



Tunnelling Asia' 2023

International Conference on
Climate Change Resilience and Sustainability
in Tunnelling and Underground Space



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Glass Fiber Reinforced Polymer (GFRP) Applications in Tunnels



by

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Dextra



November 22-23, 2023, Mumbai, India

Fiber Reinforced Polymer (FRP)



Fiber

Glass

Carbon

+

Resin

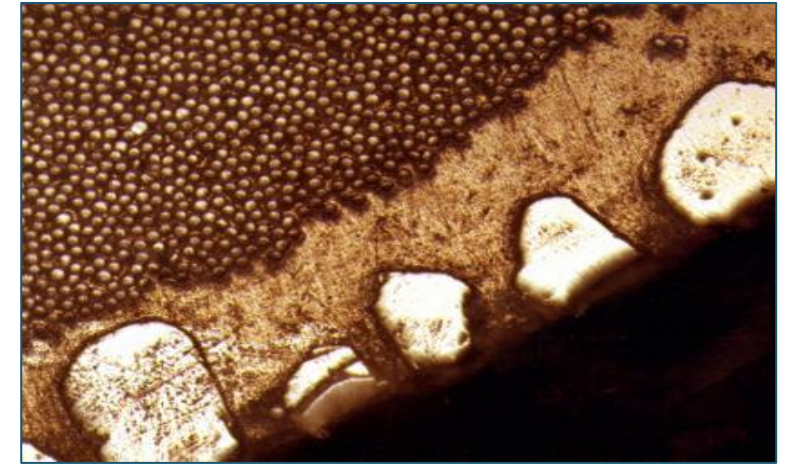
Poly-ester

Vinyl-ester

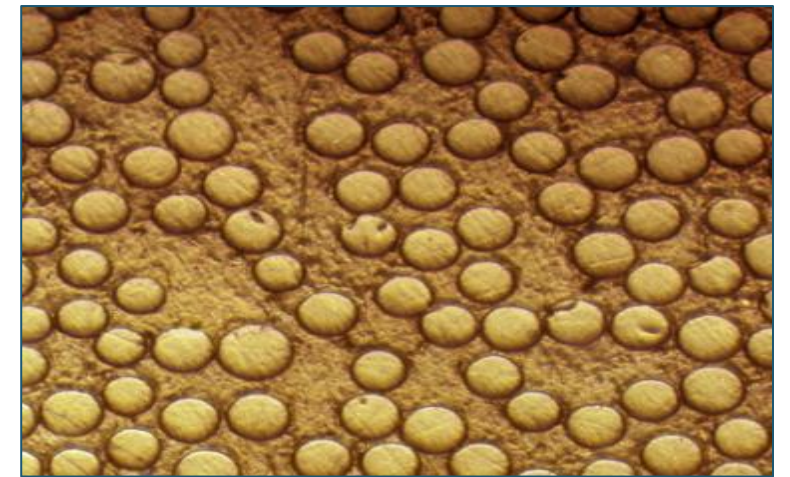
Epoxy

Temporary

Permanent



Light Microscopy 60X



Light Microscopy 240X

- ✓ Cut - ability
- ✓ 1/4 weight of steel
- ✓ Tensile strength greater than steel
- ✓ Corrosion resistant
- ✓ Electrically Non-Conductive.
- ✓ Thermally Non-Conductive.
- ✓ Transparent to magnetic fields & radio frequencies.



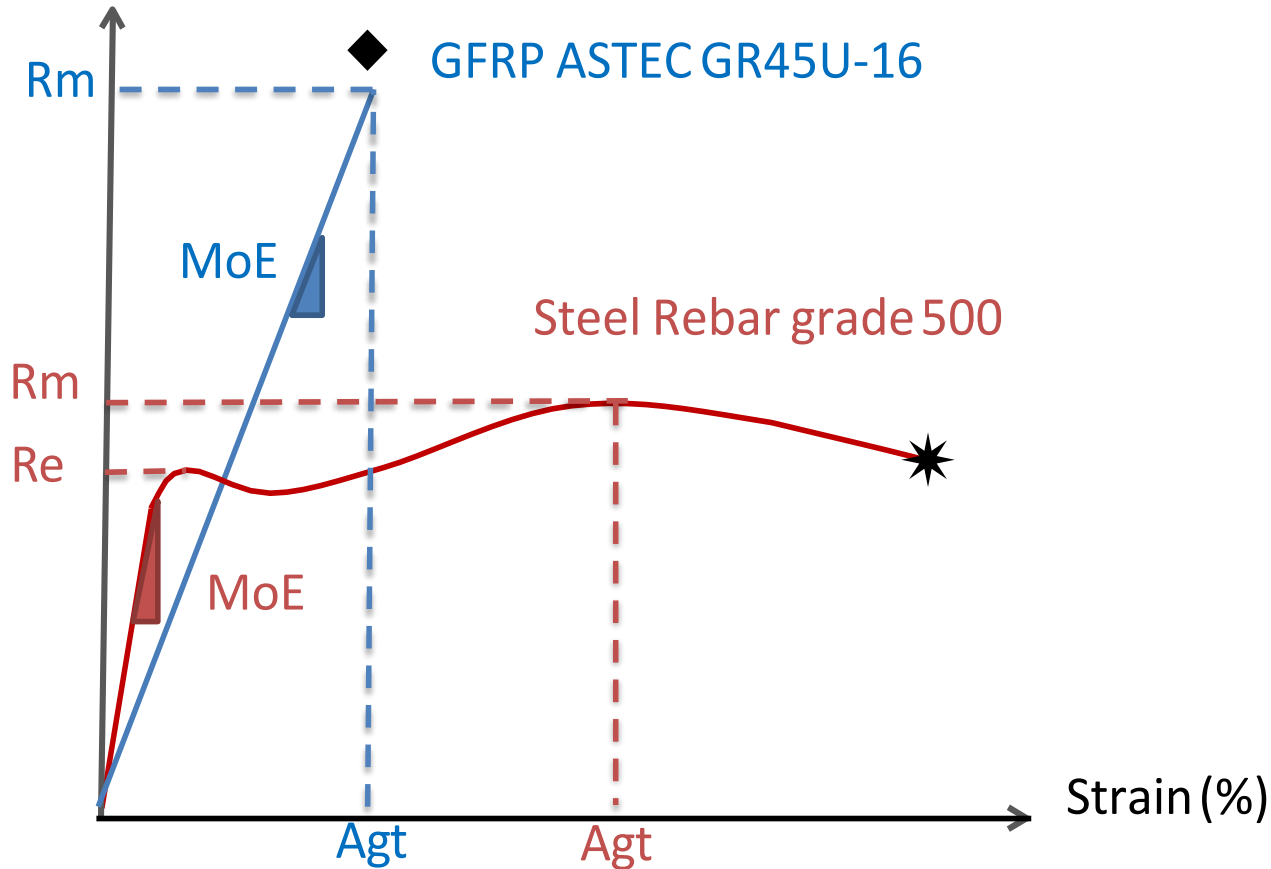


Tensile = Steel Vs FRP



Tensile test as per ASTM D7205-12

Stress (MPa)



