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consulting engineers

Geotechnical Risk Management for Water Engineering Projects

Introduction

- Geotechnical Risk – an important aspect of large-scale engineering projects.
- Ground conditions – the variable nature of soil/rock and potential geo-hazards means geotechnical risk must be carefully managed
- Water Engineering Projects – BLP involvement in two large-scale water engineering projects - management of geotechnical risk

Water Engineering Projects

Strategic Tunnel Enhancement Programme (STEP) Link Sewer Projects LS01 & LS02; Abu Dhabi

Lusail City - Doha

STEP LINK SEWER PROJECT

Contract LS01

STEP LINK SEWER PROJECT

Contract LS02

STEP Geology

Superficial Deposits

High Groundwater Table

Rock - Interbedded layers of

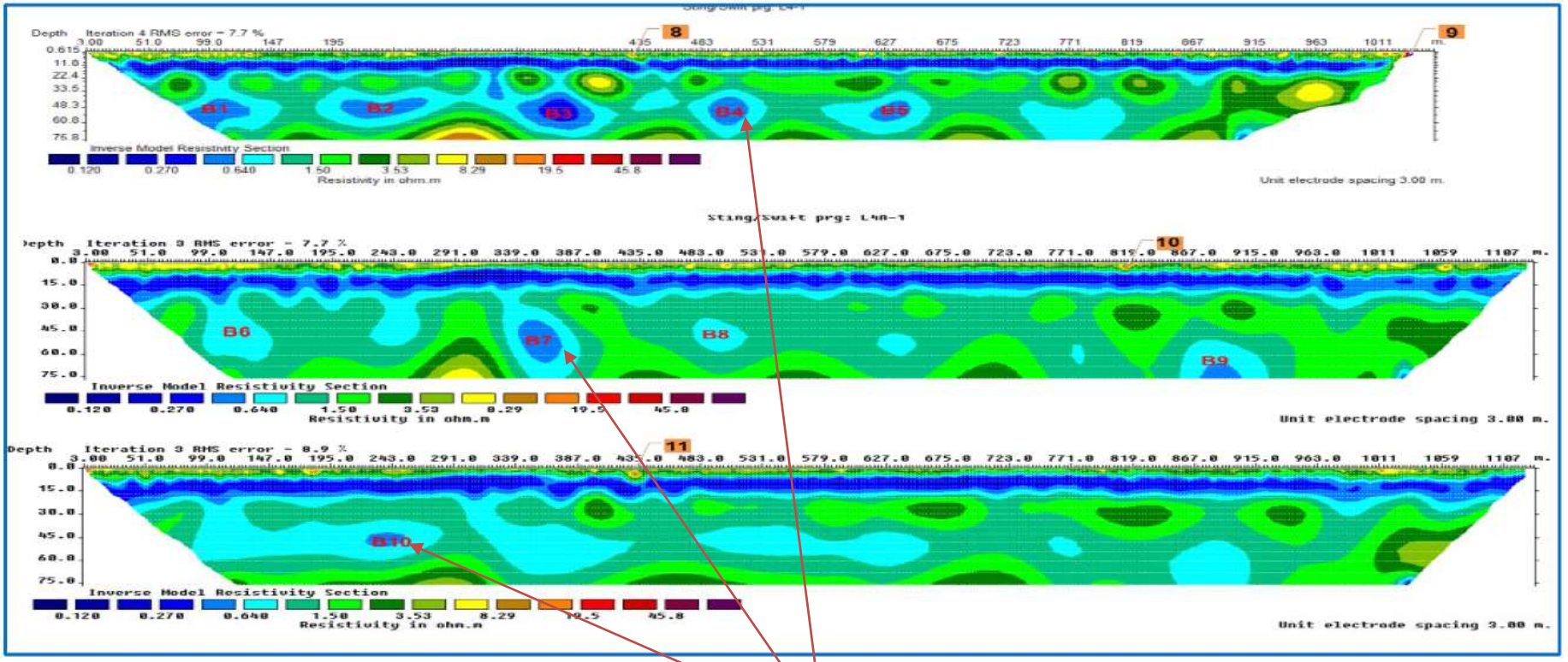
- Mudstone/Calcilutite
- Siltstone/Calcisiltite
- Gypsum
- Sandstone
- Calcarenite

