Victoria Station Upgrade

Supplementary Environmental Statement:

Technical Appendix G – Jet Grouting Trials Report

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List of Contents

1 INTRODUCTION

1.1 Jetgrouting Trials

The current design[1] requires ground treatment to be carried out in advance of the tunnel and shaft construction where the use of the sprayed concrete lining method (SCL) is to be used. The design assumes the use of jet grouting using vertical, sub vertical and horizontal techniques.

1 Because most of the vertical and sub vertical jet grouting will be executed from the surface in the vicinity of underground utilities and services, a trial was required for the following purposes:

- to verify the effectiveness of the system in achieving specified performance criteria;
- to provide information on system parameters required to construct the column diameters as required by the current;
- to monitor resultant movements and to assess the effect on adjacent services and utilities;
- to demonstrate preventative methods of potential grout intrusion into service ducts;
- to demonstrate that the exhaust spoil discharged during the process could be efficiently handled;
- to provide instrumentation on noise and vibration emissions both within the ground and the surrounding immediate area to assist with future planning of mitigation measures and the application of Section 61[2] consent during the main works;
- to provide valuable information for subsequent specialists costing the works.

This report describes the preliminary results of jet grouting trials carried out from Elliot House car park.

1.2 Scope of Trials

The scope of the trials as they were carried out is noted below:

1.2.1 Phase 1

Four jet grouts were installed to 0.5m below the London Clay/Terrace Deposits interface to determine local jet grouting construction parameters and measure achieved diameters in situ.

1.2.2 Phase 2a

Four columns were installed to investigate the mass properties of a block of jet grouted Terrace Deposits and to obtain cores for subsequent laboratory testing.

This group was reduced to four columns, incorporating two columns from phase 1 and two columns constructed as part of phase 2a.

[1] RIBA Stage E Design

[2] Section 61 of CoPA sets out procedure whereby a developer or contractor can apply to the local authority in advance of the works for consent to carry out construction activities in accordance with a schedule. The local authority has powers to set conditions regarding the works including working hours, construction methods, and noise/vibration levels.

Three full depth cores were obtained from these four columns.

1.2.3 Phase 2b

This was originally foreseen as a single 1.5m inclined (away from the Thames Water sewer) column with a variable number of 1m diameter inclined columns depending on the outcome of the monitoring of resulting movement. Because no movements resulted this was limited to a single 1.5m column and a single 1m diameter column.

1.2.4 Phase 3

This was originally foreseen as a single 1.5m inclined (underneath the Thames Water sewer) column with a variable number of 1m diameter inclined columns depending on the outcome of the monitoring of resulting movement. Because no movements resulted this was limited to a single 1.5m column and a single 1m diameter column.

1.2.5 Monitoring

Extensive structure and building, surface and sub surface instrumentation was installed to monitor potential effects of the jet grouting. This included settlement cells, rod extensometers, inclinometers, crack meters, geodetic surveying and precise levelling. In addition vibration and noise monitoring was carried out within the Victoria Palace Theatre, within the site and from the west side of Allington Street. Most of the monitoring information was made available to Thames Water on a website to allow them to closely follow the effects of the trial.

Geodetic prisms were installed within the Northbound Victoria Line Station Platform tunnel to monitor potential deformations of the cast iron linings. Monitoring was undertaken whenever jet grouting was being undertaken to provide early warning of movement.

The full scope of monitoring was installed and five further water cells were added, two for Elliot House and three for the south car park wall.

2 PERFORMANCE REQUIREMENTS

The performance requirements for the jet grouting was as follows:

(i) To demonstrate that the Unconfined Compressive strength of the jet grout columns as determined by laboratory testing of core samples lies within the range 2MPA and 4 MPa. 90% of test results should lie within this range with 95% of results within the range 1MPA and 6MPa.

(ii) To demonstrate that there are no untreated lengths of ground within the column envelope exceeding 200mm in any direction. This shall be determined by cores recovered from columns. Core recovery shall be greater than 95% for any 3m depth of column.