An ACI Standard
An ANSI Standard
Building Code Requirements for Structural Concrete Reinforced with Glass Fiber-Reinforced Polymer (GFRP) Bars—Code and Commentary

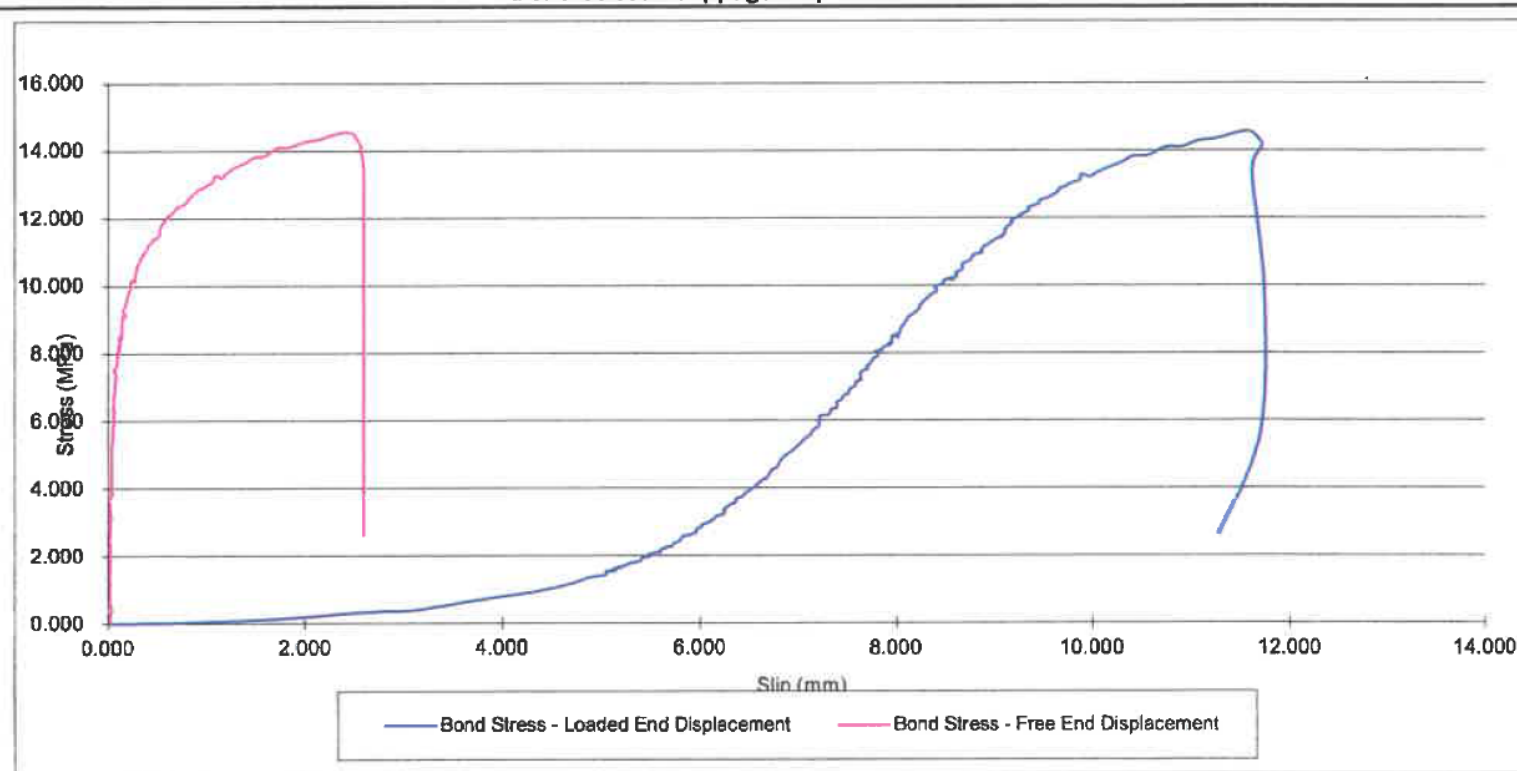
Reported by ACI Committee 440

ACI CODE-440.11-22



Mean = 13.8 MPa (OD=41mm / Oct 2021)
As per ACI 440.3R-04 – Clause B3 (HK Lab)