Thickness and sequence of rock varies

STEP – Geotechnical Risk

Karst - cavity/dissolution features in carbonate rock

STEP Geology



CAVITIES

STEP – Geotechnical Risk

- Water inflow - inundation
- Ground Movement due to water inflow / dewatering / ground loss
- Overall / Local stability of excavations
- Aggressive ground conditions due to high salinity
- Swelling and creep of gypsum

STEP – Construction procedures

Project shafts required support of superficial soils and groundwater control

- Caissons or secant pile walls were installed through the superficial deposits to provide support to the upper parts of the shaft & groundwater cut off
- Below the caissons/secant piles circular excavations in rock were undertaken

STEP – Shaft Construction

STEP – Geotechnical Risk

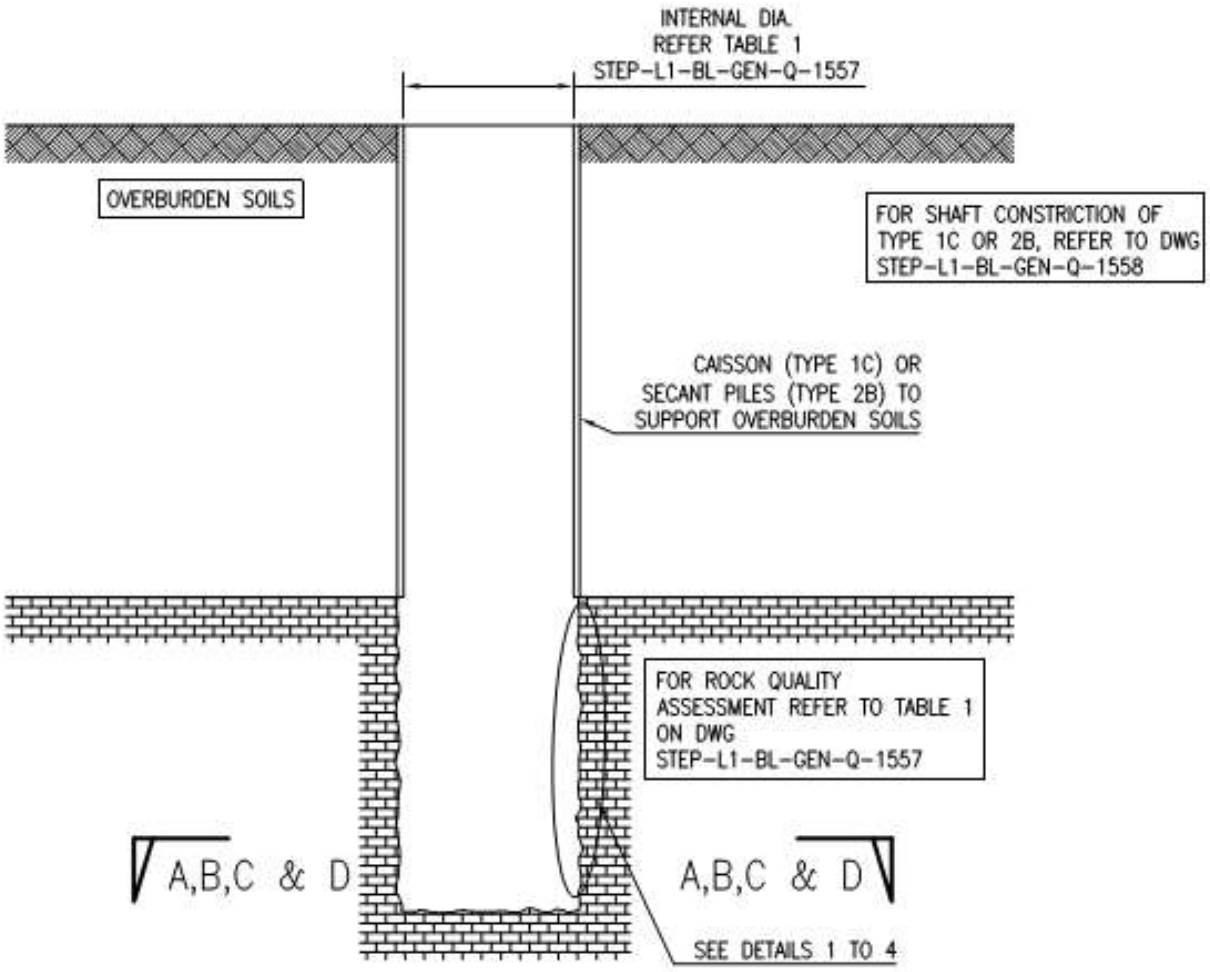
- Addressed risk by;
  - Risk Assessment of karst features
  - Additional SI at each shaft location
  - Detailed Interpretation of SI results
  - Temporary works design outlining level of rock support required to ensure stability of shafts
  - Temporary works design resulted in four rock support categories