(iii) To demonstrate that the permeability of the ground treatment is 2×10^{-8}m/s as measured by insitu constant head testing within and between columns. 90% of all results shall be less than 5×10^{-8}m/s and all results shall be less than 11^{-7}m/s

(iv) To demonstrate that movements resulting from the jet grouting operations are maintained within the following limits:

Absolute vertical movement shall not exceed 12mm

Angular rotation shall not exceed 1 in 1500

The aim of the grouting trials was to achieve zero movement on adjacent third party services and structures. However in recognition that movement might occur, the above trigger values were set to prevent damage to third party assets.

Additionally Land Securities imposed movement restrictions for Elliot House, effectively tolerating no movement above 1mm or any change in any crack width within the structure

3 JET GROUTING TRIALS PROGRAMME

The contract for the jet grouting trials was awarded to a joint venture of Keller Ground Engineering (KGE) and Smet (Belgium) on 17th March 2008. Site works commenced on 28th March and were completed on 23rd June 2008 in accordance with the Land Securities licence agreement.

4 THIRD PARTY AGREEMENTS

In advance of the contract Mott MacDonald met with all interested parties to discuss the potential impact of the trials on their assets. Third parties involved were:

- LU Engineering Directorate – to arrange permits to carry out the jet grouting within the nominal exclusion zone
- Land Securities - Owner of property, for access rights and services information within the car park
- Thames Water – Owner of asset potentially at risk from the trials
- Victoria Palace theatre – Owner of asset potentially at risk from the trials.

- EDF - Owner of asset potentially at risk from the trials
- BT - Owner of asset potentially at risk from the trials
- National Grid / Transco – Owner of asset potentially at risk from the trials
- Other utility providers whose asset may be affected by the trial.
- CoW - Relevant Planning Permissions, traffic management and licenses including Section 61

Except for Thames Water, all utility providers gave their agreement to the trials taking place without imposing any restrictions providing LU acknowledged that any damage resulting from the trials would be repaired.

A licence agreement was entered into with Land Securities to allow VSU to carry out the trials on their property within the car park of Elliot House.

Thames Water required a legal agreement to permit the trial to go ahead with their permission required to progress the trials based on their review of the Contractor's documentation and ultimately are right to veto any work if they considered their asset to be at risk.

5 TRIALS RESULTS

The factual report is still awaited from the Contractor at time of writing of this report however the following key conclusions can be stated:

5.1 Jet Grout Strength

A preliminary visual inspection of the cores indicates that the jet grout has achieved sufficient strength in the upper part of the column. Core recovery was poor in the lower part of the column however the results of the permeability testing indicates that jet grouted material was present. Actual test data will be available within a few weeks however it is concluded that the specified performance can be achieved for the main works.

5.2 Consistency of Jet Grouting

This cannot be judged objectively as the core recovery was low, potentially due to the early age low strength, however the relatively low results of the permeability testing indicate that the full depth of ground has been treated and there are most probably no untreated sections of ground within the columns.

5.3 Jet Grout Permeability

Permeability testing was carried out on piezometers sealed into the core holes and gave results in the range of 5×10^{-8} to 1×10^{-7}m/s for the bottom 3m of the columns which would be the parts of columns below the water table. The results comply with the specification in terms of a maximum permeability not to be exceeded but gave results slightly higher than the specification of 2×10^{-8}m/s. However higher values could be expected from this block at this time as:

(a) Permeability analysis is very difficult due to the small cluster shape

(b) Phase 1 columns D and F were effectively scoping columns to develop parameters and may not have achieved the full diameters thus increasing the risk of water leakage out of the cluster

(c) Sealing of piezometers to measure such low permeabilities can take time to become completely effective due to swelling of the bentonite seals

(d) The permeability of grouted bodies decreases with time thus the results should be more favourable with time especially considering that the tests were carried out within 10 days of column construction.

(e) The coring process could have induced fractures within the column due to the flush pressure

5.4 Resulting Movements

During and immediately following the jet grouting no adverse movements or distortions resulted.

Elliot House foundations were maintained within a limit of ±1mm

The Thames Water sewer was maintained within their prescribed limits with movements of less than ±1mm and the radius of curvature did not reduce to below their specified requirement of 4000m as a result of the jet grouting.