Bond Stress - Slippage Displacement Curves



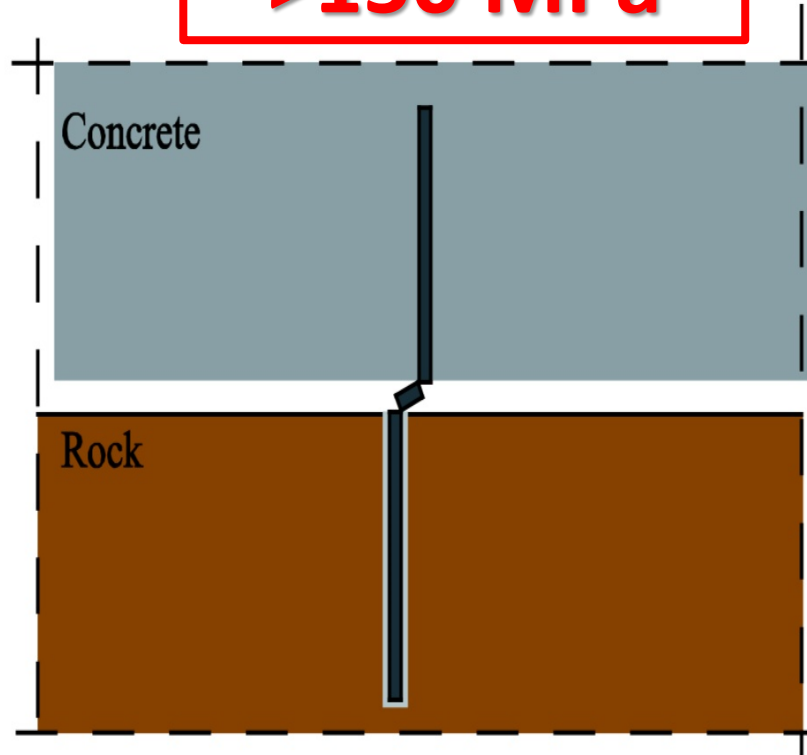
Cuttability vs Shear Capacity

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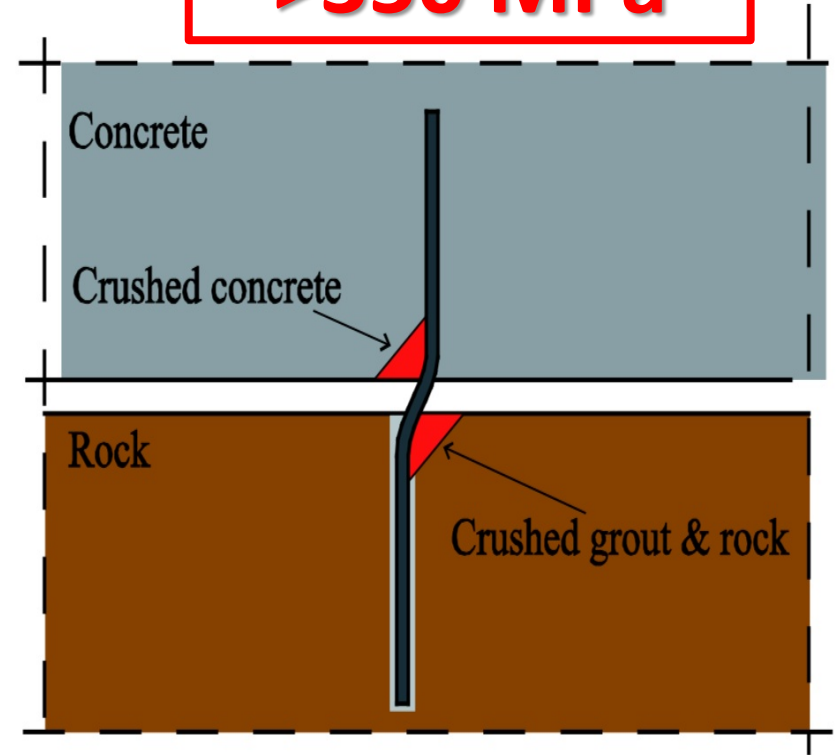
On Site Test:
Saw Test

>150 MPa



Dowel Effect

>350 MPa



Crushing of surrounding material

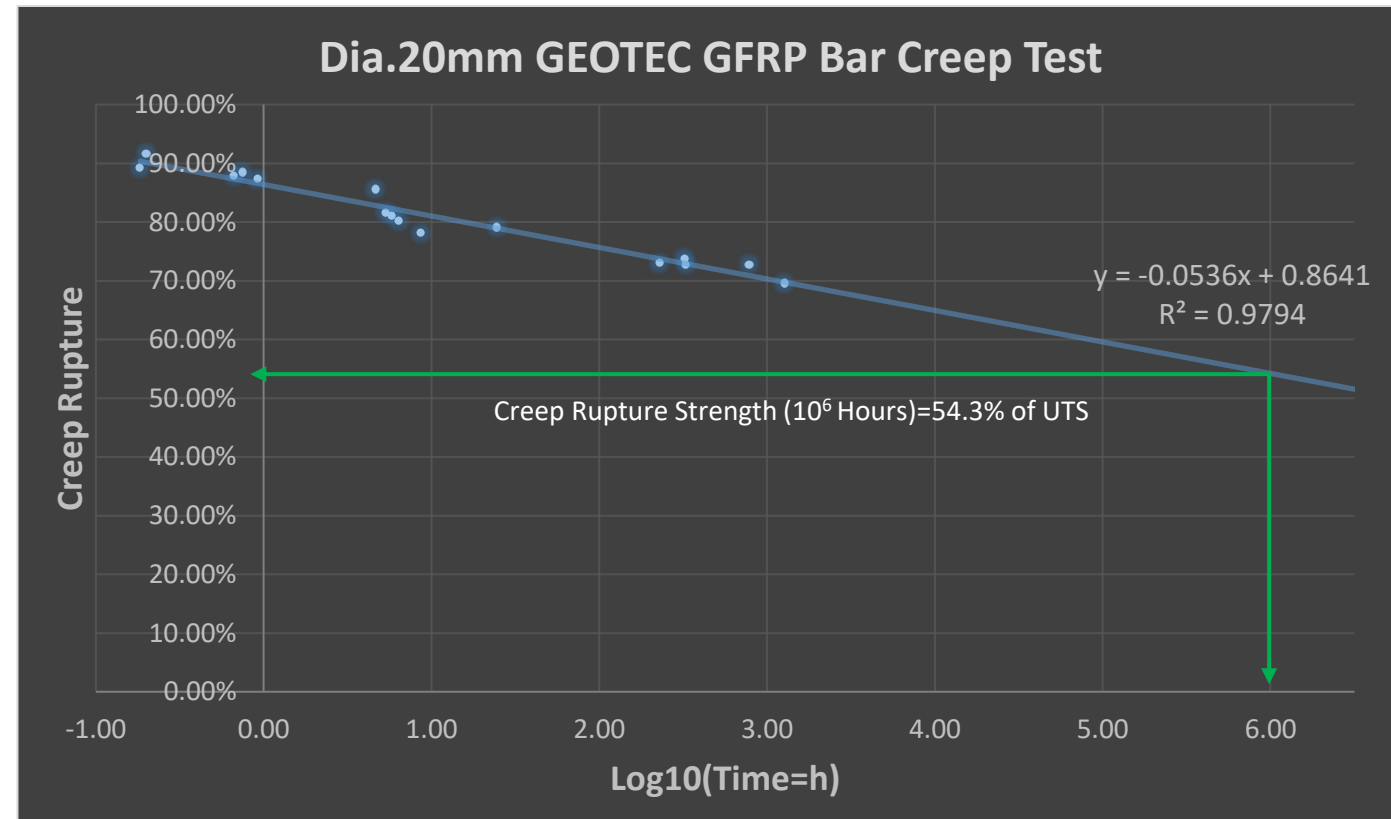
SOURCE: LOAD CAPACITY OF GROUTED ROCK BOLTS DUE TO DEGRADATION, REPORT 2017:374, SVC/ENERGIFORSK