STEP – Geotechnical Risk

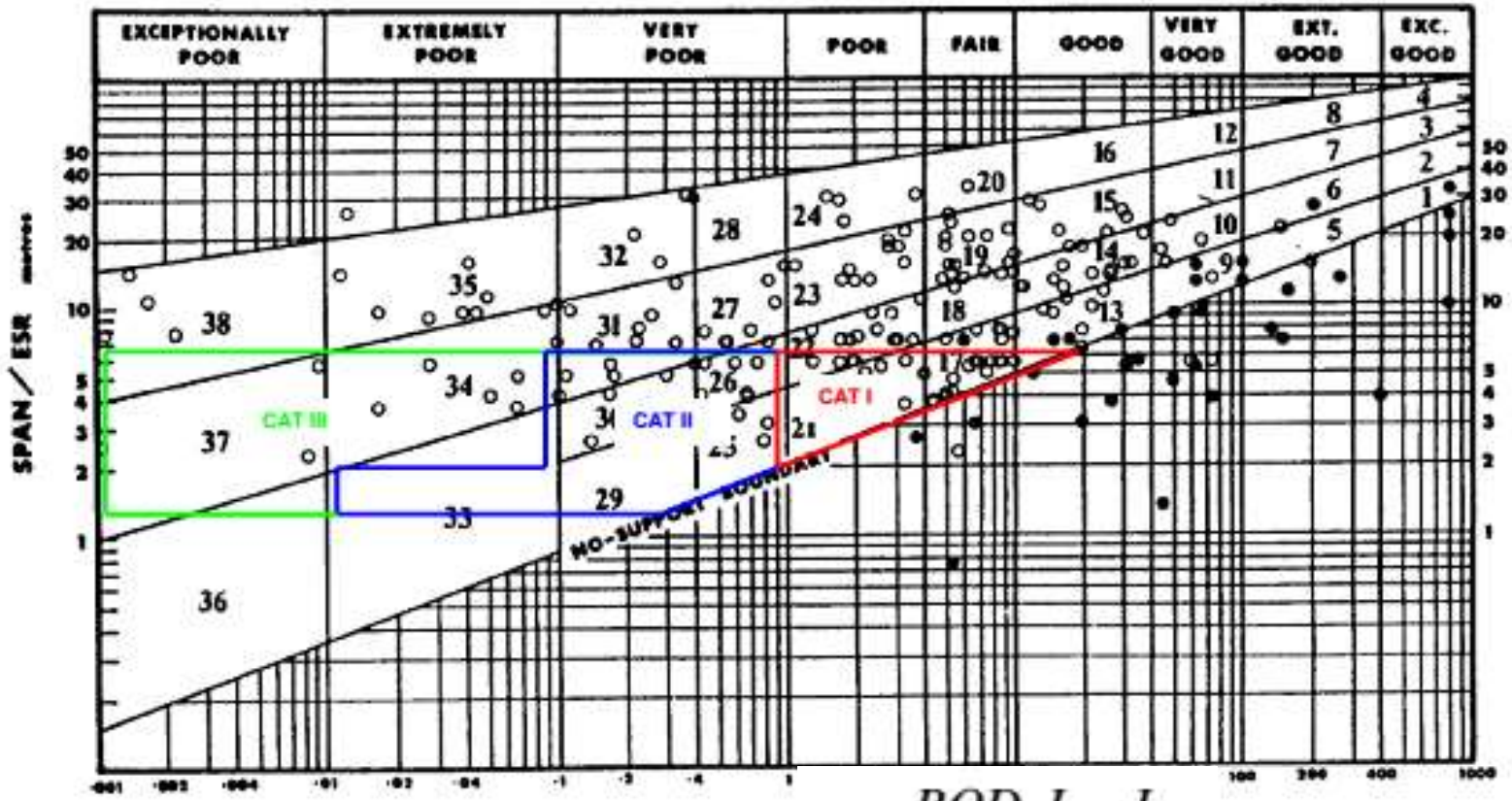
Categories of Rock support for shaft excavations