The Thames Water 125mm water main was maintained within prescribed limits with maximum movements of around 3mm potentially resulting from an episode when the Thames Water contractor attempting to repair a slight leak in the main caused a complete failure of their main

Movements recorded on the cast iron lining of the station platform tunnel was negligible and less than the 2mm initial limit imposed by the project team

6 Conclusions of Key Objectives

6.1 Achievement of Performance Requirements

It is considered that the trials have demonstrated that the jet grouting required for the main works can be successfully installed with the required performance.

6.2 Jet Grouting Parameters

In-situ measurements of diameter using two independent systems on six columns have confirmed that the main works design diameters can be reliability achieved within the Alluvium, Terrace Deposits and London Clay

6.3 Movements and Effects on Third Party Assets

The trials were completely successful in preventing any movement to any LU or third party asset. No movement in excess of 2mm was noted on any monitored service, structure or building

6.4 Grout Intrusion into Services

No grout or air escape was noted at any time during the trials. An internal survey of the Allington Street Sewer is awaited from Thames Water but is not expected to reveal anything adverse. A casing was initially installed to a depth of 4m and grouted in place to isolate the jet grouting from the shallow services and was successful in achieving no grout escape.

6.5 Jet Grout Spoil Control

Jet grout spoil was efficiently controlled by a containment tray sealed to the initial 4m casing. Spoil exited into this tray and was then pumped or sucked into a sludge tanker on standby. The interpretive report will consider expected volumes to be allowed for the main works but based on initial considerations this could be in the range of 60,000 to 80,000m^3. No spoil spillage resulted from within the immediate area of the jet grouting.

6.6 Noise and Vibration Monitoring

Noise and vibration monitoring revealed that the jet grouting could be carried out without causing nuisance. Initially work was not permitted on a Thursday afternoon as the Victoria Palace Theatre had a matinee performance but as the works proceeded, the theatre staff allowed jet grouting to carry on during performances as there was no detectable noise or vibration within the auditorium.

There were a few isolated complaints during the works but this was attributed to percussive breaking of concrete obstructions and when simple soundproofing was erected the noise was significantly reduced.

Westminster Council granted a Section 61 to allow working on Saturdays and Sundays following a trial weekend of working during which no complaints were received. The installed traffic management efficiently controlled traffic within Allington Street and local traders could receive deliveries without disruption.

6.7 Costing Information

The results of the trials will allow contractors to:

(a) Accurately assess the jet grouting parameters required to construct the design column diameters

(b) Assess the volumes and consistency of spoil that will be produced for the main works columns

(c) Assess the amounts of cement required for the main works

(d) Assess any potential restrictions that could be imposed by third parties

7 CONCLUSIONS

While the jet grout trial was not completely representative of all situations to be encountered within the main works, the trials have demonstrated that the ground treatment can be installed without causing any detrimental effect or disruption to third party assets and should be effective in providing support and groundwater control during tunnelling

1

COLLUMS	X (m)	Y (m)
A	79315,286	33994,427
C	79317,185	33994,223
D	79312,596	33998,814
F	79312,427	33997,388
ID1	79314,567	34001,886
ID2	79313,530	34005,210
IS05	79316,255	34001,173
IS10	79313,170	34003,443
S1 (H)	79313,339	33998,333
S2 (J)	79313,619	33997,042
testpile (G)	79312,536	34000,811
CORE HOLES	X (m)	Y (m)
CH1	79312,866	33998,636
CH3	79314,051	33997,307
CH2	79313,076	33997,597
GEOPHONE	X (m)	Y (m)
g.07	79312,542	33999,653
g.08	79312,134	33998,519
g.09	79312,138	33997,785
g.10	79311,714	33997,121
g.11	79311,933	33996,439
g.14	79314,893	33994,393
g.15	79315,791	33994,067
g.18	79316,562	33994,108
g.19	79317,941	33994,208

ID2
IS10
P.1
ID1
IS05
testpile (G)
g.7
D
g.8
CH2
S.1(H)
g.9
CH1
F
g.10
CH3
S.2(J)
g.11
g.14
A
g.15
g.18
C
g.19

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