- ❖ ACI 440.3R-04 B.8 = 24 samples - GEOTEC Dia.20mm bars tested for creep rupture strength.
- ❖ The samples were subjected to 4 different levels (6pcs/level) of sustained axial load.



Creep rupture strength= 54.3% of UTS

@ one-million hours = 114 years

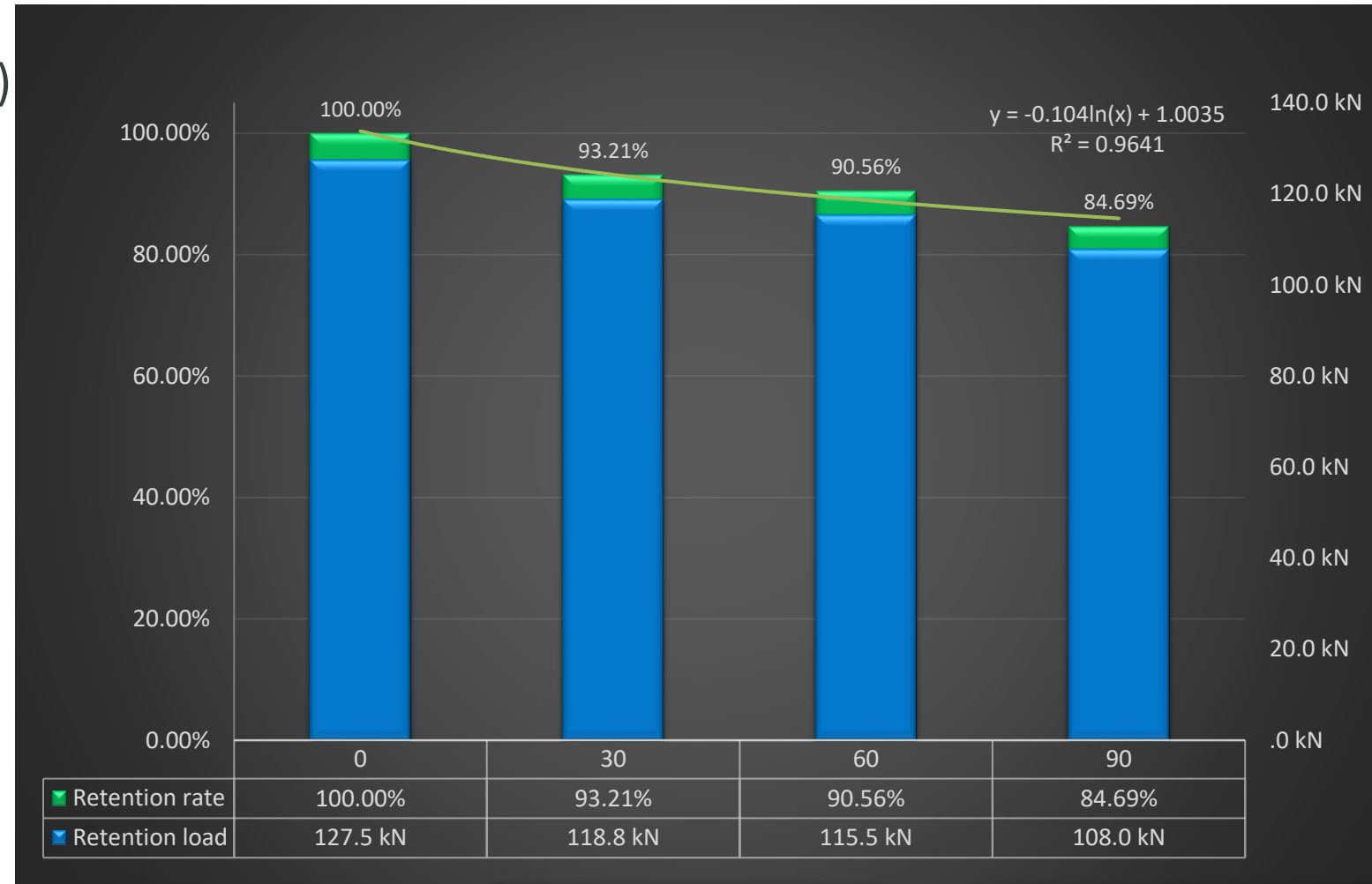
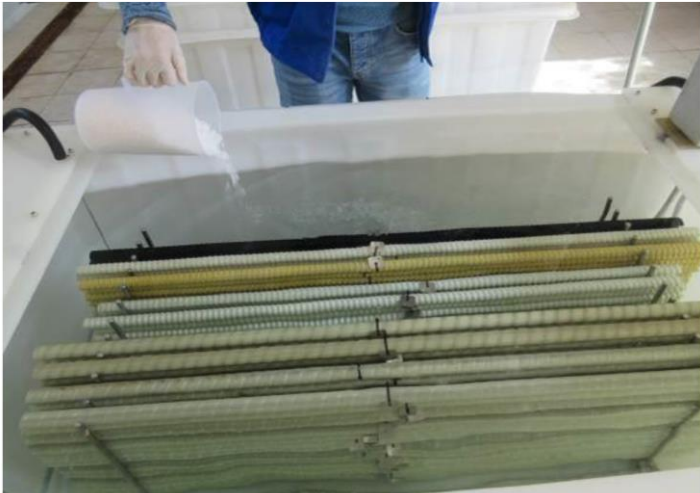


Alkali resistance (accelerated method)