- Category 0: minimum shotcrete thickness of 50mm
- Category 1: 100mm of shotcrete applied to form a hoop around the circumference of the shaft
- Category 2: 100mm of shotcrete with mesh reinforcement applied to form a hoop around the circumference of the shaft
- Category 3: Systematic rock bolting with a minimum shotcrete thickness of 200mm

STEP – Shaft Support



STEP – Geotechnical Risk



$$Q = \frac{RQD}{J_n} \frac{J_r}{J_a} \frac{J_w}{SRF}$$

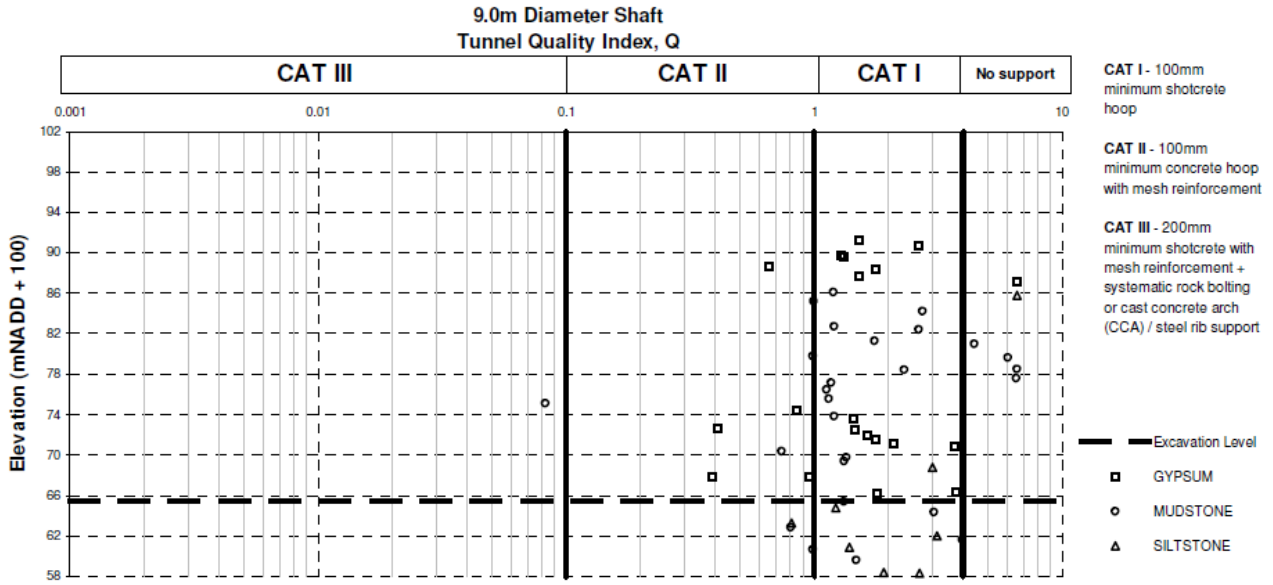
Deriving temporary support category

Shaft diameter (m)	Q Requirement (GSI Requirement)					
	Category 0*	Category I		Category II		Category III
	Min	Max	Min	Max	Min	
13.0/14.0	4.0 (32)	4.0 (32)	1.0 (21)	1.0 (21)	0.1 (4)	< 0.1 (4)

Deriving temporary support category

LINK SEWER REFERENCE	SHAFT REFERENCE	REFERENCE / COMMENTS
LS-02 MPS13 LINK SEWER	M05	

TEMPORARY ROCK SUPPORT ASSESSMENT



STEP – Geotechnical Risk

- A vital aspect to managing the risk requires visual inspections / monitoring of the rock conditions: Encountered v Expected.(validation)
- Visual assessment (validation) ensured the appropriate rock support measures applied.
- Monitoring of performance – convergence, instrumentation, groundwater inflows.

