



LUAS

Dublin Light Rail System

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OUTLINE OF PRESENTATION

- Overview of the LUAS Project and Project Team
- Summary of the Geotechnical Works
- Management of Geological / Geotechnical Risk
- Case Study: Green Line – Kilmacud Cutting

LUAS LIGHT RAIL SYSTEM : THE PROJECT

The LUAS system was planned, designed and constructed as three separate lines :

- (i) Line A : Tallaght to O'Connell Street
- (ii) Line B : Sandyford to St. Stephens Green
- (iii) Line C : O'Connell Street to Connolly Station

Operated as two lines – Red Line (Lines A and C) and Green Line (Line B). Opened in June 2004 and by June 2005 LUAS had carried over 15 million passengers.

The Red Line runs at grade, partially along preserved transport corridor, partially on existing streets. The Green Line runs mainly along segregated alignment of former Harcourt Street railway line

LUAS – DUBLIN LIGHT RAIL SYSTEM



LUAS - THE PROJECT TEAM

Client : Railway Procurement Agency

Client's Technical Advisor : Mott McDonald EPO

Design and Build Contractor : AMB – a joint venture between

AnsaldoBreda Transporti SpA (Italy)

MVM Rail (Australia)

Ballast Nedam International (Netherlands)

Track and Civil Works Contractor : MVMBNI JV

Engineering Designer : Sinclair Knight Merz (SKM)

Geotechnical Sub-consultant : John Barnett and Associates

Drainage Sub-consultant : Roughan and O'Donovan



LUAS LIGHT RAIL SYSTEM : PRINICPAL ELEMENTS

- 23km of light rail track through built up urban environment
- 5 No. underground sub-stations
- 7 No. overground sub-stations
- 5 No. new bridge structures (3 footbridges, 1 rail, 1 cable)
- Re-use of 4 No. existing masonry bridge structures
- Re-use of 1.5km of masonry embankment retaining walls
- Connolly Station Terminus
- Control and Maintenance Depots (Red Cow and Sandyford)
- Not included in Track and Civil Works Contract :
 - Dargan Bridge, Dundrum
 - Red Cow Overbridge (M50)

LUAS LIGHT RAIL SYSTEM : GEOTECHNICAL WORKS

- Track Foundation – 3 Track Types
- Underground Sub-stations: Cut & Cover Structures
- Re-use of Foundations for the Masonry Bridges along former Harcourt Street Line
- Selected Overground Structures : Sub-station Foundations
- Widening of the Kilmacud Cutting
- Depot Buildings: Foundations
- Park & Ride Facilities: Pavement Foundations

MANAGING GEOLOGICAL / GEOTECHNICAL RISK

The Employer's Requirements called for the Design and Build Contractor (AMB) to implement the UK Highways Agency methodology for the planning, management and reporting of geotechnical works as outlined in HD22/92

'Ground Investigation and Earthworks Procedure for Geotechnical Certification' (DMRB Section 4.1.1)

The following deliverables were required at key milestones in the engineering design programme :

- Procedural Statement

- Preliminary Sources Study (Certificate No.1)

- Factual and Interpretative Geotechnical Report (Certificate No. 2)

- Earthworks Design (Certificate No. 3)

- Geotechnical Feedback Report

HD22/92 GEOTECHNICAL CERTIFICATION

A **Procedural Statement** was prepared and submitted to the Client in advance of detailed engineering design.

This is a statement of intent which briefly outlines what the design proposes to do to satisfy the basic geotechnical requirements of the scheme. It includes the following : -

- Description of the Light Rail Scheme
- Statement of Geotechnical Design Philosophy / Objectives
- List of Sources of Information to be Consulted
- Details of Anticipated Ground / Groundwater Conditions
- Programme for Desk Studies / Additional Ground Investigations
- Outline of Report Formats

HD22/92 GEOTECHNICAL CERTIFICATION

Preliminary Sources Study (PSS) Reports were prepared in respect of each 'workfront' section in accordance with the design and construction programme.

Red Line : Lines A and C – Workfronts A to F (6 No.)

Green Line : Line B Workfronts K to P (6 No.)

The PSS Reports accompanied preliminary engineering design submissions to the Client.

They were accompanied by **Geotechnical Certificate 1**, confirming that the desk study element had been prepared with professional skill and care in accordance with the Procedural Statement.

