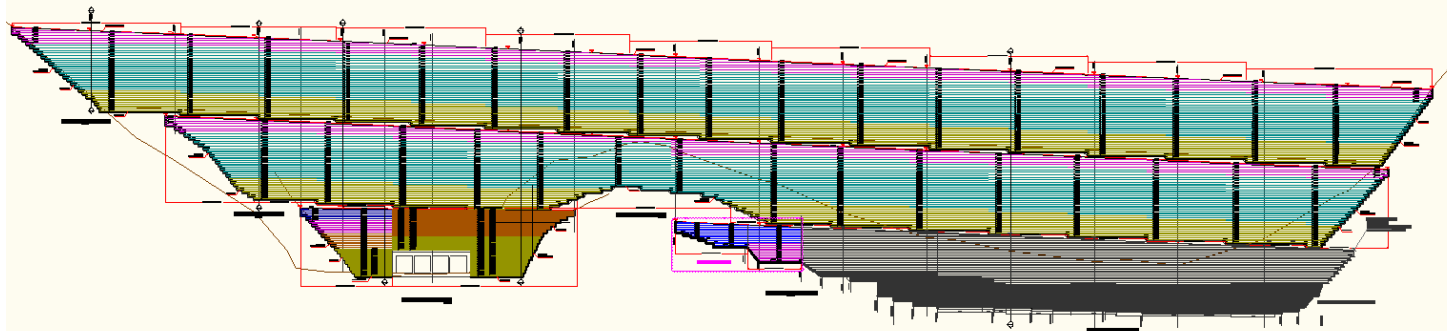


A Typical valley bridging

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Typical Section



Typical Elevation

Typical valley bridging – left hand side close up

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3-tier walls

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Typical valley bridging – right hand side close up

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Tensar Structural Solutions

3-tier walls

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- S



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Fujairah to Dubai Road Reinforced Soil Walls - Summary



- Fujairah Walls, UAE – 1.2 billion AED (\$300m US)
- Project was won following Dibba Road success
- viaduct alternative
- Cut an fill operation - Site won fill utilised – 14M.m³ blasted, crushed, sorted and reused
- No need for millions cu.m. imported concrete
- No need for excess fill off-site disposal
- Immense time and cost savings
- Speedy construction – rate of construction: 100m² to 150m² per day – total 100,000m²+ of Reinforced Soil Walls
- Almost negligible, for the scale of project deformations recorded – none visible to eye
- Reliable, low maintenance solution

Another Typical valley bridging

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