STEP – Geotechnical Risk

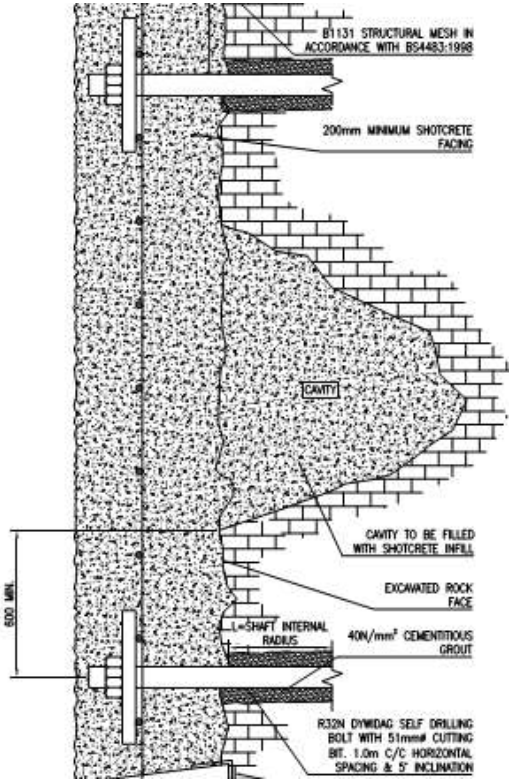
When / If Cavities encountered during shaft excavation:

- Contingency measures to deal with cavities if / when encountered
- Additional Investigation measures required to access extent and any further mitigation measures
- Geotechnical Risk posed cavities is managed.

STEP – Geotechnical Risk

Cavity encountered in shaft

Cavity Mitigation



Introduction- Lusail City

- Construction of 15 No. deep stormwater shafts
  - Excavation of deep storm water shafts form part of the Micro-tunnel works serving the storm water network for Lusail City
  - Shaft depths ranging from 14.9m to 30.7m
  - Shaft diameters of 13m and 14m
  - Adjacent and parallel to a sunken expressway.

Lusail Project includes bulk excavation

- Surficial marine sands
  - Simsima Limestone Formation
  - Midra Shale Formation
  - Rus Formation
- Majority of shaft excavation undertaken in Simsima Limestone