- ACI 440.3 Method B6
- ASTM D7705 / D7705M-12

GFRP bars subjected to:

- High pH ($12.6 \leq \text{pH} \leq 13.0$)
- 60 degrees Celsius



3 Months

12% Sustained Load

Retention > 84%

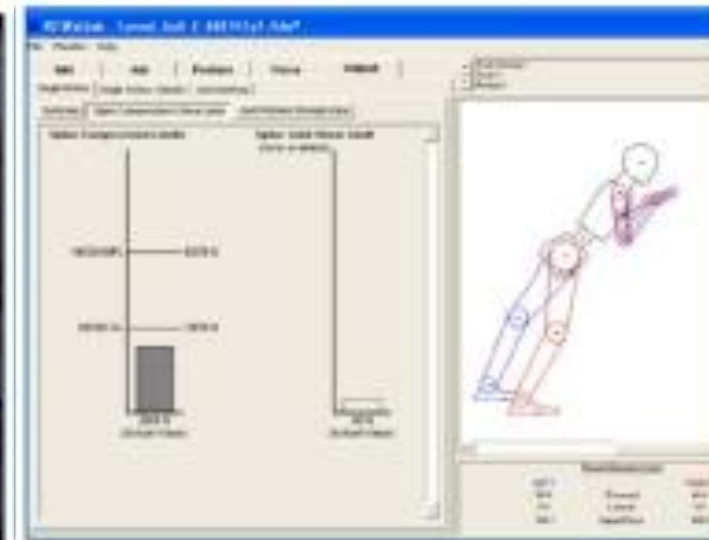
Same diameter 25mm:

> GFRP bolt => 4x LIGHTER

> GFRP bolt => 30% STRONGER

Material	Diam	Unit Weight	Min UTS	Typical UTS
	mm	kg/m	kN	kN
GFRP	25	0.95	350	400
Steel	25	3.85	270	300

A recent Swedish study found that typically the loads on the body were 20% lower when using GFRP bolts, compared to steel.





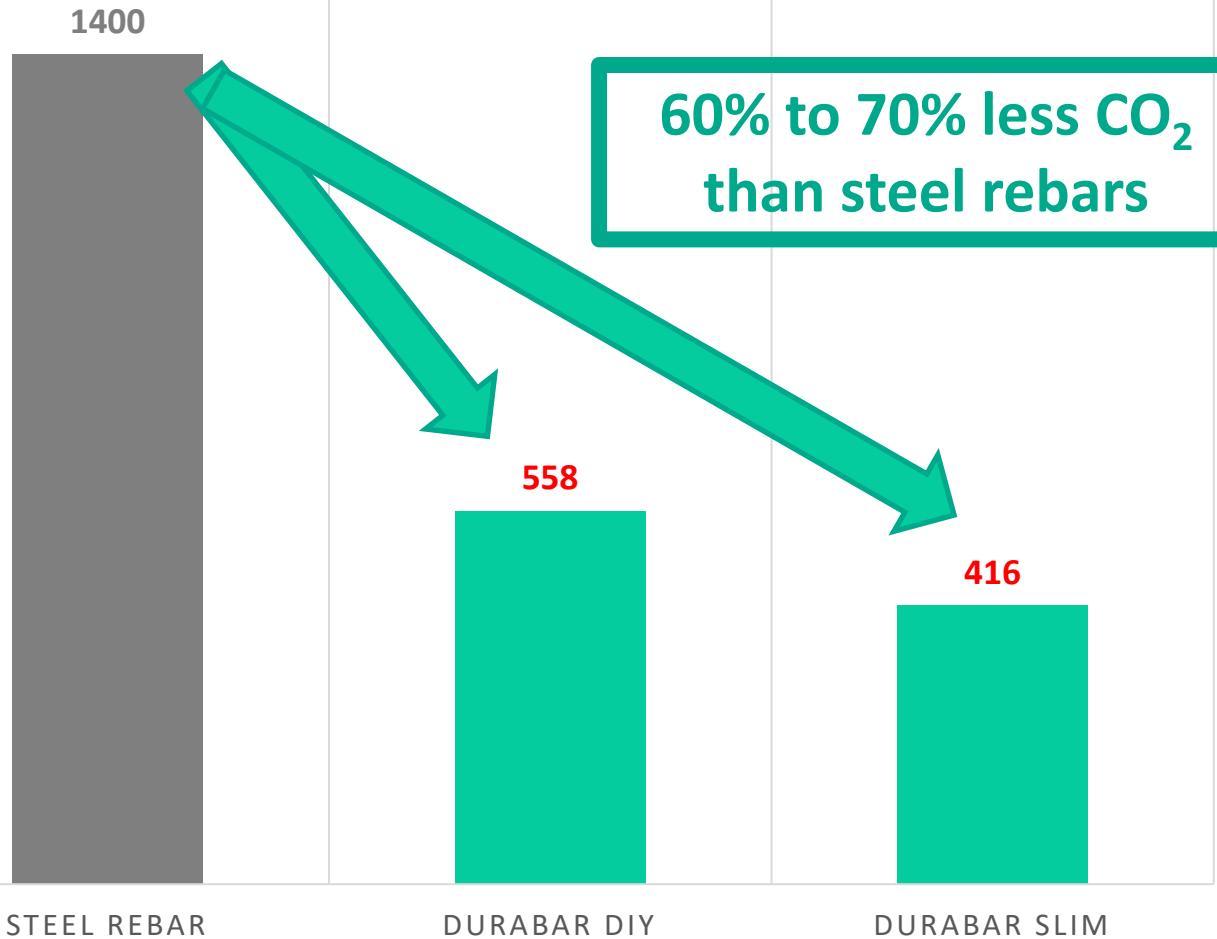
Environmentally Responsible



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CO₂ Emissions (KgCO₂/t) for GFRP - equivalent to steel rebars



- As per Dextra Environmental Product Declaration, EPD S-P-09434 in accordance with ISO 14025:2006.
- Cradle-to-Grave = 1 ton of DURABAR[®] GFRP rebar is generating 2,230 kg of CO₂ equivalent.
- For 1-to-1 substitution with steel rebars, the CO₂ equivalent are expressed as per the weight ratio (i.e. 25%).
- For optimized substitution with steel rebars the CO₂ equivalent are expressed as per the weight ratio (i.e. 18%).