HD22/92 : PRELIMINARY SOURCES STUDY

The Preliminary Sources Study Reports presented details of the following :

- Published Regional Geology (Quaternary and Solid)
- Existing / Previous Land Use (Historic OS Maps)
- Previous Ground Investigations (largely sourced by RPA)
- Findings of Field Studies / Walkover Surveys
- Description of Ground and Groundwater Conditions
- Preliminary Engineering Assessment (based on available data)
- Detailed Proposals for Additional Ground Investigation (scope, location, fieldwork and laboratory testing)

ADDITIONAL GROUND INVESTIGATIONS

Workfront PSS Reports identified a need for significant additional ground investigation, over and above that provided at Tender Stage

Additional GI generally done at start of construction phase along edge of workfront as :

- (i) much of site on heavily trafficked streets
- (ii) much of site unavailable due to advance utility diversion contracts
- (iii) much of former Harcourt Street to Bray line overgrown
- (iv) no continuous access along elevated embankment (Harcourt St. Line)

As such, time available to complete the additional ground investigation and prepare subsequent Factual and Interpretative Geotechnical Reports was severely constrained.

HD92/22 : GEOTECHNICAL REPORTS

Factual Geotechnical Reports presenting the findings of the additional ground investigations were prepared by IGSL Ltd. for track foundations and individual structures along each workfront.

Interpretative Geotechnical Reports were prepared by JBA for individual workfronts and addressed all geotechnical design and construction issues.

The Interpretative Reports were a further development of the Preliminary Sources Study Report and accompanied detailed design submissions to the Client.

HD22/92 : GEOTECHNICAL REPORTS

Interpretative Geotechnical Reports for each workfront included

- Details of additional project-specific ground investigation
- Interpretation of ground profiles and groundwater regime
- Assessment of geotechnical design parameters
- Engineering design recommendations

The Interpretative Reports were 'live' documents, revised and updated several times to take account of

- additional GI data acquired
- observations / experience gained during construction phase.

They were accompanied by **Geotechnical Certificate 2**, confirming that geotechnical reporting had been undertaken with professional skill and care.

HD22/92 : GEOTECHNICAL REPORTS

Geotechnical Feedback Reports were prepared for each workfront section by the Track & Civil Works Contractor (MVMBNI

These reports include details of planning and execution of geotechnical construction works, with particular emphasis on problems encountered and solutions implemented. Particular emphasis on

- Earthworks (materials, quantities, suitability criteria, instability)
- Pavement (subgrade preparation)
- Drainage (temporary / permanent)
- Structural foundations
- Materials Testing
- Instrumentation

GREEN LINE (LINE B – WORKFRONT ‘N’) KILMACUD CUTTING

- Introduction
- Typical Ground Profile & Groundwater Regime
- Slope Analysis: Parametric Study
- Cutting Design
- Slope Treatments

LUAS LIGHT RAIL SYSTEM : KILMACUD CUTTING



KILMACUD CUTTING : BACKGROUND

- Existing Cutting: Old Harcourt Street Line
- Cutting length: approximately 2 km
- Dundrum Station to the Kilmacud Footbridge
- Proposed use for LUAS light rail scheme and future Metro required widening of the existing cutting.
- Interaction of a number of factors: Track width, OCS system and poles, drainage and ducts, stations, ground / groundwater conditions and localised historical instability.

TRACK ALIGNMENT

- Constant track centres required for Metro operation: 3400mm
- This includes a dynamic kinematic envelope (DKE) clearance allowance between each track of 400mm
- OCS poles located at side of track
- Track levels optimised (within constraints such as fixed bridge locations etc.) to require to deepen the cutting

GROUND PROFILE

- Programme of ground investigation (trial pits, boreholes, groundwater standpipes and lab testing: strength)
- Typical ground profile comprises :
 - Topsoil
 - Made Ground
 - Glacial Till
 - Granite
- Groundwater: > 1 m below existing GL

LOCALISED INFILLED CHANNELS IN GRANITE



GLACIAL TILL : EFFECTIVE STRESS STRENGTH PARAMETERS

- Programme of shear box tests
- Samples recovered from depths ranging from 1.0 to 3.5 metres
- Design parameters: $c' = 5\text{kPa}$, $\Phi = 32$ degrees.

SLOPE ANALYSIS : PARAMETRIC STUDY

Parametric study undertaken to assess the maximum 'safe' height for slopes developed in Glacial Till.