Simsima Limestone in open cut

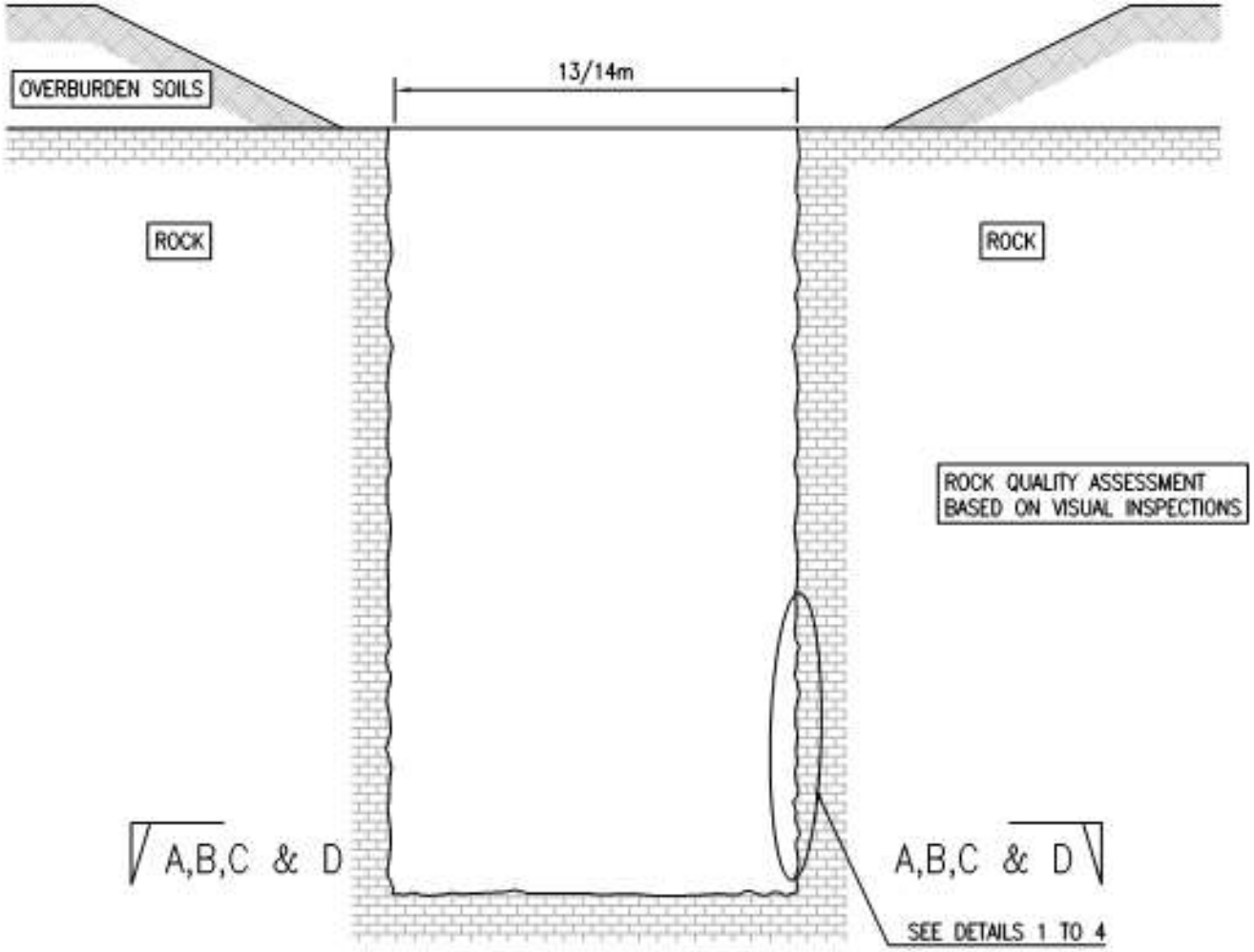
Main alignment, looking South

Stable Simsima cutslopes. With mesh face protection to catch any freed clasts. Overlying uncemented marine sands laid back at 1v:2h. Stormwater drains run parallel to left of shot at 7-8m below the base of the cut.

Lusail – Construction procedures

- For this project circular shafts were excavated vertically
- Unconsolidated marine sands were removed and set back a safe distance from the edge of the excavation in rock
- Superficial deposits trimmed back at an angle of 1V:2H, as for the adjacent open cuts.
- Vertical excavations in rock then undertaken

Lusail – Construction procedures



16.5m Shaft

Lusail – Geotechnical Risk

- Karst dissolution features, in Simsima limestone in particular
- Water inflows
- Overall stability of excavation
- Local stability of excavation

Typical occasional void.

Interconnected Cavity

Lusail – Geotechnical Risk

- Addressed risk by;
  - Risk Assessment of karst features
  - Detailed Interpretation of SI results & validation by inspection of excavation faces
  - Temporary works design outlining level of rock support required to ensure stability of shafts
  - Temporary works design resulted in four rock support categories

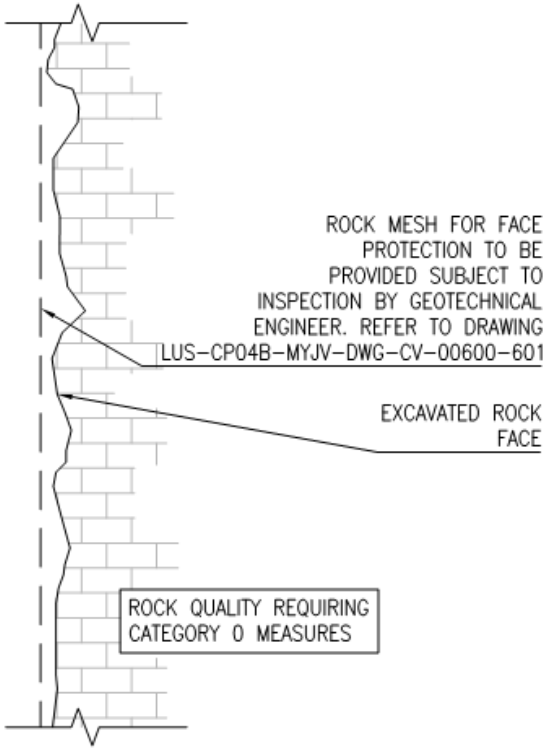
Lusail – Geotechnical Risk

- What category OF Rock Support is required?
  - Visual Inspection of shaft excavation
  - ‘Rate’ the rock mass based on the Geological Strength Index (GSI) system.
  - Based on the results of this inspection the GSI value can be correlated to a Q value (similar to that used for STEP) and a category of support can be assigned to the shaft