- ❑ Primary support = Essential load bearing & safety element
- ❑ Hard Rock = Reduce/eliminate secondary concrete lining = huge saving in cost
- ❑ Light weight solution = Project productivity is extra-ordinary
- ❑ 10-15% cheaper over the life cycle of the project

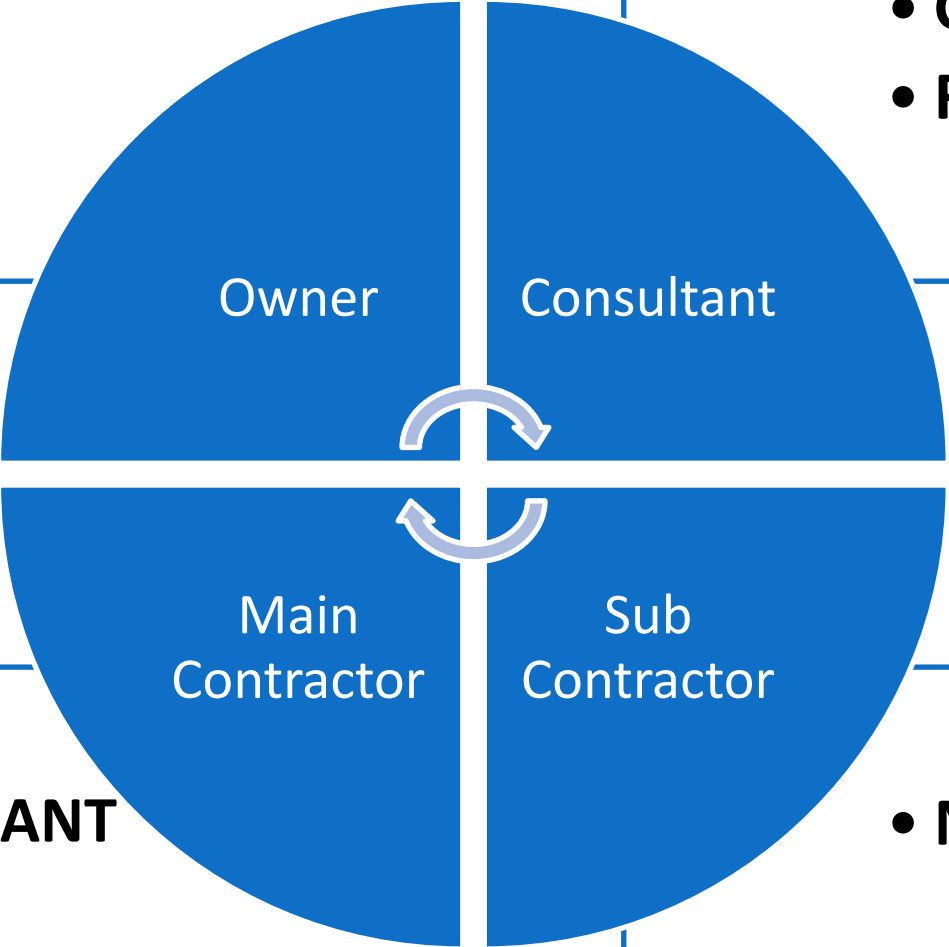


World Largest Cavern (UAE)



- ADNOC
- UAE

- GEOSTOCK
- FRANCE



- SK ECOPLANT
- KOREA

- NONE



World Largest Cavern (UAE)

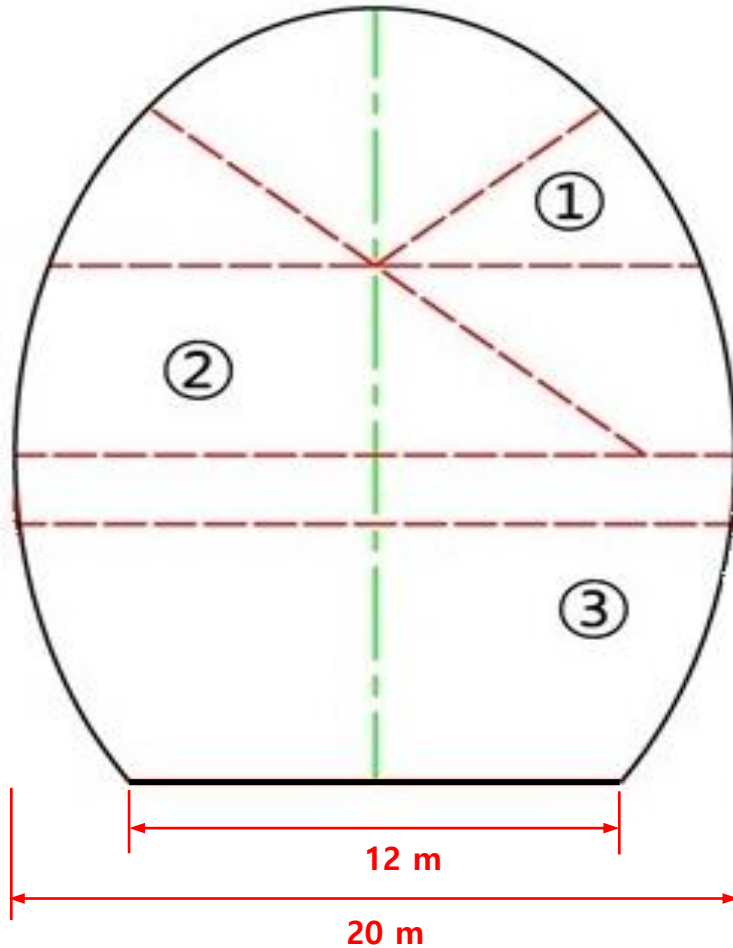
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Construction Depth:

- Within -100m

Main Storage Gallery:

- 20m x 25m x 16 km
- Area = 433m²

GFRP Rockbolts:

- 2.5m to 9.0m
- 600,000+ pcs



November 22-23, 2023, Mumbai, India



HYOSUNG CAVERN PROJECT – CAI MEP (VIETNAM)