- Shear Strength: $c' = 5\text{kPa}$, $\Phi = 32$ degrees
- Varying slope angles: 25, 35, 45 degrees
- Varying GWL's: 1, 2 and 3 m below existing GL
- Target FoS (on soil Strength) = 1.3

SLOPE ANALYSIS

Parameters: $c' = 5\text{kPa}$, $\Phi = 32$ degrees
GWL at 2 metres bGL

Maximum slope heights for $\text{FoS} = 1.3$

- 25 deg: $> 6\text{m}$
- 35 deg: 4.7m
- 45 deg: 3.8m

Note: Use of apparent cohesion, c' , is conditional on presence of good quality vegetation and ongoing vegetation maintenance.

SLOPE ASSESSMENT

- Detailed topographic surveys
- Walkover inspection: existing slopes logged at 10m intervals East and West sides of cutting
- Cutting Classification
- Methodology for Assessing Slope Treatment

SLOPE INSPECTION



CUTTING CLASSIFICATION

Rock Slopes : 1A

Rock / Soil Slopes : 2A (Soil < 26 deg.) to
2D (Soil > 45deg).



Soil Slopes : 3A (< 26 deg.) to 3D (> 45 deg.)

TREATMENT CLASSIFICATION

In order to optimise the cutting design and construction, within the physical and programme constraints, a range of slope treatments were designed.

Following the slope inspection and assessment an appropriate slope treatment was selected and specified.

SLOPE INSPECTION METHODOLOGY

Dublin LRT - LUAS Line B; Workfront N: Kilmacud Cutting		
SLOPE INSPECTION & STABILISATION WORKS		
LOCATION	CHAINAGE: 17300 CUTTING SIDE: WEST Pre-treatment: 0385 DIGITAL PHOTO NUMBER: Post-treatment:	
	SOIL: <input type="checkbox"/> ROCK, or <input type="checkbox"/> SOIL & ROCK: <input checked="" type="checkbox"/> EXISTING SLOPE, or <input type="checkbox"/> WIDENED / EXCAVATED SLOPE: <input checked="" type="checkbox"/> PRELIM. DESIGN TREATMENT OPTION (refer to SKM Dwg No 4505): T9	
SLOPE CLASSIFICATION & TREATMENT	SOIL SLOPE SLOPE HEIGHT: 1.0m SLOPE ANGLE: 60° SOIL DESCRIPTION: TOPSOIL / MADE GROUND / GLACIAL TILL GROUNDWATER: NONE RECOMMENDED TREATMENT: SOIL NAILS / SHOTCRETE (T4)	ROCK SLOPE SLOPE HEIGHT: 6.5m SLOPE ANGLE: 60° - 80° ROCK DESCRIPTION: FRESH, MEDIUM TO WIDELY JOINTED GRANITE GROUNDWATER: NONE ROCK MAPPING SHEET No: TV1_1 RECOMMENDED TREATMENT: ROCKFALL NETTING AND SPOT BOLTING (T5 / T9)
	NOTES: i) Slope measurement accuracy: Angles $\pm 5^\circ$, heights $\pm 0.5m$. ii) For further details of recommended treatments refer to SKM drawings and specifications.	
ADDITIONAL COMMENTS	_____ _____ _____ _____ _____	
DISTRIBUTION: <input type="checkbox"/> JBA <input type="checkbox"/> SKM <input type="checkbox"/> WYMN JV <input type="checkbox"/> OTHER		

TYPES OF SLOPE TREATMENT

- T3 : Soil slopes - Provision of vegetation and geogrids
(Where slope height exceeds design 'safe' height slope to be re-graded or stabilised using retaining structure or soil nails, e.g. T6)
- T4 : Rock slopes - Rock bolts or support rock slope (plus rockfall netting).
- T5 : Soil / Rock slopes - Rockfall netting to rock slope and vegetation / geogrids for glacial till.
- T6 : Soil slopes - Cantilever insitu concrete retaining wall.