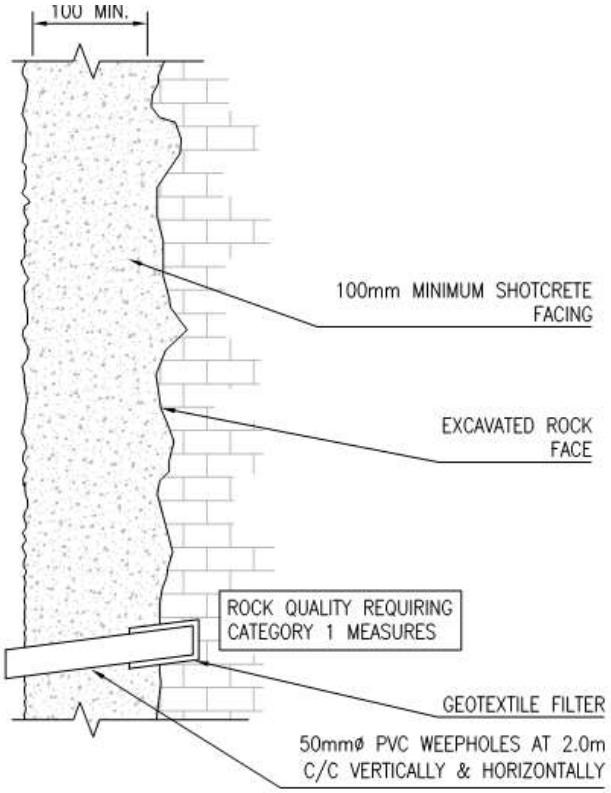
Lusail – Geotechnical Risk

- Categories of support for shaft excavations
  - Category 0: No support required
  - Category 1: 100mm of shotcrete applied to form a hoop around the circumference of the shaft
  - Category 2: 100mm of shotcrete with mesh reinforcement applied to form a hoop around the circumference of the shaft
  - Category 3: Systematic rock bolting with a minimum shotcrete thickness of 200mm