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- HYOSUNG CORP
- KOREA



Owner

- GEOSTOCK
- FRANCE

Consultant



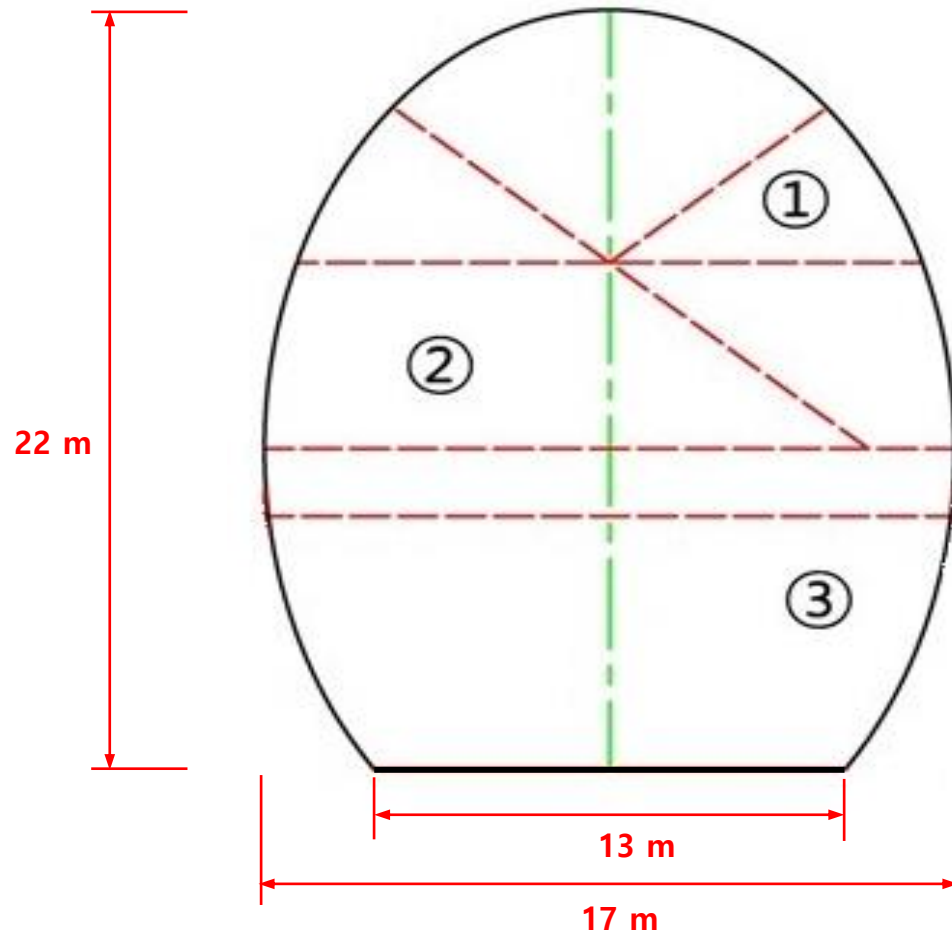
Main Contractor

Sub Contractor



- HYUNDAI E&C
- KOREA

- GUSAN
- KOREA



Construction Depth:

- -110m to -150m

Main Storage Gallery:

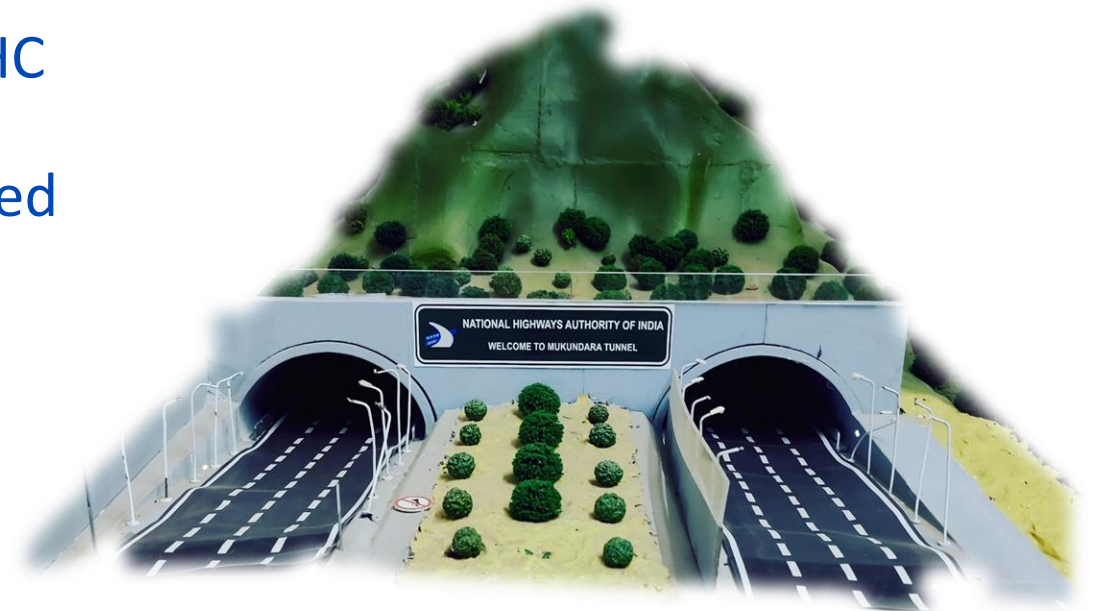
- 17m x 22m x 1.5km
- Area = 310m²

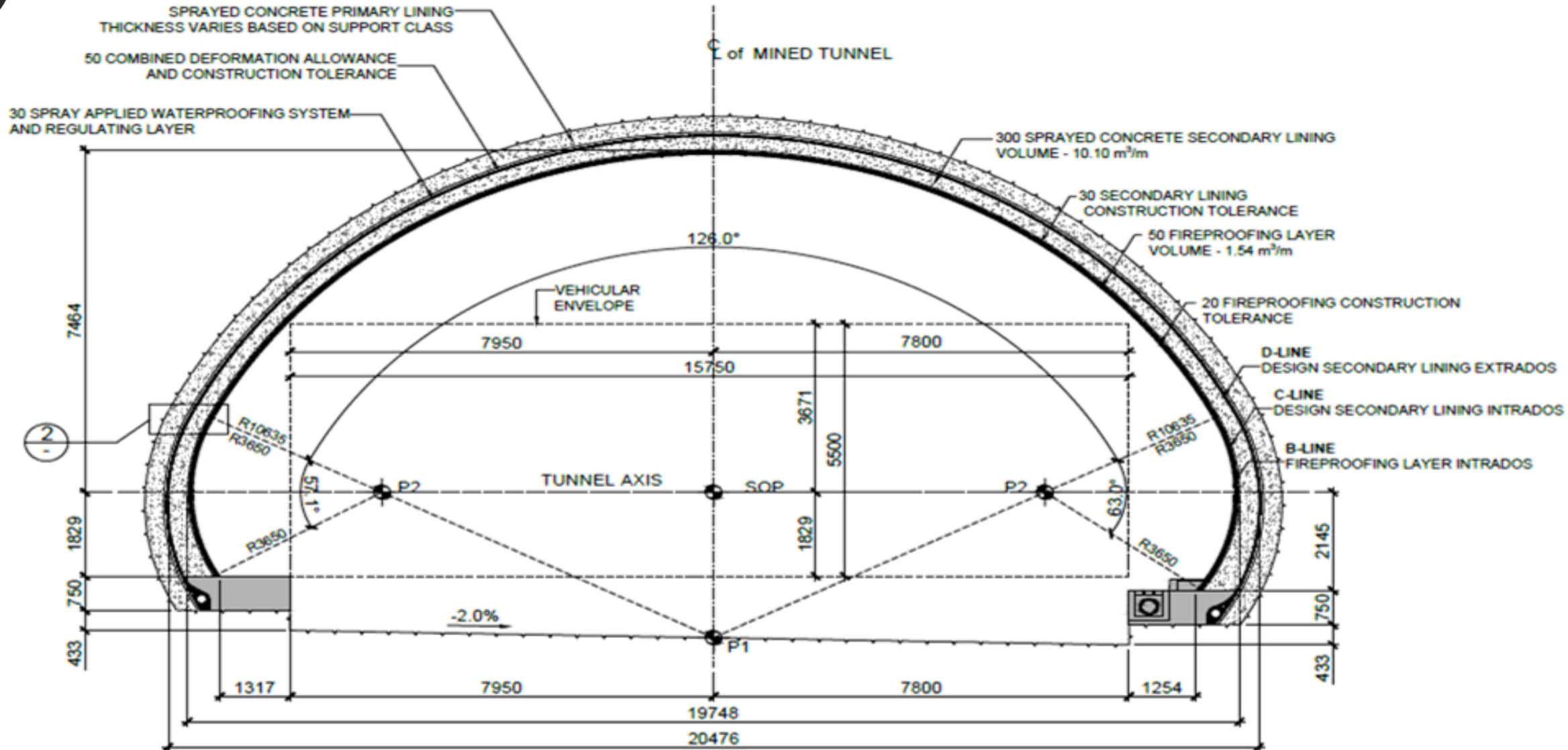
GFRP Rockbolts:

- 2.5m to 6.5m
- Approx 30,000 pcs

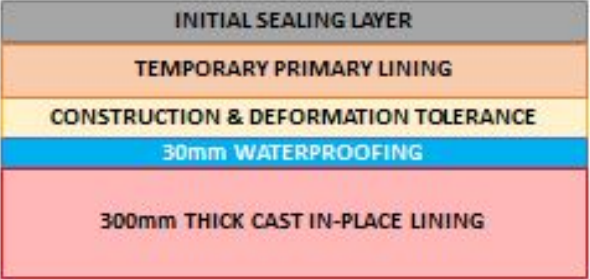



- Configuration – Twin tube, 4.9 Km length, 21 mtr width
- Client - NHAI (National Highways Authority of India)
- Authority Engineer: ICT (Intercontinental Consultants & Technocrats Pvt. Ltd.)
- Contractor - Dilip Buildcon Limited in JV with AHC
- Consultant - Infinite Civil Solutions Private Limited
- Location – Near Kota, Rajasthan
- GFRP Rock Bolts – 100,000+





EFFICIENCY WITH PERMANENT GFRP BOLTS

LINING CONFIGURATION WITHOUT PERMANENT GFRP BOLTS	LINING CONFIGURATION WITH PERMANENT GFRP BOLTS (100 YEARS DESIGN LIFE)
	
<ul style="list-style-type: none"> • MORE EXCAVATION • MORE CONCRETE → HIGH CARBON FOOT PRINT • MORE TIME • MORE MONEY 	<ul style="list-style-type: none"> • SIGNIFICANT REDUCTION IN EXCAVATION AREA • LESS CONCRETE → REDUCED CARBON FOOTPRINT • MORE ECONOMICAL

Credits:

Infinite Civil Solutions



BEDI Consulting





LAYER/ ELEMENT	A) STEEL TEMPORARY BOLTS	B) GFRP PERMANENT BOLTS
PRIMARY SCL LINING (SUPPORT P2/P3)	150/225	150/225
PRIMARY LINING TOLERANCE	50	50
REGULATING LAYER AND WATERPROOFING	30	30
SECONDARY LINING	300	150
SECONDARY LINING TOLERANCE	30	30
TOTAL	560/635	410/485

	Option A Steel TEMPORARY PRIMARY LINING - THICKNESS (m3/m)	Option - B GFRP PERMANENT ROCKBOLTS - THICKNESS(m3/m)	Difference (cum)	Total length of tunnel (m)	Single tube concrete saving (Cum)	Twin tube concrete saving (Cum)
Secondary Lining Volume	10.1	5.37	4.73	4,900	23,177	46,354

Worth Remembering...



Replacement of Steel by GFRP – Strategy for Long Term

- Not only temporary but also permanent applications

Selection of right Resin type is of utmost importance.

- Temporary = Polyester v/s Permanent = Vinylester

Credibility of Supplier – Key to Success

- Project references / track records + 3rd party laboratory

भारतीय मानक
Indian Standard

IS 18256 : 2023

कंक्रीट प्रबलन के लिए काँच रेशा प्रबलित
पॉलिमर (जीएफआरपी) के ठोस गोल सरिरे
— विशिष्टि

**Solid Round Glass Fibre Reinforced
Polymer (GFRP) Bars for Concrete
Reinforcement — Specification**

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WWW.DEXTRAGROUP.COM

For more information on FRP Applications:

Please visit stall no 12



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