RESTRICTED ACCESS TO CUTTING



LRO BOUNDARY CONSTRAINTS



TREATMENT T3 : REGRADE + BIOMAT



TREATMENT T6 : RC WALL : CHAINAGE 16350



TREATMENT T5 : ROCKFALL NETTING : CHAINAGE 1705



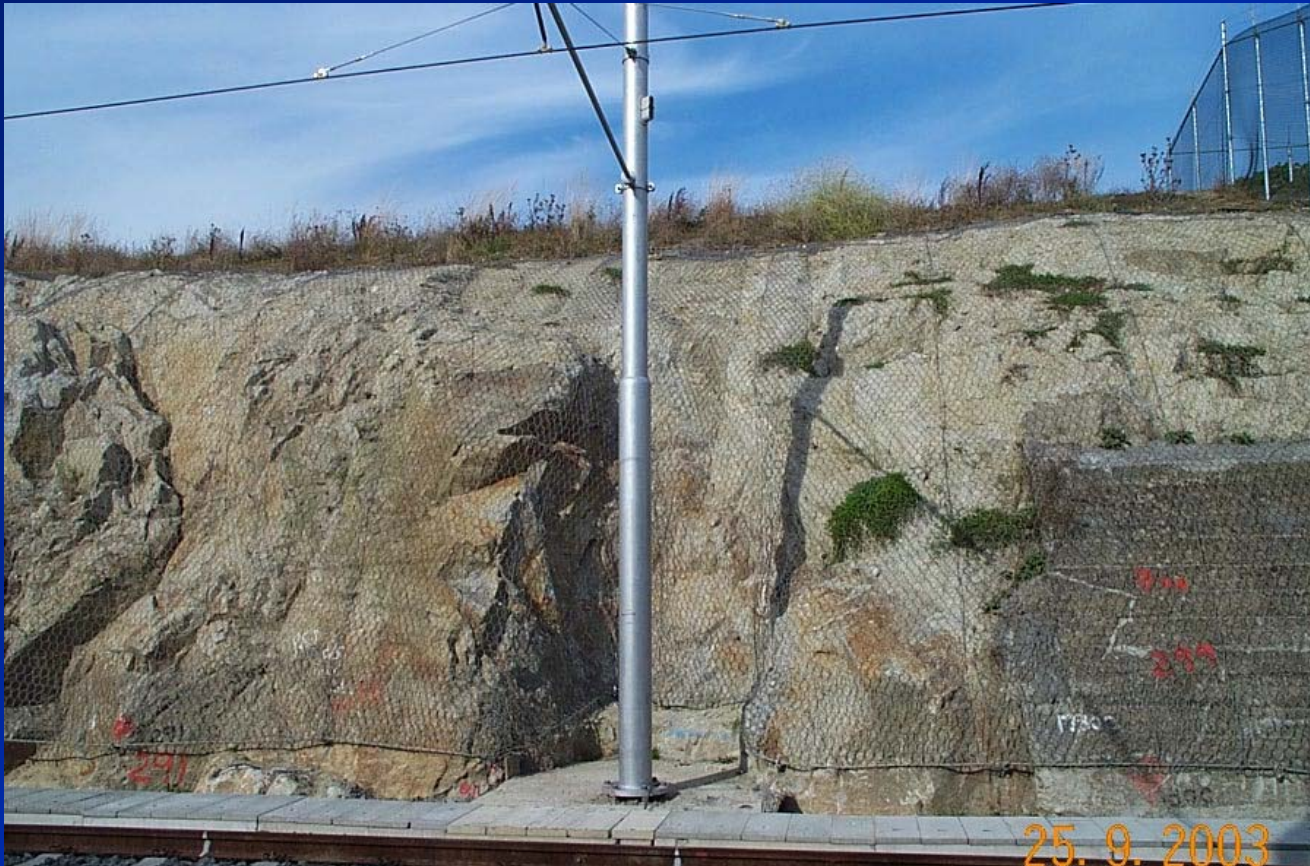
TREATMENT T3 : GABION WALL : CHAINAGE 17400



TREATMENT T4 : ROCK BOLTING AND ROCKFALL NET



OCS RECESS : CHAINAGE 17300



'AS CONSTRUCTED' CUTTING - SITE RECORDS

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PROJECT : LUAS : Line B Workfront N : Kilmacud Cutting

SUBJECT : SLOPE TREATMENT WORKS (AS-CONSTRUCTED RECORD)

DATE : September 2003



Chainage : 17325 W

Photo Reference : 2818_7Ch17325_W.jpg

RC retaining wall No. 5 as per report B600CD0631Q2 and drawing No. B600CD4504Q4.



Chainage : 17350 W

Photo Reference : 2818_7Ch17350_W.jpg

Mac Mat R applied to re-graded soil slope. Refer to SKM email dated 9 February 2003. Tie-in with Motorway bridge designed and constructed by others.

COMPLETED CUTTING : CHAINAGE 17100



COMPLETED CUTTING : CHAINAGE 16900



COMPLETED TRACK : CHAINAGE 17700



LUAS 'GREEN' LINE : KILMACUD CUTTING

SUCCESSFUL MANAGEMENT OF GEOLOGICAL / GEOTECHNICAL RISK