Lusail Shafts - Rock Support

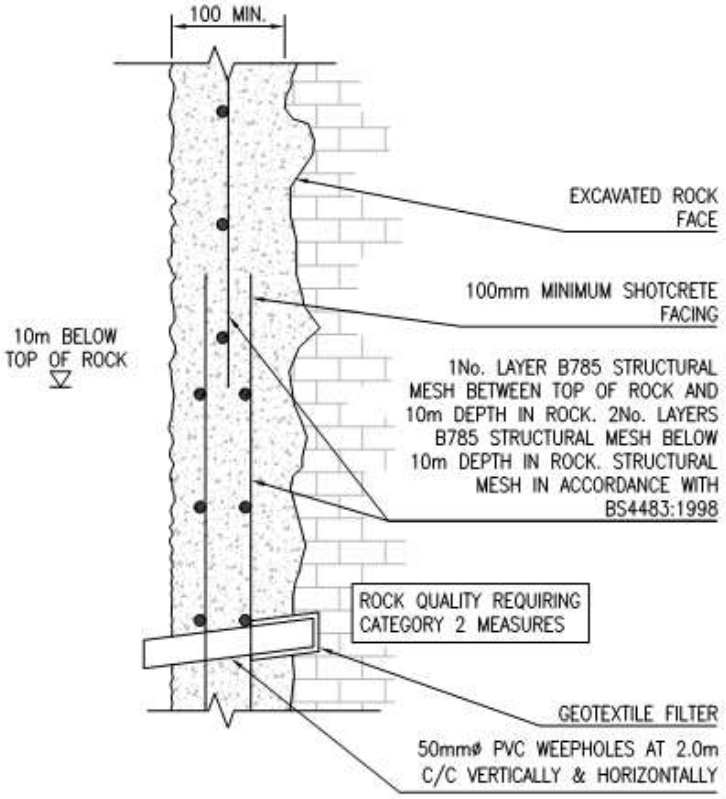


0-0 / 1:5 CATEGORY 0 SUPPORT MEASURES
DETAIL 0

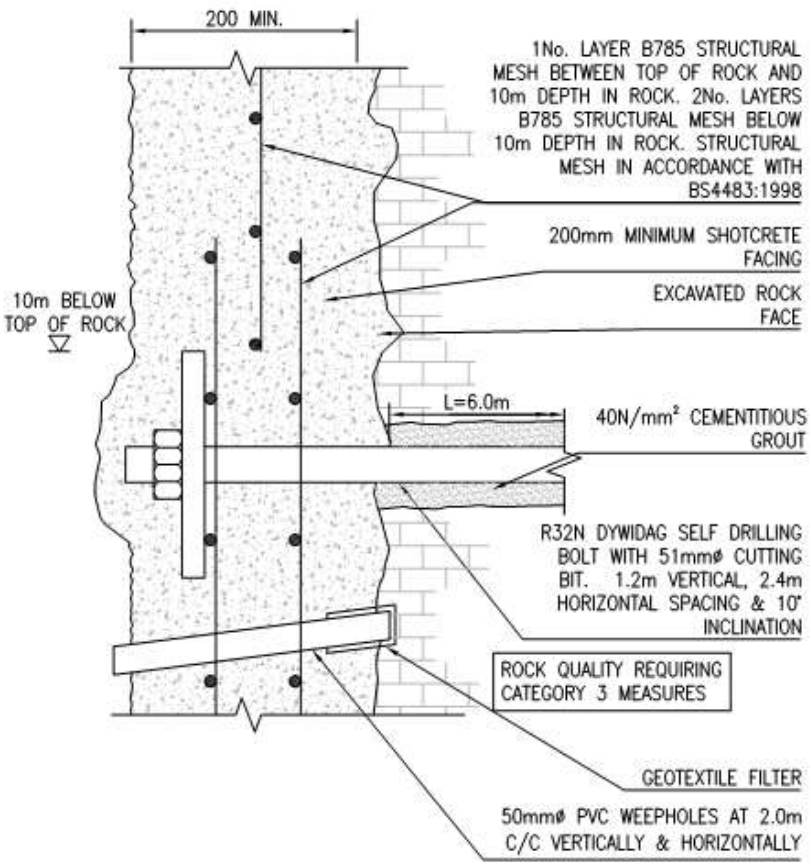


1-1 / 1:5 CATEGORY 1 SUPPORT MEASURES
DETAIL 1

Lusail Shafts - Rock Support



2–2 / 1:5 CATEGORY 2 SUPPORT MEASURES
DETAIL 2



3–3 / 1:5 CATEGORY 3 SUPPORT MEASURES
DETAIL 3

Range of GSI and Q values based on rock descriptions

Rock Description	Range	GSI Value	Q Value	Log_eQ
Very Good	Max	62.5	100	4.61
	Min	40	40	3.69
Good	Max	52.5	40	3.69
	Min	35	10	2.30
Fair	Max	45	10	2.30
	Min	25	4	1.39
Poor	Max	37.5	4	1.39
	Min	15	1	0.00
Very Poor	Max	27.5	1	0.00
	Min	5	0.1	-2.30

Typical Textures

Variable matrix type and proportion

Missing, toppled.

Lusail – Geotechnical Risk

- What is GSI? Geological Strength Index
  - A rock mass classification system that has been developed in engineering rock mechanics to meet the need for reliable input data for designing tunnels, slopes or foundations in rocks
  - GSI was used in this case as there was less SI information available at this site than there was at STEP and this rock mass classification system is well-recognised for Simsima rock (Fourniadis 2010)

TBM breakthrough

“Soft-eye” and Thrust block

Lusail – TBM critical lift.

Lusail Survey Monitoring

- Shaft Walls for convergence.
- Tower Crane bases for settlement.

- Thus far no movements recorded. All readings within margins of survey error.

Example of fissure infill with uncemented sand

Misreading the ground

STEP and Lusail

- Sinking temporary shafts in Carbonates and Sabkha-like deposits.
- Requires sedimentological understanding.
- Importance of regular inspections.
- Minimise risk by following careful procedures and using ‘tried and trusted’ rock mass classification systems.
- Open shafts/cuts standing 10 months.

Endnote

- Sound, integrated geotechnical assessment and involvement, pays dividends and provides evidence with which to reassure both Client and Contractor.